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Analysis of fragmentation results from limestone blasting activities at Semen Padang company

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ABSTRACT
Semen Padang is a company engaged in the mining of limestone and silica rock as the main raw materials for cement production. The mining system used is open-pit mining. This study discusses the effect of geometry on rock fragmentation. The purpose of this study is to determine the blasting geometry and identify the causes of limestone block formation at the PT. Semen Padang site. The research focuses on fragmentation because fragmentation is a determining factor in the success of blasting activities. Fragmentation plays an important role in improving the company's targets, and the distribution of fragmentation must be optimal. To control fragmentation, blasting geometry is required as a parameter. Based on the results of the researcher's observations in the field, the size of rock chunks in the company that are larger than 80 cm is around 25%, so it is necessary to re-evaluate the blasting geometry. The purpose of this study is to determine the geometric design that produces the desired fragmentation, which is below 15% on an 80 cm sieve, so that production can be increased and a comparison can be made between the R.L Ash, C.J Konya, and ICI Explosive methods. The method used for the ideal blasting geometry design is the R.L Ash method with supporting theory using the Kuz-Ram theory. After data processing, the ideal geometry was obtained with a load value of 4.32 m, a distance of 5.18 m, stemming of 4.32 m, a blasting hole depth of 12.1 m, a filling column length of 7.78 m, and a blasting hole diameter of 5 inches, with a lump fragmentation percentage of around 15%.

Keywords: blast geometry, fragmentation, R.L Ash, Kuz-Ram, C.J Konya, ICI Explosive.

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Introduction

Indonesia is one of the countries blessed with abundant natural resources, particularly as a source of energy and for community needs [1]. Natural resource management in Indonesia is generally managed through the mining sector. One of the mining companies in Indonesia that produces cement raw materials is PT Semen Padang. PT Semen Padang is engaged in limestone mining in the Bukit Karang Putih area, Indarung Village, Padang City, West Sumatra [2]. The limestone mining process is carried out using the blasting method. This is done because the rock layer has a high level of hardness [3].

Blasting is the process of breaking up large volumes of rock using explosives so that the rock mass is easier to excavate and transport [4]. The blasting process aims to break up the rock so that it is easier to excavate and load into transport vehicles, thereby enabling mining operations to run effectively and efficiently [5].

One of the factors that influences the success of blasting is the blasting geometry. The blasting geometry includes burden, spacing, stemming, subdrilling, blast hole depth, charge column length, blast hole diameter, and bench height. Blasting geometry will affect the size of fragmentation and the success of blasting. Fragmentation in the mining sector is one of the important things that needs to be considered. Fragmentation is a measure that shows each piece of rock resulting from blasting [6].

The level of rock fragmentation is an important indicator in assessing the success of a blasting activity, where material with a uniform size is more desirable than material that contains many large pieces [7]. Fragmentation is a measure that shows each piece of rock resulting from blasting. Fragmentation resulting from blasting is often used as a problem in blasting activities [8]. The larger the fragmentation, the longer it will take to excavate the blasted material. Meanwhile, the better and more uniform the size of the fragmented rock, the easier it will be for the excavator to dig and load the rock. This will have an impact on the effectiveness of mining activities. Large fragmentation is influenced by a reduction in explosives, or it could also be because when charging explosives, in this case Ammonium Nitrate and Fuel Oil (ANFO), they do not enter the blast hole optimally [9].

The results of several blasting operations show that there is still uneven rock fragmentation and boulders larger than 80 cm (estimated to be around 25% of the total amount of rock excavated). The company expects the amount of blasted material larger than 80 cm to be less than 15%. With fragmentation larger than 80 cm, the company may encounter difficulties in the crushing process. The occurrence of such fragmentation risks, which cannot be predicted accurately, will affect the digging time. Therefore, it is necessary to have a fragmentation prediction model using software, one of which is Split Desktop 4.0 software.

The main raw material in cement production is limestone, which has a high level of hardness and therefore cannot be excavated directly by loading equipment such as excavators or power shovels. To break up the relatively hard limestone, drilling and blasting are carried out to ensure that mining operations are carried out effectively and efficiently. Next, the limestone material resulting from the blasting is handled through excavation and loading [10]. The limestone is obtained from the mining process at the Bukit Karang Putih quarry of PT. Semen Padang using the side hill type open pit mining system, which is an open pit mining system applied to mine rocks or industrial mineral deposits located on hillsides or deposits that form hills [11].

Experimental part

The study analyzes the fragmentation that occurs due to blasting activities. The data sources used consist of primary and secondary data. Primary data was obtained through direct measurements in the field and field documentation, including the actual geometry of the blasting, such as burden, spacing, stemming, subdrilling, blast hole depth, fill column length, blast hole diameter, and bench height, as well as documentation of the fragmentation resulting from the blasting. Secondary data is obtained from company archives, such as PT Semen Padang location maps, geological maps, research area condition maps, blasting geometry reports, and geological data on the research area.

Data collection techniques are obtained by conducting direct observations in the field, namely observations of geometry and fragmentation data, as well as literature studies and company documentation. The type of data collected was quantitative, in the form of actual geometric data of the blasting in the field. For data analysis, the fragmentation in the field was processed using Split Desktop 4.0 software. This application was carried out by taking photos of the fragmentation results of the blasting using a 38 cm rubber ball as a reference, then analyzing them using the software. The average fragmentation results from the geometry obtained based on the theories of R.L Ash, C.J Konya, ICI Explosive, and the Kuz-Ram equation can be compared with the fragmentation size obtained in the field using Split Desktop 4.0 software after being processed manually.

Blasting Geometry R.L. Ash

The parameters used in the blasting geometry design use R.L. Ash's theory [12], namely burden (B), spacing (S), blast hole depth (L), subdrilling (J), bench height (H), stemming (T), and number of explosive charges (PC).

Blasting Geometry C.J. Konya

Konya and Walter [13] explain the parameters used in blasting geometry design, namely burden (B), spacing (S), stemming (T), subdrilling (J), blast hole depth (H), bench height (L), amount of explosive charge (PC), and loading density (de).

ICI-Explosive Blasting Geometry

ICI-Explosive blasting geometry design is a way to design blasting geometry through trial and error or the rule of thumb. The parameters calculated are bench height (H), burden (B), spacing (S), subgrade (J), stemming (T), and powder factor (PF).

Kuz-Ram Method

The larger the size of the resulting fragmentation, the longer the time required by the loading equipment to excavate the blasted material, and vice versa. If the resulting fragmentation is smaller, the faster the time required by the loading equipment to excavate the blasted material. The level of rock fragmentation is the level of material breakage as a result of the blasting process. To estimate the average size of rock fragmentation resulting from blasting, the Kuznetsov [14] equation can be used. The Kuz-Ram method pays close attention to the size distribution of rock fragmentation resulting from blasting, whereas the image analysis method does not pay much attention to the size distribution of rock fragmentation, but rather directly to the degree of uniformity of rock fragmentation [15].

Split Desktop 4.0

The Split Desktop 4.0 program can present size distributions in three formats, namely ISO standard, UK standard, and custom standard. In addition, the percentage [16].

Results and Discussion

Blasting is a demolition activity that uses explosives to break up the overburden, thereby facilitating excavation by mechanical equipment [17]. In general, the blasting pattern shows the sequence or sequence of explosions from several blast holes. There are several factors that influence the blasting pattern, including the delay time in blasting activities [18]. The actual blasting geometry in ten blasts was obtained with an average burden (B) of 3.13 m, spacing (S) of 3.17 m, subdrilling (J) of 0.94 m, bench height (L) of 10.1 m, blast hole depth (H) of 11.03 m, stemming (T) of 4 m, powder column (PC) of 7 m, and hole diameter (De) of 5 inches can be seen in Table 1 below.

Limestone is an industrial mineral composed of calcium carbonate ($CaCO3$) and other elements, including magnesium. One important thing to note in analyzing limestone is the presence of Ca and Mg elements. If the Ca content is high and the Mg content is low, the quality is good. Conversely, if the Ca content is low and the Mg content is high, the quality is poor. High Mg content will interfere with the hardening process, because Mg cannot bind with other elements in cement. Limestone containing more than 50% CaO (by weight) is excellent for use as a building material in the form of cement. Limestone generally originates from the shells of mollusks, foraminifera, coelenterates, and carbonate sediments [19].

Blasting geometry can be defined as the relationship between various types of dimensions used in blasting planning [20]. Stemming that is too deep or long can cause chunks to form because the force generated is not strong enough to destroy the rock. Meanwhile, short stemming can cause small rock fragments and fly rock [21].

Table 1 - Actual Blasting Geometry Data in the Field

No	Date	B (m)	S (m)	J (m)	L (m)	H (m)	T (m)	PC (m)	De (inc)
1	23 Nov 2024	3.2	3	0.96	10.04	11	4	7	5
2	2 Dec 2024	3.2	3.2	0.96	10.34	11.3	4	7	5
3	6 Dec 2024	3	3.2	0.90	9.40	10.3	4	7	5
4	9 Dec 2024	3.2	3.3	0.96	10.04	11	4	7	5
5	10 Dec 2024	3.2	3.3	0.96	10.34	11.3	4	7	5
6	11 Dec 2024	3.1	3.1	0.93	10.17	11.1	4	7	5
7	12 Dec 2024	3	3	0.90	10.40	11.3	4	7	5
8	13 Dec 2024	3	3	0.90	10.10	11	4	7	5
9	16 Dec 2024	3.4	3.6	1.02	9.98	11	4	7	5
10	18 Dec 2024	3	3	0.90	10.10	11	4	7	5
	Total	31.3	31.7	9.39	100.91	110.3	40	70	50
	Mean	3.13	3.17	0.94	10.1	11.03	4	7	5

Figure 1 - Results of Limestone Blasting

Table 2 - Geometric Calculation Results According to R.L Ash

B (m)	S (m)	J (m)	L (m)	H (m)	T (m)	PC (m)	De (inchi)
4.32	5.18	0.86	11.24	12.1	4.32	7.78	5

Table 3 - Geometric Calculation Results According to C.J Konya

B (m)	S (m)	J (m)	L (m)	H (m)	T (m)	PC (m)	De (inchi)
3.51	4.91	1.05	10.2	11.25	2.46	8.79	5

Table 4 - Geometric Calculation Results According to ICI Explosive

B (m)	S (m)	J (m)	L (m)	H (m)	T (m)	PC (m)	De (inchi)
3.81	4.76	1.27	11.43	12.7	3.18	9.52	5

The highest variation in this data occurred on December 16, 2024, when the Burden (3.4 m) and Spacing (3.6 m) values were at their highest compared to other days. Conversely, on December 6, 2024, the hole depth (L) was recorded at its shallowest at 9.40 meters. Overall, the blasting operations in the field showed a high degree of consistency, particularly in terms of hole diameter and fill column, with minor adjustments to the burden and spacing distances depending on the specific daily conditions in the field.

From Table 2 above, the blast geometry design is obtained with a burden (B) of 4.32 m, spacing (S) of 5.18 m, stemming (T) of 4.32 m, subdrilling (J) of 0.86 m, bench height (L) 11.24 m, Blast Hole Depth (H) 12.1 m, Filling Column Length (PC) 7.78 m, Blast Hole Diameter (De) 5 inches.

In the observations to be conducted, there are several blast geometry parameters that determine the fragmentation of the blast results according to [22]. From Table 3 above, the blast geometry design is obtained with a burden (B) of 3.51 m, spacing (S) of 4.91 m, stemming (T) of 2.46 m, subdrilling (J) of 1.05 m, bench height (L) of 10.2 m, blast hole depth (H) of 11.25 m, Filling Column Length (PC) of 8.79 m, and Blast Hole Diameter (De) of 5 inches.

Fragmentation is a general term used to indicate the size of rock fragments resulting from blasting [23]. Blasting fragmentation can be predicted in various ways, one of which is by using the Kuz-ram equation. The Kuznetsov equation is used to determine the average fragmentation size, and the Rosin-Rammler equation is used to determine the percentage of material. From Table 4 above, the designed blasting geometry was obtained with a burden (B) of 3.81 m, spacing (S) of 4.76 m, stemming (T) of 3.18 m, subdrilling (J) of 1.27 m, bench height (L) 11.43 m, Blast Hole Depth (H) 12.7 m, Filling Column Length (PC) 9.52 m, Blast Hole Diameter (De) 5 inches.

Table 5 - Percentage of Actual Geometric Fragmentation Size Using the Kuz-Ram Formula

Size (cm)	*Kuz-Ram*	
	Held back (%)	Pass (%)
10	91	9
20	80	20
30	58	42
40	68	32
50	48	52
60	39	61
70	31	69
80	25	75
90	20	80
100	16	84

Table 6 - Percentage of Fragmentation Size of R.L Ash's Method Using the Kuz-Ram Formula

Size (cm)	*Kuz-Ram*	
	Held back (%)	Pass (%)
10	87	13
20	72	28
30	58	42
40	45	55
50	34	66
60	26	74
70	19	81
80	15	85
90	11	89
100	8	92

Table 7 - Percentage of Fragmentation Size in C.J. Konya's Method Using the Kuz-Ram Formula

Size (cm)	*Kuz-Ram*	
	Held back (%)	Pass (%)
10	81	19
20	60	40
30	42	58
40	29	71
50	20	80
60	13	87
70	8	92
80	5	95
90	3	97
100	2	98

Table 8 - Percentage of Fragmentation Size of ICI Explosive Design Method Using the Kuz-Ram Formula

Size (cm)	*Kuz-Ram*	
	Held back (%)	Pass (%)
10	79	21
20	59	41
30	41	59
40	28	72
50	18	82
60	11	89
70	7	93
80	5	95
90	3	97
100	2	98

Table 9 - Comparison of Actual and Design Geometry

Geometry	B (m)	S (m)	T (m)	J (m)	L (m)	H (m)	PC (m)
Actual	3.13	3.17	0.94	10.1	11.03	4	7
R.L Ash	4.32	5.18	0.86	11.24	12.1	4.32	7.78
C.J Konya	3.51	4.91	1.05	10.2	11.25	2.46	8.79
ICI Explosive	3.81	4.76	1.27	11.43	12.7	3.18	9.52

From the percentage of fragmentation size in Table 5, it was found that 75% of fragments measuring 80 cm passed through the sieve, marked in red, while fragments measuring < 80 cm that passed through the sieve were marked in green.

From the percentage of fragmentation size in Table 6, it was found that 85% of fragments measuring 80 cm passed through the sieve, marked in red, while fragments measuring < 80 cm that passed through the sieve were marked in green. From the percentage of fragmentation size in Table 7, it was found that 95% of fragments measuring 80 cm passed through the sieve, marked in red, while fragments measuring < 80 cm that passed through the sieve were marked in green.

From the percentage of fragmentation size in Table 8, it was found that 95% of fragments measuring 80 cm passed through the sieve, marked in red, while fragments measuring < 80 cm that passed through the sieve were marked in green. After calculating the actual geometry and the design geometry, the following is a comparison of the actual geometry with the design geometry, as shown in Table 9 and Figure 1 below.

From the table above, it can be seen that from a comparison of actual geometric data, R.L Ash, C.J Konya, and ICI Explosive obtained the ideal blasting geometry, namely R.L Ash.

The actual blasting geometry data in the field above was collected during 10 blasts. From November 23 to December 2, there were several days when blasting activities were not carried out due to visits to check the explosives warehouse, so there were no blasting activities on those days. The actual blasting geometry in ten blasts was obtained with an average burden (B) of 3.13 m, spacing (S) of 3.17 m, subdrilling (J) of 0.94 m, bench height (L) of 10.1 m, blast hole depth (H) of 11.03 m, stemming (T) of 4 m, Powder Column (PC) of 7 m, and hole diameter (De) of 5 inches.

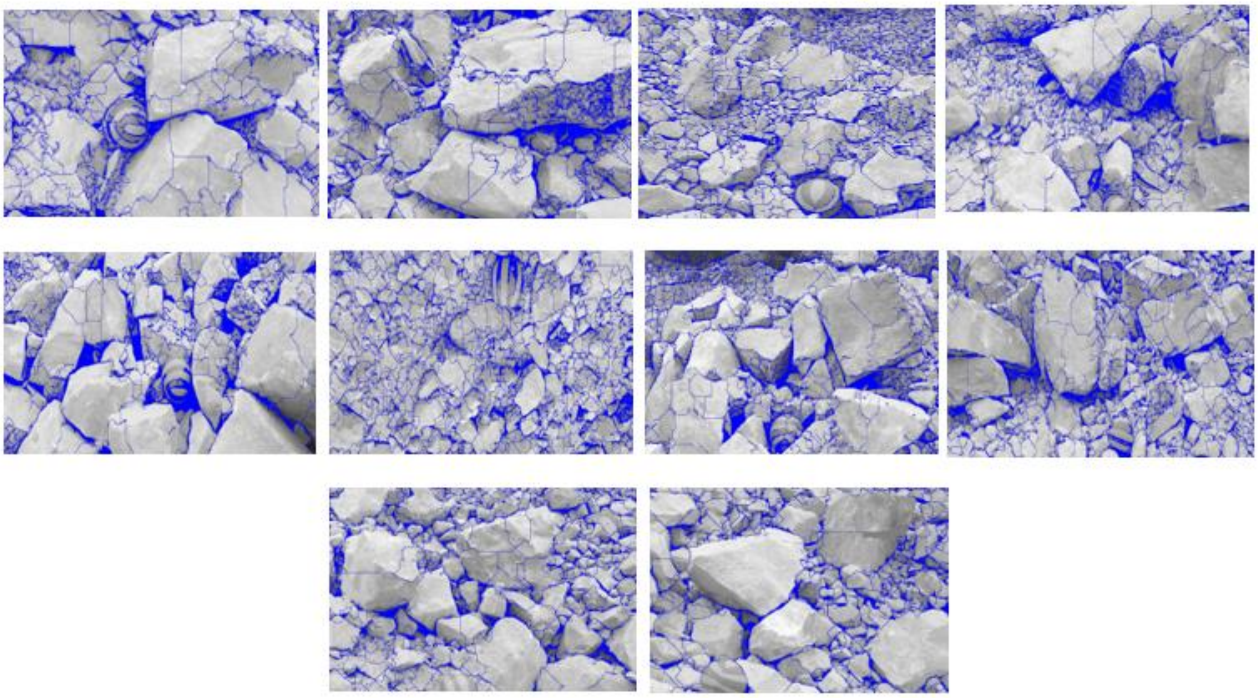

Figure 2 - Actual Fragmentation

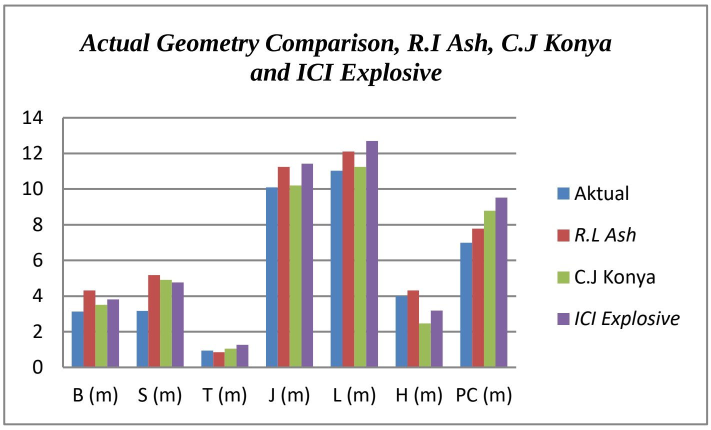

Figure 3 - Comparison Chart of Actual and Design Geometry

Table 10 - Comparison of Actual and Design Geometric Fragmentation Percentages

Size (cm)	Pass rate comparation %			
	Aktual	*R.L Ash*	*C.J Konya*	*ICI.Explosive*
10	9	13	19	21
20	20	28	40	41
30	42	42	58	59
40	32	55	71	72
50	52	66	80	82
60	61	74	87	89
70	69	81	92	93
80	75	85	95	95
90	80	89	97	97
100	84	92	98	98

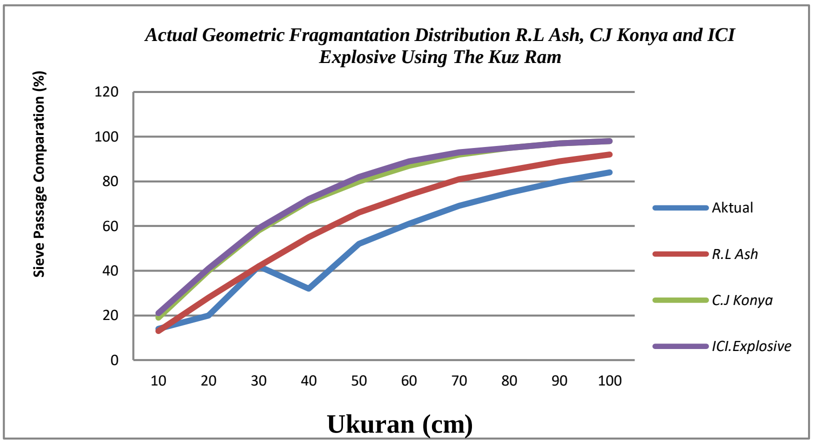

Figure 4 - Actual Geometric Fragmentation Distribution Graph, RL. Ash, C.J Konya, ICI Explosive Using the Kuz-Ram Method

As the blasting geometry increases, the fragmentation results decrease, and as the blasting geometry decreases, the fragmentation results increase. A comparison of the actual fragmentation results with the design processed using the Kuz-Ram method can be seen in Table 10 and Figure 2 below.

From the comparison results above, which passed with a size of < 80 cm, it can be concluded that the geometric design results using R.L Ash's theory are better than the actual geometry.

This can also be seen based on the Powder Factor values, where the Powder Factor value for R.L Ash is 0.44 kg/m3, C.J Konya is 0.76 kg/m3, and ICI Explosive is 0.47 kg/m3. It can be seen that the R.L. Ash method produces a smaller Powder Factor value than C.J. Konya and ICI Explosive, thus supporting the ideal geometric design using the R.L. Ash method as being better than C.J. Konya and ICI Explosive.

Conclusions

The results of the study show that the cause of boulders larger than 80 cm is due to improper blasting geometry, which prevents the company from achieving its targets. The geometry measured or obtained in the field differs from the geometry obtained by the company; it is necessary to evaluate the blasting geometry in order to achieve these targets. The actual blasting geometry of PT. Semen Padang has an average burden value of 3.13 m, spacing of 3.17 m, subdrilling of 0.94 m, bench height of 10.1 m, blast hole depth of 11.03 m, stemming of 4 m, filling column length of 7 m, and blast hole diameter of 5 inches, resulting in boulders > 80 cm amounting to 25%. The results of the actual fragmentation distribution in the field and using the R.L Ash, C.J Konya, and ICI Explosive methods, which use the Kuz-Ram method, each show a fragmentation size of 80 cm that passes through the sieve, namely, actual 75%, RL Ash 85%, C.J Konya 95%, and ICI-Explosive 95%. Based on the Powder Factor value, the R.L Ash method produced a smaller Powder Factor value compared to the C.J Konya and ICI Explosive methods, where the Powder Factor value for R.L Ash was 0.44 kg/m3, C.J Konya was 0.76 kg/m3, and ICI Explosive was 0.47 kg/m3. Using the R.L. Ash blasting geometry, the company's target of having boulders (>80 cm) at <15% can be achieved.

Conflicts of interest. If you agree, you should not delete this statement: On behalf of all authors, the corresponding author states that there is no conflict of interest.

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Semen Padang кәсіпорнында әктасты өндіру бойынша жарылыс жұмыстары кезіндегі фрагменттеу нәтижелерін талдау

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Қабылданды: *27 ақпан 2026*

ТҮЙІНДЕМЕ
Semen Padang - цемент өндірісі үшін негізгі шикізат ретінде әктас пен және кварц жыныстарын өндірумен айналысатын компания. Тау-кен өндіру жүйесі ашық тәсілмен пайдаланылады. Бұл зерттеуде геометрияның тау жыныстарының фрагментациясына әсері талқыланады. Осы зерттеудің мақсаты.жарылыс жұмыстарының геометриясын анықтау және PT Semen Padang кен орнында әктасты блоктардың пайда болу себептерін анықтау болып табылады. Зерттеу фрагменттеуге бағытталған, өйткені фрагменттеу жарылыс қызметінің табысты болуының анықтаушы факторы болып табылады. Фрагменттеу компанияның мақсаттарын жақсартуда маңызды рөл атқарады және фрагменттеуді бөлу оңтайлы болуы тиіс. Параметр ретінде фрагменттеуді бақылау үшін құм ағынымен өңдеу геометриясы талап етіледі. Зерттеушінің осы саладағы бақылауларының нәтижелерін негізге ала отырып, компанияда 80 см-ден асатын жыныс кесектерінің көлемі шамамен 25% -ды құрайды, сондықтан жарылыс жұмыстарының геометриясын қайта бағалау қажет. Бұл зерттеудің мақсаты 80 см ұяшық өлшемімен елеуіште 15% -дан кем болатын, ұяшықтың қажетті деңгейін қамтамасыз ететін геометриялық құрылымды анықтау болып табылады, бұл өнімділікті арттыруға R.L Ash, C.J Konya және ICI Explosive әдістерін салыстыруға мүмкіндік береді. Жарылыстың идеалды геометриясын жобалау үшін Куз-Рам теориясын қолдана отырып, Р.Л. Эш әдісі пайдаланылды. Деректерді өңдегеннен кейін, жүктеме мәні 4,32 м, қашықтық 5,18 м, кенжардың ұзындығы 4,32 м, жарылыс ұңғымасының тереңдігі 12,1 м, толтыру бағанасының ұзындығы 7,78 м және жарылыс ұңғымасының диаметрі 5 дюйм, бөлшектеу пайызы шамамен 15% болатын мінсіз геометрия алынды.

Түйін сөздер: жарылыс геометриясы, фрагментация, Р.Л. Эш, Куз-Рам, К.Дж. Конья, ICI жарылғыш заты.

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Анализ результатов фрагментации при взрывных работах по добыче известняка на предприятии Semen Padang.

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Semen Padang –компания, занимается добычей известняка и кварцевой породы в качестве как основного сырья для производства цемента. Горнодобывающая система используется открытым способом. В этом исследовании обсуждается влияние геометрии на фрагментацию пород. Цель данного исследования является определение геометрии взрывных работ и выявление причин образования известняковых блоков на месторождении PT. Semen Padang. Исследование сосредоточено на фрагментации, потому что фрагментация является определяющим фактором успеха взрывной деятельности. Фрагментация играет

Поступила: *5 января 2026* Рецензирование: *29 января 2026* Принята в печать: *27 февраля 2026*	важную роль в улучшении целей компании, и распределение фрагментации должно быть оптимальным. Для контроля фрагментации в качестве параметра требуется геометрия пескоструйной обработки. Основываясь на результатах наблюдений исследователя в этой области, размер кусков породы в компании, которые превышают 80 см, составляет около 25%, поэтому необходимо переоценить геометрию взрывных работ. Цель данного исследования является определение геометрической конструкции, обеспечивающую желаемый уровень фрагментации, составляющий менее 15% на сите с размером ячейки 80 см, что позволит увеличить производительность и провести сравнение методов Р.Л. Эша, К.Дж. Конья и ICI Explosive. Для проектирования идеальной геометрии взрыва использовался метод Р.Л. Эша с применением теории Куз-Рама. После обработки данных была получена идеальная геометрия со значением нагрузки 4,32 м, расстоянием 5,18 м, длиной забоя 4,32 м, глубиной взрывной скважины 12,1 м, длиной заполняющей колонны 7,78 м и диаметром взрывной скважины 5 дюймов, с процентом фрагментации куском около 15%.
	Ключевые слова: Геометрия взрыва, фрагментация, Р.Л. Эш, Куз-Рам, К.Дж. Конья, ICI Explosive.
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