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Analysis of blasted rocks fragmentation using digital image processing (Case study: Limestone quarry of Obajana Cement Company)

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Abstract

Purpose. Blasting is an important aspect of mining activities in which fragmentation is the key component that determines its efficiency. Fragmentation is the first result of blasting, and is directly related to the costs of mining.

Methods. There are two basic methods for determining the degree of rock fragmentation, the direct and indirect methods. The direct method includes sieve analysis while the indirect method involves observational, empirical and digital image processing methods. The digital image processing method with the aid of Split Desktop software was used in this study, to analyze the size of fragmentation in Obajana limestone quarry. Two pits of similar line of operation were considered.

Findings. In each of the pits considered, five muckpiles of blasted rocks after blasting with different blasting patterns were analyzed to study the fragmentation phenomenon. The F_{80} and F_{90} values from the Split Desktop image analysis for the 5×3 m and 4×3 m in Pit 1 and Pit 2 were approximately 87.96 and 96.20 cm; and 91.34 and 98.66 cm respectively. Also, the F_{80} and F_{90} values obtained from the Kuz-Ram model for the 5×3 m and 4×3 m of Pit 1and Pit 2 were 99.9967 and 99.9994 cm; and 99.9957 and 99.9993 cm respectively. The results of the Split Desktop were compared to the results of the Kuz-Ram experiential model. The values of F_{80} and F_{90} of the blasted rocks are very close to the crusher gape value of 1 m, which reduces the production costs, and that is an outcome practically realized for the two pits of Obajana quarry.

Originality. The findings showed that the output obtained from the Split Desktop software which is a digital image processing method were in conformity with the Kuz-Ram experiential model which is based on empirical relationship.

Practical implications. In conclusion, the results of the investigation have significant implications for the practical application. It gives more options to explore for rock blast fragmentation efficiency of the desired area.

Keywords: *blasting, fragmentation, muckpile, limestone deposit, digital image processing, desktop software*

1. Introduction

Blasting operation involves breaking or loosening the rock, ore and waste into minimum size and to extract largest possible size at minimum cost. Drilling and blasting are necessary to penetrate and fragment the rock mass and is given a generic term rock breakage. The first objective of blasting is to achieve size reduction of maximum amount of earth material at a reduced cost. To achieve this objective, quantitative and qualitative requirements of blast fragmentation are necessary conditions that must be met [1], [2]. Blasting is carried out in mining and quarrying to reduce the in-situ rocks to smaller size fragments that can be easily handled by the available loading and haulage equipment. The size of fragments obtained must also not exceed the gape of the crushing plant for efficient operation. Hence, blasting could be seen as the first comminution process in quarrying and mining [3]-[5]. Fragmentation degree plays an important role in control and reduction of loading, transportation, and crushing expenses [6]-[8]. The efficiency of these operations depends on the size distribution of blasted rocks. It is therefore important for measurement and analysis of fragmentation of blasted rock masses [6]. To essentially optimize blast fragmentation, elimination of extremely big fragments or minimization of excessive fines in the muckpile must be considered. Kuz-Ram model has been used to appraise blast design alternatives and minimize the number of trial blasts to produce the required optimal results [9]. The most common empirical model to evaluate blast fragmentation is the Kuz-Ram model established by Kuznetsov [10]. The Kuz-Ram model [10] is an empirical relationship that evaluates blast fragmentation by incorporating blast design parameters – blast geometry, explosive characteristics, quantity of explosive used and rock factors. Kuz-Ram model measures fragmentation by estimating the 50% passing block size of a

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muckpile. There are two major methods for assessment of blast fragmentation. The methods are direct, which includes the sieving analysis method and indirect, which includes observational, experimental and image analysis methods [11], [12]. Each of the models has its intrinsic merits and de-merits. However, digital image analysis is a product of technological advancement and has become the most commonly used indirect approach for evaluating blast fragmentation [6], [13]-[15]. To compare the results of the two techniques, statistical ana-lyses were performed.

To determine the grain size distribution, the mechanism requires three basic phases using the image analysis method, these are; selection of sampling site, imaging, and image analysis. The sampling phase involves selection of sites to obtain samples that represent the blasted rock mass. At the imaging phase, high quality images, which can be analyzed in the image analysis phase, are prepared. In the last phase, the size distribution of fragments marked on the image is measured after drawing the perimeter of fragments on the image [11].

Generally, digital image processing programs are operated the same way, therefore, it is only some unique features which makes the distinctions among these programs. One of its biggest advantages is its ability to display real-time measurement results, which can consequently be used to quickly transmit information to control systems, allowing them to process the data online [16].

Split Desktop image analysis software was used in this re-search to study fragmentation. Split Desktop is one of the latest digital images processing software, featuring advantages such as a more user-friendly interface compared to its previous versions. More importantly, the results of this software are more accurate and involve less error. Because of these suitable features, this research is carried out using Split Desktop worldwide.

2. Methods

Four blasting operations at Obajana Quarry face (two blasts from each Pit 1 and 2 of the same line of operation) were studied and the resulting fragmentation evaluated using the Split Desktop. Split Desktop is designed for analysis of digital images obtained from the digital camera and for determining the rock fragmentation gradation distribution. The best basic version of this software was developed by some researchers from the mining engineering and earth sciences department of Arizona University in the United States of America. The merit of this software can be found in [17].

Split Desktop software involves five main phases of analysis for each image. The image is scaled in the first stage. The second stage is dedicated to segmentation of rock fragments in each image. The third stage allows the permission for editing the desired rock fragments to ensure precision of results. The fourth stage involves analysis of rock fragments marked in the image. Finally, in the fifth phase, the size distribution results are displayed in the form of diagrams [18].

2.1. Description of the study location

Dangote Cement Plant is one of the biggest industrial units of Nigeria located in Obajana town of Kogi State, Nigeria. The limestone deposit is located at the Oyo Iwaa village, which is about 12 km North East of Obajana town and it is approximately 200 km South West of Abuja, the capital of Nigeria. The large deposit of limestone is available in the North of the hosting community, Oyo Iwaa and it is located by grid reference latitude 07°59′48.1″ N and longitude 006°25′59.6′ E. The Oyo Iwaa limestone deposit exhibits undulated to hilly topography with a gentle slope towards the North East. The vegetation in the area is Guinea savanna type which is a mixture of two types; savanna woodland, where trees and shrubs form a fair close canopy and tree savanna, where trees and shrubs are scattered. The area which appears to occupy two shallow valleys is drained mainly by Mimi River and its tributaries which form the dendrite pattern of drain-age surrounded by ridges of gneiss and discharge their water southward into river Niger [19]. This area of study is as well characterized with distinctive wet and dry season. The rainy season is between the period of April to September or October with annual rainfall of about 12000 mm and mean temperature of about 30°C. The dry season begins from October to around March and it is very humid [20].

The effective use of land in that area is strictly on quarrying of raw material for cement production. There is a scattered settlement within the study area which the villagers use the vast land for agricultural operations such as farming, fishing, hunting and timbering. The geological map of Kogi State indicating the study area is as shown in Figure 1. The elevation of the plain at which the factory was located was about 230 m above the sea level.

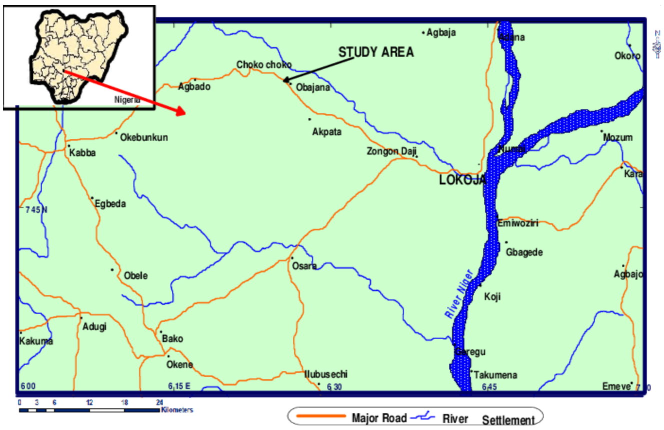

Figure 1. Geographical Map of Kogi State, Nigeria

The success of Obajana Cement Company is hinged on its use of low-cost and high-quality raw materials, which are available in the town and its environs. The benches in Pit 1 and Pit 2 of the mine generally have heights of 14.5 and 9.5 m respectively, and similar blast holes diameter of 125 mm. The sub-drilling is assumed to be 1 m.

In both pits, low and high explosive type of 18 and 22 kg were used. Considering the blast pattern, the primers are distributed differently in the blast holes. The powder factor used in Pit one and Pit two are 3.2 and 2.5 kg/tons respectively. In addition, ANFO of 16 kg is used in each pit as the main charge, while electric detonators are used in each blast holes to blasting.

To begin blasting, the first-row blast holes are blasted with a 2-unit delay. The delay between 2 consecutive detonators is 17 and 25 milliseconds. A delay of 0.05 s is applied to ensure the efficiency of explosion between two rows of blast holes and to improve fragmentation. Figures 2 and 3 show the site following the blasting operation.

Figure 2. Obajana Quarry Site after Blasting (Pit 1)

Figure 3. Obajana Quarry Site after Blasting (Pit 2)

3. Results and discussion

The results of processing and analyzing information on the blasted rock fragments are recorded as follows.

A total of ten blasted muckpiles (five each from the two pits) were analyzed.

At Obajana Cement Mine, there are two major types of Crushers; Impact Crushers (for Lines 1 and 2, and Line 5) and Double Roll Crushers (for Lines 3 and 4). The Impact Crushers for limestone are supplied by Hazemag GmbH while the Double Roll Crushers are supplied by TKF (ThyssenKrupp Forder technique) GmbH. The feed for Obajana Cement Plant's crusher varies from line to line. The lines are for different crushers. Pit one and Pit two serves the lines. For line one and two, the feed is between 1-1.2 m for fine rocks and 1.5 m for larger rocks depending on the height of blow bar. While for line three and four, it is 1 m to avoid interlocking of stones. The latter rocks are known as boulders and need secondary fragmentation which brings additional costs, and hence the pattern specified for each blast operation should be designed such that more desirable fragmentation and the highest efficiency are obtained at low drilling and blasting costs.

A total number of five muckpiles for each Pit were analyzed. In the first Pit, the burden thickness was 5 m with the longitudinal spacing of blast holes of 3 m. In the second Pit, the burden thickness was 4 m with the longitudinal spacing of blast holes of 3 m. Apart from the values of burden thickness, longitudinal spacing of blast holes and powder factor that were different, other parameters of drilling pattern and blasting were the same for the two pits.

Tables 1 and 2, present the data for drilling and blasting of Pit 1 and Pit 2 respectively.

Table 1. Data for drilling and blasting of Pit 1

S/N	Parameter	Value
1	Burden (m)	5
2	Spacing (m)	3
3	Bench height (m)	14.5
4	Hole diameter (mm)	125
5	Stemming (m)	3
6	Sub-drill (m)	1
7	Powder factor (kg/tons)	3.2
8	Quantity of explosive per meter	ANFO = 16 kg
9	Explosive type	Low explosive = 18 kg Bulk emulsion = 22 kg
10	Delay time/interval	17 ms 25 ms

Table 2. Data for drilling and blasting of Pit 2

S/N	Parameter	Value
1	Burden (m)	4
2	Spacing (m)	3
3	Bench height (m)	9.5
4	Hole diameter (mm)	125
5	Stemming (m)	2.5
6	Sub-drill (m)	1
7	Powder factor (kg/tons)	2.5
8	Quantity of explosive per meter	ANFO = 16 kg
9	Explosive type	Low explosive = 18 kg Bulk emulsion = 22 kg
10	Delay time/interval	17 ms 25 ms

Results of analyzing the fragmentation of the five muckpiles in each of the two Pits with the use of Split Desktop are shown in Tables 3 and 4. From these tables, average values of F_5, F_{10}, F_{20}, F_{30}, F_{40}, F_{50}, F_{60}, F_{70}, F_{80}, F_{90} and F_{100} obtained from analysis of images of blasted rocks from the Pits are listed from the Table 5, the final average values of F_{80} and F_{90} for both pits are very close to the gape of the crusher (i.e. 87.96 and 96.20 cm for Pit 1; 91.34 and 98.66 cm for Pit 2). This indicates that both Pits 1 and 2 contain high-quality limestone and has relatively desirable geological and tectonic conditions as well as joints and cracks. However, the only difference between the two pits is the burden dimension which is reduced by 1 m, bench height is reduced by 5 m and powder factor is reduced by 0.7 kg/ton in Pit 2.

Table 3 and 4 show the values of F_5, F_{10}, F_{20}, F_{30}, F_{40}, F_{50}, F_{60}, F_{70}, F_{80}, F_{90} and F_{100} obtained from analysis of images of blasted rocks of the five Muckpiles in each of Pit 1 and Pit 2.

Table 3. Values obtained from Split Desktop image analysis of blasted rocks in Pit 1

Muckpile	A	B	C	D	E
F_5	3.60	20.9	14.6	18.5	10.4
F_{10}	9.21	32.7	28.2	26.2	18.1
F_{20}	28.7	43.5	37.5	39.5	28.7
F_{30}	47.1	51.1	44.1	47.1	47.1
F_{40}	52.3	57.8	51.7	52.7	52.3
F_{50}	64.8	62.9	66.9	63.8	78.5
F_{60}	70.1	74.3	73.1	70.9	82.4
F_{70}	75.9	80.9	87.4	78.4	87.5
F_{80}	82.4	88.7	91.8	85.7	91.2
F_{90}	96.5	95.1	99.6	90.3	99.5
F_{100}	100	100	100	100	100

Table 4. Values obtained from Split Desktop image analysis of blasted rocks in Pit 2

Muckpile	A	B	C	D	E
F_5	12.7	10.4	15.6	18.3	14.7
F_{10}	21.9	22.6	20.1	29.5	23.4
F_{20}	38.3	39.8	46.6	41.9	38.2
F_{30}	49.7	55.0	50.3	52.4	42.5
F_{40}	60.2	60.1	62.8	61.9	57.8
F_{50}	67.1	69.8	73.5	73.7	62.9
F_{60}	78.6	75.9	82.0	81.0	70.3
F_{70}	84.3	80.7	90.8	87.3	82.4
F_{80}	90.2	87.2	96.2	92.6	90.5
F_{90}	99.6	96.4	99.9	98.2	99.2
F_{100}	100	100	100	100	100

Analysis of the F_{80} and F_{90} values obtained from the fragmentation analysis of both Pits 1 and 2 indicate average values of 87.96 and 96.20 cm; and 91.34 and 98.66 cm respectively, which is smaller than the crusher's gape. Although this pattern yields a suitable F_{90} value, it increases drilling costs by adding to the number of blast holes, which is not economically desirable. Figure 4 depicts the cumulative grain-size curves obtained from analysis of the five images A-E of Pit 1, while Figure 5 shows the cumulative grain-size curves obtained from analysis of the five images A-E of Pit 2.

In comparing the Image Analysis results with the results of Kuz-Ram experiential model, the results and diagrams obtained from the Kuz-Ram experiential model reveals that the model is suitable for the conditions of Obajana Cement Limestone quarry, because the results are similar to the results of digital image analysis in Split Desktop.

According to Tavakol and Hosseini [16], Souza et al. [21] Equation (1) is used for the purpose of this comparison. The results generated from the digital image analysis are compared to results of the Kuz-Ram experiential model:

$$X_{50} = A \cdot (PF)^{-0.8} \cdot Me^{0.167} \cdot \left(\frac{115}{RWS_{anfo}}\right)^{0.633}, \quad (1)$$

where:

X_{50} – particle size of muckpile (cm);

A – rock coefficient, which is assumed to be 10;

PF – specific charge (kg/m^3);

Me – charge mass per blast holes (kg);

RWS_{anfo} – the relative weight strength of the explosive to ANFO (%).

Equation (2) is used for size distribution curve:

$$R(X) = 1 - e^{-\left(\frac{X}{X_c}\right)^n}, \quad (2)$$

where:

$R(X)$ – % passing through the screen opening of size X;

X – screen size (cm);

X_c – the characteristic size (cm);

n – uniformity index.

Uniformity index and characteristic size were calculated using Equations (3) and (4):

$$n = \left(2.2 - 14\frac{B}{d}\right)\left(\frac{1 + \left(\frac{S}{B}\right)^{0.5}}{2}\right) \cdot \left(1 - \frac{E_p}{B}\right)\left(\frac{L}{H}\right). \quad (3)$$

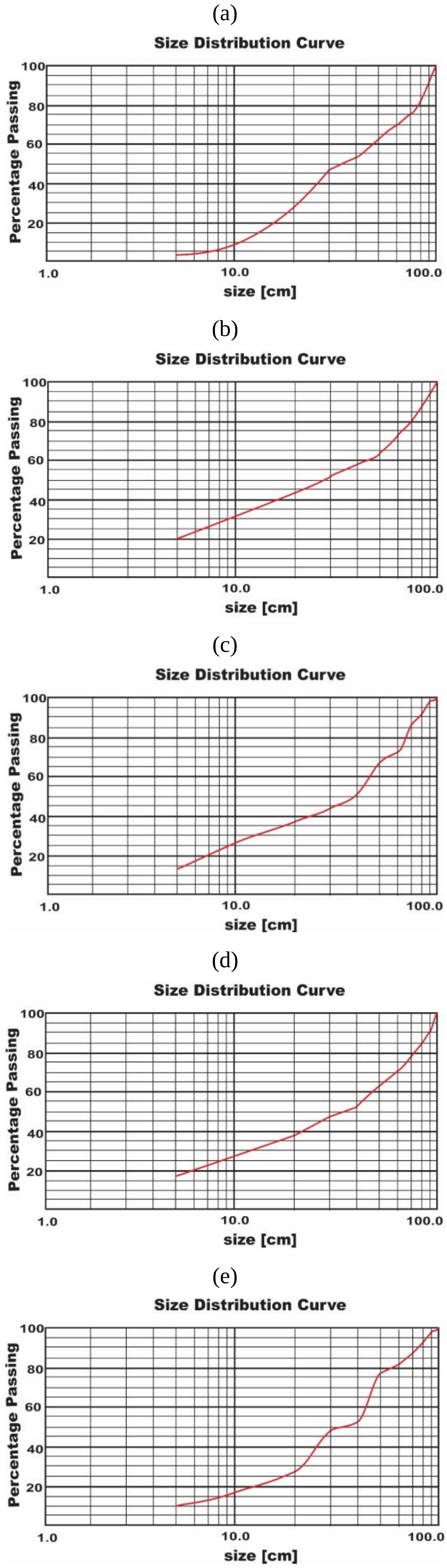

Figure 4. Cumulative grain-size curves of image analysis of blasts in Pit 1: (a) image A; (b) image B; (c) image C; (d) image D; (e) image E

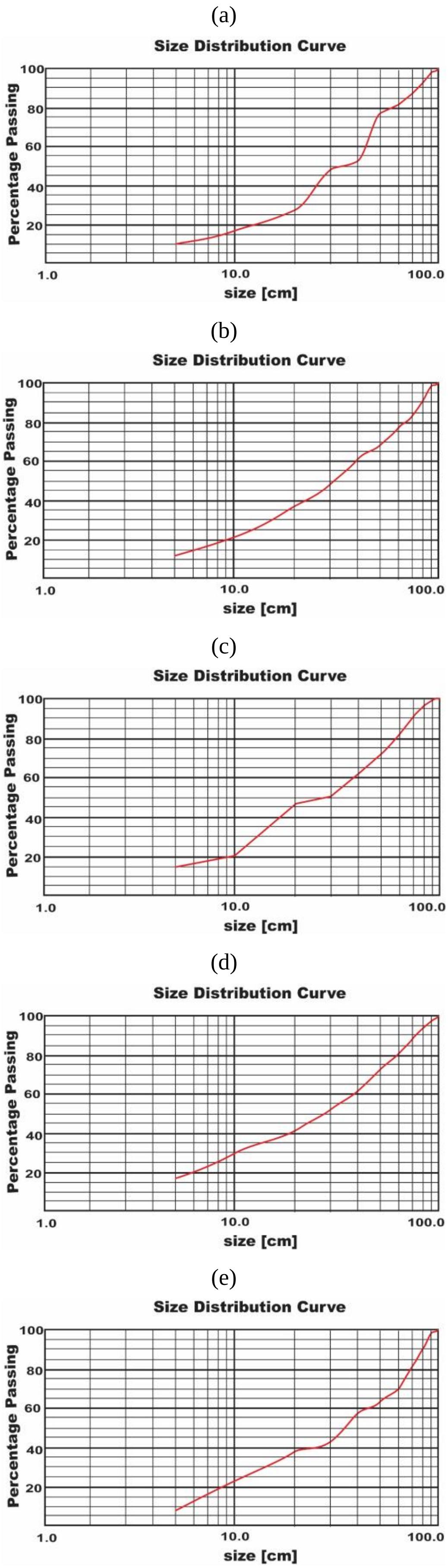

Figure 5. Cumulative grain-size curves of image analysis of blasts in Pit 2: (a) image A; (b) image b; (c) image C; (d) image D; (e) image E

$$X_c = \frac{X_{50}}{(0.693)^{1/n}}, \quad (4)$$

where:

L – the charge length (m);

H – the bench height (m);

S – longitudinal spacing of blast holes (m);

B – the burden (m);

d – the blast holes diameter (mm);

E_p – the blast holes deviation [22].

Figures 6 and 7 show the size distribution curve of the blast design obtained from the Kuz-Ram model for the two pits while Figures 8a-e and 9a-e compare the Kuz-Ram curve with the five results obtained from the Split Desktop for Pit 1 and Pit 2 respectively. The Split Desktop analyses show a closely related particle size distribution for the five blasts in each of the two pits with uniformity indices of 1.26 and 1.38 respectively.

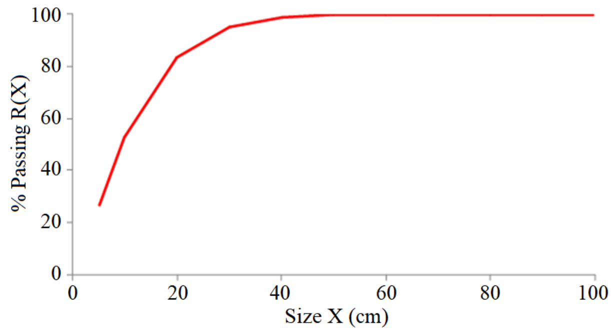

Figure 6. Kuz-Ram size distribution curve for blast design in Pit 1

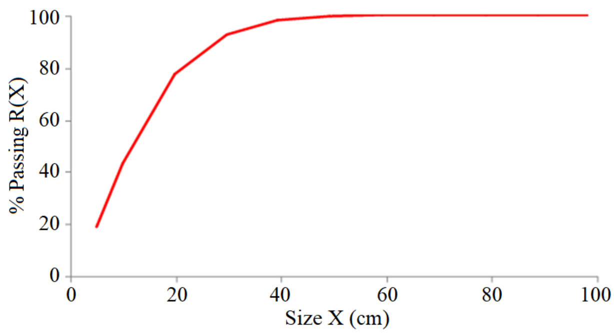

Figure 7. Kuz-Ram size distribution curve for blast design in Pit 2

It is observed that the particle size distribution obtained from the Kuz-Ram model significantly deviates from that of the Split Desktop model despite showing similar trends, while the Kuz-Ram model shows that all the fragments of the muckpile are less than 100 cm benchmark.

Table 5 shows the results of the Kuz-Ram experiential model for both Pit 1 and Pit 2.

Details of the percentage passing obtained from the pits and Kuz-Ram analyses are shown and compared in Tables 6 and 7, while Tables 8 and 9 show the characterization features of the analyses.

The five independent results for each of the pits from Split Desktop are very close as shown in Figures 10 and 11 and thereby showing the same design. The differences between them can be attributed to their variations in rock mass structural features [23], [24].

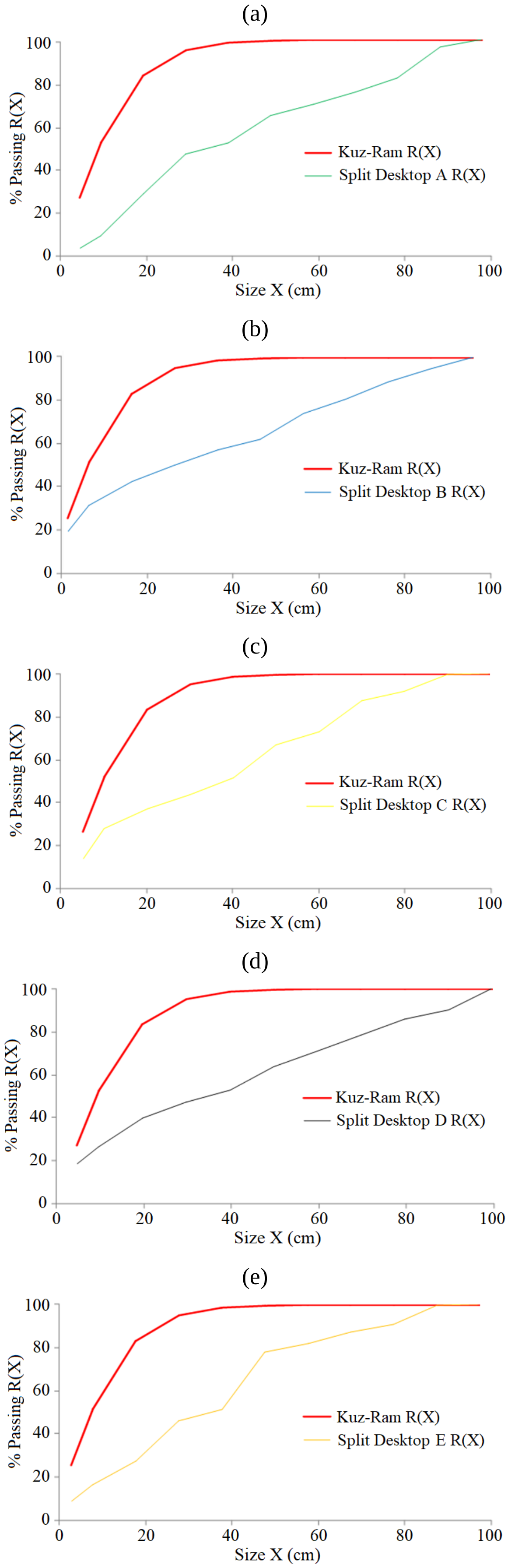

Figure 8. Kuz-Ram versus Split desktop size distribution curves in Pit 2: (a) for blast A; (b) for blast B; (c) for blast C; (d) for blast D; (e) for blast E

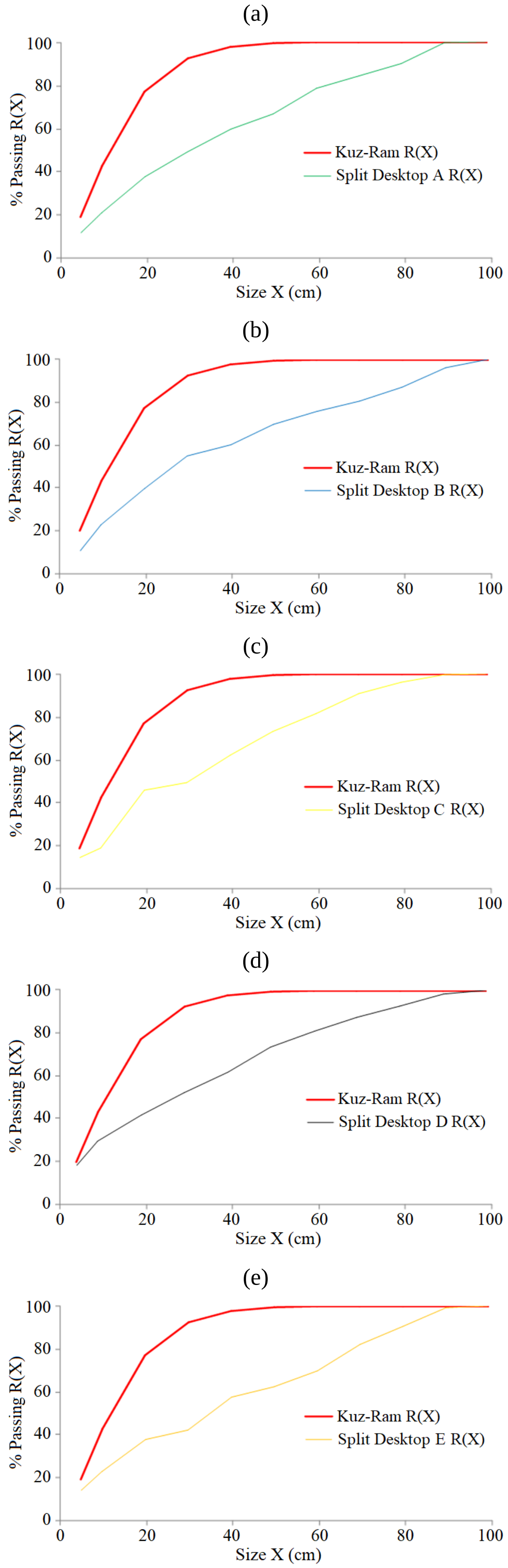

Figure 9. Kuz-Ram versus Split desktop size distribution curves in Pit 2: (a) for blast A; (b) for blast B; (c) for blast C; (d) for blast D; (e) for blast E

Table 5. Results of the Kuz-Ram experiential model for Pit 1 and Pit 2

Size (cm)	Pit 1	Pit 2
F_5	26.6455	19.6769
F_{10}	52.4973	43.4657
F_{20}	83.2741	77.3378
F_{30}	94.9504	92.5558
F_{40}	98.6374	97.9013
F_{50}	99.6641	99.4791
F_{60}	99.9233	99.8842
F_{70}	99.9836	99.9767
F_{80}	99.9967	99.9957
F_{90}	99.9994	99.9993
F_{100}	99.9999	99.9999

Table 6. Basic percentage passing for Kuz-Ram and Split Desktop analyses of Pit 1

Size, X (cm)	Kuz-Ram, %	Split Desktop blast				
		A, %	B, %	C, %	D, %	E, %
100	99.9999	100	100	100	100	100
90	99.9994	96.5	95.1	99.6	90.3	99.5
80	99.9967	82.4	88.7	91.8	85.7	91.2
70	99.9836	75.9	80.9	87.4	78.4	87.5
60	99.9233	70.1	74.3	73.1	70.9	82.4
50	99.6641	64.8	62.9	66.9	63.8	78.5
40	98.6374	52.3	57.8	51.7	52.7	52.3
30	94.9504	47.1	51.1	44.1	47.1	47.1
20	83.2741	28.7	43.5	37.5	39.5	28.7
10	52.4973	09.2	32.7	28.2	26.2	18.1
5	26.6455	03.6	20.9	14.6	18.5	10.4

Table 7. Basic percentage passing for Kuz-Ram and Split Desktop analyses of Pit 2

Size, X (cm)	Kuz-Ram, %	Split Desktop blast				
		A, %	B, %	C, %	D, %	E, %
100	99.9999	100	100	100	100	100
90	99.9993	99.6	96.4	99.9	98.2	99.2
80	99.9957	90.2	87.2	96.2	92.6	90.5
70	99.9767	84.3	80.7	90.8	87.3	82.4
60	99.8842	78.6	75.9	82.0	81.0	70.3
50	99.4791	67.1	69.8	73.5	73.7	62.9
40	97.9013	60.2	60.1	62.8	61.9	57.8
30	92.5558	49.7	55.0	50.3	52.4	42.5
20	77.3378	38.3	39.8	46.6	41.9	38.2
10	43.4657	21.9	22.6	20.1	29.5	23.4
5	19.6769	12.7	10.4	15.6	18.3	14.7

Table 8. Characterization features of the analyses from Pit 1

	X_{50} (cm)	X_c (cm)	*n*
Kuz-Ram	9.45	12.64	1.26
Split Desktop of blast A	38.6	51.64	1.26
Split Desktop of blast B	28.9	38.66	1.26
Split Desktop of blast C	39.8	53.25	1.26
Split Desktop of blast D	34.8	46.56	1.26
Split Desktop of blast E	32.8	43.88	1.26

Table 9. Characterization features of the analyses from Pit 2

	X_{50} (cm)	X_c (cm)	*n*
Kuz-Ram	11.51	15.01	1.38
Split Desktop of blast A	32.1	41.87	1.38
Split Desktop of blast B	27.2	35.48	1.38
Split Desktop of blast C	25.6	33.39	1.38
Split Desktop of blast D	28.6	37.31	1.38
Split Desktop of blast E	35.8	46.70	1.38

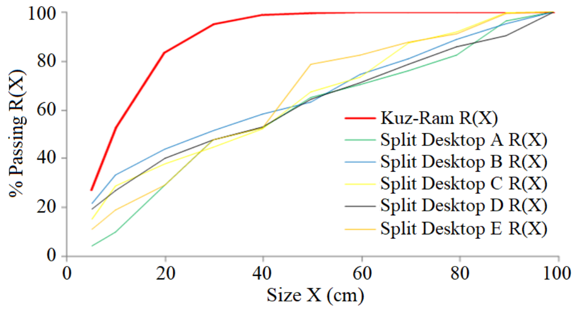

Figure 10. Kuz-Ram versus Split desktop size distribution curves for blast A, B, C, D and E in Pit 1

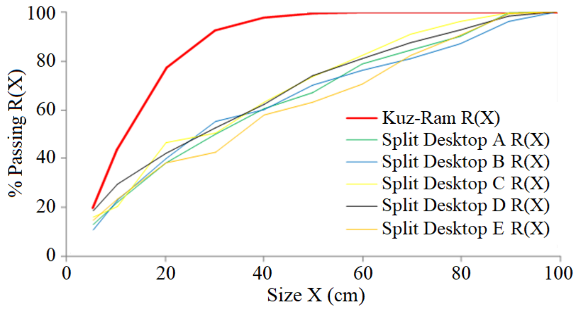

Figure 11. Kuz-Ram versus Split desktop size distribution curves for blast A, B, C, D and E in Pit 2

According to Shehu et al.[3], fragmentation indicator (FI) for assessing the quality of blast fragmentation is as expressed in Equation (5):

$$FI = \frac{X_{kr}}{X_{bm}}, \quad (5)$$

where:

FI – fragmentation indicator;

X_{kr} – expected ideal mean size of the blasted material from Kuz-Ram model (cm);

X_{bm} – size of blasted muck pile from particle distribution analysis (cm).

The fragmentation efficiency is given by the fragmentation indicator (FI) by comparing the fragment produced with the estimated ideal size obtained from the Kuz-Ram model by incorporating blast design parameters and rock factor. If the value of FI is less than unity (1), it implies that the average fragment size obtained is larger than the ideal size and when the value of FI is greater than or equal to 1, it shows a highly efficient fragmentation with average fragment size less than or equal to the ideal size [3]. However, the value of FI could hardly be greater than 1. Tables 10 and 11 show the fragmentation indication values for the five blasts for Pit 1 and Pit 2 respectively.

It is observed that the blast event values from Pit 2 (varied from 0.322 to 0.450) are higher than the values of blast events of Pit 1 (varied from 0.237 to 0.327).

Table 10. Fragmentation Indicators for Pit 1

S/N	Blast events	X_{kr} (cm)	X_{bm} (cm)	FI
1	Blast A	9.45	38.6	0.245
2	Blast B	9.45	28.9	0.327
3	Blast C	9.45	39.8	0.237
4	Blast D	9.45	34.8	0.272
5	Blast E	9.45	32.8	0.288

Table 11. Fragmentation Indicators for Pit 2

S/N	Blast events	X_{kr} (cm)	X_{bm} (cm)	FI
1	Blast A	11.51	32.1	0.359
2	Blast B	11.51	27.2	0.423
3	Blast C	11.51	25.6	0.450
4	Blast D	11.51	28.6	0.402
5	Blast E	11.51	35.8	0.322

Also, in Pit 1, blast B has the best efficient fragmentation while in Pit 2, blast C has the best efficient fragmentation. However, the blast event C in Pit 2 has the overall highest FI value of 0.450 and hence is the most efficient fragmentation.

4. Conclusions

This research investigated blast-induced fragmentation in two pits of Obajana Cement quarry using the digital image processing feature of Split Desktop. It was observed that rock mass characterization is very essential when it comes to the best performance of the blasting operation. A more detailed study of rock mass does not only reduce the transportation, handling and crushing costs but also reduce the cycle time and increase production. In both Pits 1 and 2, the same line of operation (Line 2) was used, which served the crusher gape of 1 m. The only variations from both pits are burden, bench height and powder factor while other parameters are similar. F_{80} of Pit 1 yielded an average value of 87.96 cm and Pit 2 yielded 91.34 cm; while F_{90} of Pit 1 yielded an average value of 96.20 and Pit 2 yielded 98.66 cm from the image analysis. The values of F_{80} and F_{90} percentage passing of blasted rocks in both pits after analyzing them by the use of Split Desktop are considered suitable for the quarry operation due to the fact that the values are very close to 1 m, which is the gape of the crusher. It can be said that the Kuz-Ram fragmentation model assisted by simulation shows the efficiency in predicting the rock fragmentation using explosives.

The diagram of size distribution of blasted rocks actually reflects a similarity between the results of digital image processing in Split Desktop and that of the Kuz-Ram experiential model. Hence, the results prove that the models are important in predicting blast fragmentation in order to maintain a normal operating level and desired degree of fragmentation by blasting.

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Аналіз фрагментації підірваних порід із використанням цифрової обробки зображень (на прикладі вапнякового кар'єру компанії Obajana Cement Company)

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Мета. Аналіз фрагментації підірваних порід із використанням цифрової обробки зображень на прикладі вапнякового кар'єру компанії Obajana Cement Company для оцінки ефективності параметрів вибухових робіт.

Методика. Існує два основних методи визначення ступеня фрагментації гірських порід: прямий і непрямий. Прямий метод включає ситовий аналіз, тоді як непрямий метод включає методи спостереження, емпіричні та цифрові методи обробки зображень. У цьому дослідженні використовувався метод обробки цифрових зображень за допомогою програмного забезпечення Split Desktop для аналізу ступеня фрагментації порід вапнякового кар'єру Обаяна. Розглянуто два рудники з аналогічною виробничою лінією.

Результати. У кожному з розглянутих рудників були проаналізовані п'ять відвалів підірваних порід після вибухових робіт з різними типами вибухів для вивчення явища фрагментації. Встановлено, що значення F_{80} і F_{90}, отримані за допомогою Split Desktop аналізу зображень для рудника 1 – 5×3 м і рудника 2 – 4×3 м склали приблизно 87.96 і 96.20 см і 91.34 і 98.66 см відповідно. На основі моделі Куз-Рам були отримані значення F_{80} і F_{90} для рудників 1 і 2 розміром 5×3 м і 4×3 м, які склали 99.9967 і 99.9994 см та 99.9957 і 99.9993 см відповідно. Виконано порівняння результатів Split Desktop з результатами експериментальної моделі Куз-Рам. Визначені величини F_{80} і F_{90} підірваних порід, які дуже близькі до величини зазору дробарки в 1 м, що знижує виробничі витрати на двох рудниках кар'єра Обаяна.

Наукова новизна. Встановлено тісний взаємозв'язок результатів дослідження фрагментації підірваних порід, отриманих за допомогою методу обробки цифрових зображень і експериментальної моделі Куз-Рам, що заснована на емпіричній залежності.

Практична значимість. Вибухові роботи – важливий аспект діяльності гірничодобувного підприємства, в якій фрагментація є ключовим компонентом, що визначає її ефективність. Фрагментація є першим результатом вибухових робіт і безпосередньо пов'язана з витратами на видобуток корисних копалин. Дослідження дають більше можливостей для вивчення ефективності фрагментації гірської породи у бажаній області.

Ключові слова: *вибухові роботи, фрагментація, відвал, родовище вапняку, цифрова обробка зображень, програмне забезпечення*

Анализ фрагментации взорванных пород с использованием цифровой обработки изображений (на примере известнякового карьера компании Obajana Cement Company)

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Цель. Анализ фрагментации взорванных пород с использованием цифровой обработки изображений на примере известнякового карьера компании Obajana Cement Company для оценки эффективности параметров взрывных работ.

Методика. Существует два основных метода определения степени фрагментации горных пород: прямой и косвенный. Прямой метод включает ситовый анализ, тогда как косвенный метод включает методы наблюдения, эмпирические и цифровые методы обработки изображений. В этом исследовании использовался метод обработки цифровых изображений с помощью программного обеспечения Split Desktop для анализа степени фрагментации пород известнякового карьера Обаяна. Рассмотрены два рудника с аналогичной производственной линией.

Результаты. В каждом из рассматриваемых рудников были проанализированы пять отвалов взорванных пород после взрывных работ с различными типами взрывов для изучения явления фрагментации. Установлено, что значения F_{80} и F_{90}, полученные с помощью Split Desktop анализа изображений для рудника 1 – 5×3 м и рудника 2 – 4×3 м составили приблизительно 87.96 и 96.20 см и 91.34 и 98.66 см соответственно. На основе модели Куз-Рам были получены значения F_{80} и F_{90} для рудников 1 и 2 размером 5×3 м и 4×3 м, которые составили 99.9967 и 99.9994 см, 99.9957 и 99,9993 см соответственно. Выполнено сравнение результатов Split Desktop с результатами экспериментальной модели Куз-Рам. Определены величины F_{80} и F_{90} взорванных пород, которые очень близки к величине зазора дробилки в 1 м, вследствие чего снижаются производственные затраты на двух рудниках карьера Обаяна.

Научная новизна. Установлена тесная взаимосвязь результатов исследования фрагментации взорванных пород, полученных с помощью метода обработки цифровых изображений и экспериментальной модели Куз-Рам, которая основана на эмпирической зависимости.

Практическая значимость. Взрывные работы – важный аспект деятельности горнодобывающего предприятия, в которой фрагментация является ключевым компонентом, определяющим ее эффективность. Фрагментация является первым результатом взрывных работ и напрямую связана с затратами на добычу полезных ископаемых. Исследования дают больше возможностей для изучения эффективности фрагментации горной породы в желаемой области.

Ключевые слова: *взрывные работы, фрагментация, отвал, месторождение известняка, цифровая обработка изображений, программное обеспечение*