

Image Processing Analysis of Blast Fragmentation: A Case Study of Sandstone Mining Area of Jodhpur

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Abstract- The blasting operation plays an important task in the overall economics of opencast mines. The degree of fragmentation affects the loading, transport, crushing operations. Various rock fragmentation measurement methods are available and used by researchers but most of the methods are time consuming and costly. Rock Fragmentation measurement by digital image processing is a quick and low cost process. Under the present study a size distribution of blasted sandstone quarry was carried out using the Split-Desktop image processing software with acquired digital images. Image processing of the data shows that, the mean fragment size obtained is 409.09 mm, top-size is 1,442.58 mm and 5% of the fragments are below 20 mm. Outputs obtained from the software were also compared to results of the Kuz-Ram experimental model. Results showed that the performances of the digital image processing approach are approximate to Kuz-Ram model.

Index Terms- Rock Fragmentation; Sandstone Mining; Image processing; Kuz-Ram Model.

1. INTRODUCTION

The open-pit mining process is generally made up of a sequence of unit operations including drilling, blasting, loading, hauling and crushing (Jasmin Jug et al 2017). Drilling and blasting, being the first unit operations, can have a major impact on the performance and cost of subsequent operations. The objective of production blasting is to achieve optimum rock fragmentation which improves the energy efficiency of comminution processes and saves thousands of kilowatt-hours energy per year (I.C. Engin, 2010, Bhandari and Rathore,2002). Production of finer fragments in blasting operation reduces the workload of primary crushers; therefore, increasing the crusher efficiency and reducing the crushing cost (Siddique FI et. al. 2009).

Various models have been developed for the prediction of the size distribution in the blasted rock. Amongst them and the most popular is the Kuz-Ram model, an empirical fragmentation model based on the Kuznetsov (1973) and Rosin and Rammler (1933) equations modified by Cunningham (1983, 1987) which provide the uniformity index for the Rosine Rammler equation that computes the data from blasting process.

Rock properties, explosive properties, and design variables are combined in this modern version of the KuzeRam fragmentation model (P.K. Singh et al. 2015, M. Akbari et al. 2015, Jethro MA et al. 2016, B. A. Kansake et al. 2016). A dedicated software package Split Desktop was used to estimate the fragmentation distribution by analyzing scaled images from the post blast (Kulula M.I. et al. 2017).

Experiments were carried out in the sand stone mines in Jodhpur district of Rajasthan state. Rajasthan state produces high quality sandstone in the country. The important historical monuments of the country speak much about the unique quality of the sandstone of the Jodhpur area. Varied colour shades, texture and fabulous look have put the sandstone at par with marble. It is preferred over granites and marble specially, when used in flooring, fencings paneling, wall facing and in pillars.

It is especially useful for exterior cladding in sea shore buildings due to acid & thermal resistant properties. Even it is not affected with the salinity of the climate. The sandstone is being quarried and used from centuries and a number of historical buildings and monuments such as Buddhist Stupas of Sarnath, Red Fort, and National Museum, Delhi; Chhitar Palace, Jodhpur etc. are made of sandstone.

2. STUDY AREA

The mining site area is located at a latitude of 26° 19' 55.02" to 26° 19' 56.49" North and longitude of 72° 59' 57.78" to 72° 59' 58.01" East (Fig.1) in Fidusar Chopar, north of Jodhpur city. The study area has a natural drainage slope from North-North East to South-South East towards Jojari River. There are three main mining blocks in the Jodhpur mining area. The various mining quarry of the area are Fidusar, kaliberi, Balsamand and Keru. In Fidusar Soorsagar area the total number of plots/leases sanctioned are about 3600, out of which 2500 are presently operating. The area is

undulating and consists of small hillocks. (Borana et al. 2014) It is surrounded by a hilly terrain. In the North and North East of the area hills exist between 275 - 335 M altitude and in the South of the area hills of 290 - 366 M altitude exist. Geologically the area consists of Malani Igneous Suite as basement and overlain by Sonia formation (Jodhpur Group) of the Marwar Super group. (Yadav et al. 2017) The Sonia formation comprises of a sequence of Sandstone, Shale and Cherty dolomite Limestone. The prominent rock type of the study site comprises of fine grained to medium grained red and buff colored Sandstone. The common Physico-mechanical properties of the rock is given in Table-1.

Table 1 Properties of Sandstone

S.No	Properties	
1	Density	2.4kg/m ³
2	Compressive Strength	390kg/cm ³
3	Modulus of Rupture	220kg/cm ³
4	Poisson's Ratio (GPa)	0.1 – 0.3
5	Water Absorption	1.25%

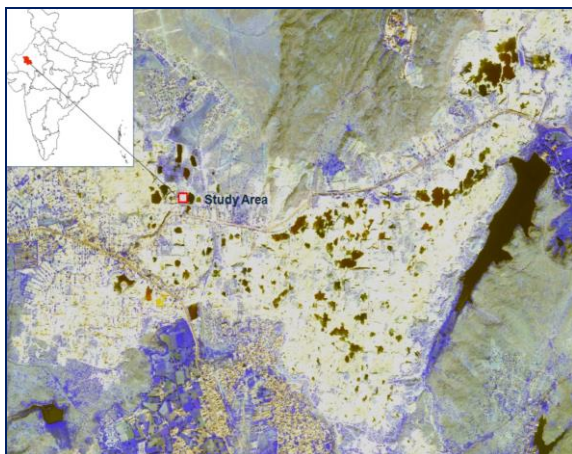


Figure 1 Study Area map.

3. BLASTING METHODS & OPERATIONS

Rock blasting is an important and essential operation in surface mining to break the rock and to reduce the size for comfortable excavation. Drilling is inevitable operation to be carried out before blasting. Other than production drilling sometimes it is also used as exploratory drilling to investigate the depth-wise distribution of minerals during prospecting. (Esen and Bilgin, 2001) In Indian mines mostly the type of the explosive used are slurries, dry mixes, emulsions and the hybrid heavy ANFO (ammonium nitrate/fuel).



Figure 2 Filed Photo of Blast holes

3.1. Drilling & Blasting Pattern

Various drilling patterns have been suggested. A drilling pattern with staggered holes is a commonly adopted in surface mines where the holes are drilled in rows and columns on the surface like grids. Inclination of hole and spacing between the rows and column are pre decided and vary depending upon the geology of the area and properties of rock. (Balasubramanian, 2017, Jimeno et al. 1995) (Fig.2&3).



Figure 3 Filed Photo of Blast holes.

3.2. Hole Diameters & Explosive Charge

Diameter of a hole is restricted by the capabilities of the drill used. Mostly in small scale quarries and in construction presplits small diameter holes, ranging from 2 to 4 inches are adopted. Presplit spacing is varied on the basis of rock type, area of operation and the bench height. Explosive charge loads will also vary depending on rock characteristics, spacing etc. The holes are charged with primer cartridge at the bottom. Main charge is filled above this as column charge. Trials should be conducted to determine the optimal blast parameters.

4. DATA AND SOFTWARE USED

Observations were made on 30-01-2018. Details of the equipment's used for observation and the software used for analysis is provided in Table 2.

Table 2 Equipment and Software Used

S.No	Software & Equipments	Applications
1	Split-Desktop Software	Digital Image Analysis after blasting for rock size distribution
2	Google Earth Satellite data	Satellite Images : 15/01-2018 and 10-02-2018. Visualization of the site and change detection in Pre & Post Blasting in the mine site.
3	High Speed Camera	for recording of high-speed digital images during blasting.
4	GPS & Laser Range Finder	Ground Control Point data.

4.1. Data Collection

Observations were taken on the blasting operations carried out in a sandstone quarry and a database was prepared as narrated in Table 3. In this database, burden (B), spacing(S), diameter of hole (D), bench height (H), blast pattern factor (P), stemming length (L), powder factor(K), relative effective energy of explosive(REE), mass of explosive per hole and standard deviation of drilling error were measured or calculated and have been included as input parameters. Fig. 4 & 5 shows the Satellite Image and field photograph of study area before and after blast. Fig.6 depicts the view of the detonation sequence of sandstone quarry blast at study area.

Table 3 Blasting Parameters

S. No	Parameters	Description
1	Hole diameter	104 mm
2	Bench Height	12 meters
3	Sub-drilling	0.5 meter
4	Burden	3 meter
5	Spacing	4 meter
6	Stemming	3 meter
7	Blasting Pattern	Rectangular
8	Initiation System	Nonel or Shock-tube
9	Powder Factor	0.25 kg / m ³
10	Charge Length	6m
11	Drill Accuracy SD	0.1m



Figure 4 Satellite Image of the Study area (a) before blast and (b) after blast.



Figure 5 Field Photo of the Study area (a) before blast and (b) after blast.

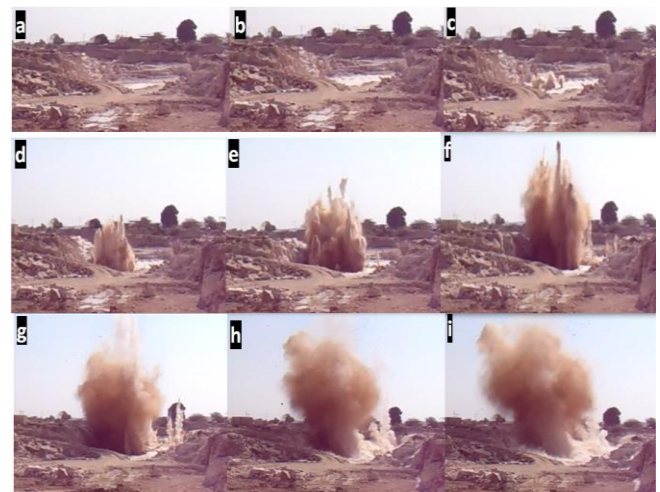


Figure 6 View of the detonation sequence (a to i) of blast conducted at Sandstone Quarry.

5. DATA ANALYSIS

Split-Desktop® software is an image-processing program designed to calculate the size distribution of rock fragments through analyzing digital grayscale images. Split-Desktop software has five progressive steps for analyzing each image. The first step in the program allows the scale to be determined for each image taken in the field. In the next step, automatic delineation of the fragments is carried out for each acquired images. Systems facilitate editing of the delineated fragments for obtaining accurate output. Calculation of the size distribution is obtained for the delineated fragments. Finally, the graphing is carried out to display the size distribution outputs.

5.1. Image Acquisition

Image acquisition process of blasted fragments rock for size distribution computation is the important part of the whole data analysis process. The location of image taking is important, and any method out of two sampling methods, random and systematic may be followed. A digital camera was used to get the images of the blasted muck, which was used in Split Desktop

Software. Images were taken randomly in the field and a reference of 1.5 inch in diameter was used to provide scale in the images. Single scaling object was used in this investigation. Total 5 images were taken for analysis.

5.2 Fragment Delineation and Editing

After the image acquisition, generation of binary images data is carried out from the acquired images which explicits outlines of the rock particles in the image. Split Desktop performs the automatic delineation of the particles in the image. Editing of the images is required to enhance the delineation of the individual fragment and some manual editing was carried out on the image for outlined in a continuous line (Fig.7a and b).

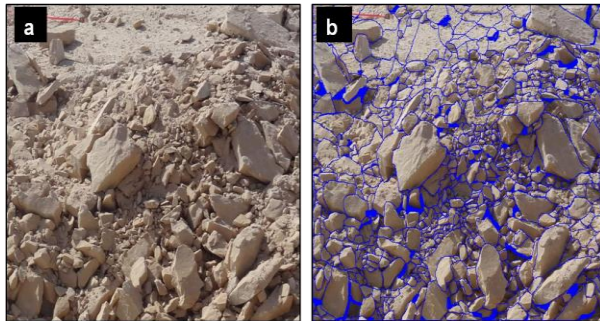


Figure 7 . (a) Field Image for calculation of size distribution and (b) Delineated image.

6. RESULTS AND DISCUSSION

The obtained size distribution curve is depicted in Fig.8. The percentage values, Rosin-Rammler uniformity index and mean fragment size are given in Tables 4 and 5. The results obtained from the analysis of muckpile images using Split-Desktop shows that the mean fragment size is 149.76 mm and F20, F80, and Top-size are 124.53 mm, 898.82 mm and 1442.58 mm respectively. The available crusher at the quarry site accepts the fragments size as large as 1000 mm and then crush fragments to the size of 30 mm. Results shows that approximately 10% of the rock fragments size are below 30 mm. Results also shows that 5% of the rock fragments is above 1000 mm size and it requires further secondary breakage.

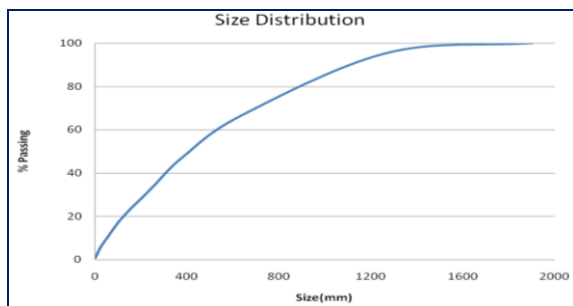


Figure9. Size distribution results using Split S/w.

Table 4 Cumulative Percent Passing.

Size [mm]	% Passing
1905	100.00
1270	95.49
635	66.47
381	47.42
254	33.89
203.2	28.48
152.4	23.32
101.6	17.13
50.8	10.11
25.4	5.96
19.05	4.78
12.7	3.51
9.53	2.81
6.35	2.06
4.75	1.65
2	0.85

Table 5 Fragment Size Characteristics.

Size fractions	Size [mm]
F10	50.10
F20	124.53
F30	217.77
F40	308.96
F50	409.09
F60	533.06
F70	702.32
F80	898.82
F90	1,099.49
Top size (99.95%)	1,442.58
Rosin-Rammler uniformity index	1.04
Mean fragment size	409.09

6.1. Comparing Split Desktop results with results of Kuz-Ram experiential model

Digital image processing outputs are compared to the available outputs of the Kuz-Ram model. For this analysis, Mean size fragment (m) X50 can be calculated using Equation (1).

$$X_{50} = A \times [PF]^{-0.8} \times Me^{0.167} \times \left(\frac{115}{RWSanfo} \right)^{0.633} \tag{1}$$

where PF is Specific charge in kg/m³, Me is the Charge mass per blast holes in kg, RWSanfo is the relative weight strength of the explosive to ANFO in %, and A is the Rock coefficient, which is assumed to be 10. Equation (2) is used for size distribution curve (Tavakol Elahi and Hosseini, 2017).

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

Uniformity index and characteristic size were calculated via Eqs. (3) and (4).

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

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

where L gives the charge length in meter, H is the bench height (m), S is the longitudinal spacing of blast holes (m), B is the burden (m), and d is the blast holes diameter (mm), and E_p is blast holes deviation. Table-6 presents results of the Kuz-Ram experiential model. Semi-logarithmic diagram computed from the Kuz-Ram model and the diagram generated from image analyses process is shown in Figs. 8, 9 and 10.

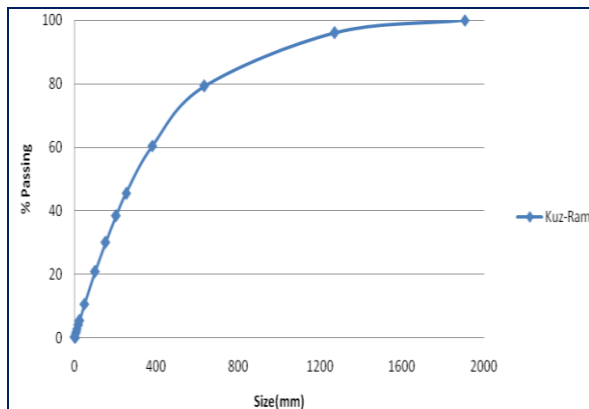


Figure 10. Size Distribution Results using Kuz-Ram Model.

Table 5 Cumulative Percent Passing (Kuz-Ram)

Size (mm)	% Passing
1905	100
1270	96.1
635	79.3
381	60.4
254	45.5
203.2	38.4
152.4	30
101.6	20.8
50.8	10.7
25.4	5.4
19.05	4
12.7	2.7
9.53	2
6.35	1.3
4.75	0.1
2	0.4

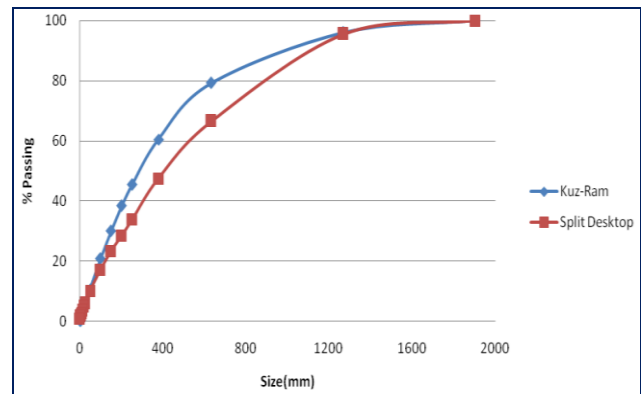


Figure 11. Kuz-Ram model and Split-Desktop Software to Rocks Blasting.

The Rosin-Rammler uniformity index of the entire muckpile is 1.04. This index is commonly applied to approximate the size distribution of rock fragments in blasted operations. The index value ranges between scale of (0.5) very non-uniform and (2) very uniform. So from the analysis work, computed index value confirms that size distribution is non-uniform. As the results indicate that 10% fragments are below 30 mm, which is product size of the crusher, this percentage can be enhanced by optimizing the overall blasting operation.

A comparison of the results and diagrams obtained from the Kuz-Ram experiential model reveals that this model suits the conditions of sandstone quarry, because the results are similar to the results of digital image analysis in Split Desktop.

7. CONCLUSION

The easiest and economic way to mine the valuable ore bodies is through the use of explosives and well-planned blasting layouts which can produce good fragmentation profiles. Since the productivity largely depends on fragmentation, its control through effective blast design is a major challenging task in mining.

Comparison of the analysis results of the digital image processing approach with that of Kuz-Ram model, clearly shows a similarity between two and hence indicates the equal performance of the two methods.

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