Effect of Stemming to Burden Ratio and Powder Factor on Blast Induced Rock Fragmentation– A Case Study

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Abstract: Rock fragmentation size is very important parameters for economical point of view in any surface mining. Rock fragment size direct effects on the costs of drilling, blasting, loading, secondary blasting and crushing. The main purpose of this study is to investigate effect of blast design parameters such as burden, blast hole length, stemming length, and powder factor on rock fragmentation. The fragment sizes (MFS, K50, m), and maximum fragment size (K95, m) of rock were determined by using the computer software. For every blast, after blasting operation, the images of whole muck pile are captured and there images were used for fragmentation analysis by using the Fragalyst software. It was observed that the optimal fragment size (MFS, K50, m and maximum fragment size, K95, m) of rock depends strongly on the blast design parameters and explosive parameters.

Keywords: Blast design parameters; Overburden bench; Powder factor; Rock Fragment size

1. INTRODUCTION

Blasting is the important technique for the size of rock fragmentation in any open cast mine. The main purpose of the bench blasting is to facilitate the fracturing and moving of the rock mass so that it can be loaded, hauled and further processed in an easy and efficient way. There are numerous parameters which depend on upon the rock fragmentation, in bench blasting. For rock fragmentation, two types of parameters can be classified as: first is controllable parameter and second is a non-controllable parameter. Controllable parameters are the burden, spacing, height of the bench, stemming length, blast hole length, delay sequence, firing pattern, diameter of hole, number of holes, explosive per hole, and powder factor [1], [2]. This type of parameter can be controlled on the basis of the rock characteristics. The distance between the bench face to the first row of the blasted hole is known as burden. Normally, the value of burden is equal to the range of 20 to 40 D, depending upon the properties of the rock mass [3]. Spacing is the distance between the two successive holes. Spacing is a function of the burden, delay timing between blast holes and initiation sequence. This parameter basically depends upon the diameter of drilling hole, bench height of the face and the desired degree of fragmentation and displacement. Stemming length is usually more than 25 times diameters of the blast hole [4], depending on the rock type, the explosive used and particular factors of blasting. Stemming is also equal to the multiple of burden [5]. Subgrade drilling or under drilling denotes the drilled depth of the blast holes underneath the proposed grade in order to ensure proper breakage at the grade level.
Subgrade drilling must be optimum. Subgrade drilling is set equal to 8 times the bore hole diameters. As suggested by [6], sub grade drilling is required to be 0% of the maximum burden. But according to [5], under certain conditions, very little or no sub drilling may be required.

The powder factor is defined as the amount of explosive required to break 1 m$^3$ or 1 tonne of rock [4]. It can serve a variety of purposes, such as an indicator of hardness of the rock, or the cost of explosive needed, or even as a guide to planning a shot. There are several possible combinations that can express the powder factor. Non–controllable parameters are geological properties like joint, dips, strike, strength of the rock which cannot be controlled by a mining engineer. In rock breakage, the broken rock size distribution is considered one of the most important indices of production blasting because it influences the costs of drilling and blasting and on the economics of the subsequent operations of loading, hauling and crushing [7]-[9]. Mackenzie (1996) [10] found that the efficiency of all the subsequent operations are dependent on the rock sizes. To him, drilling and blasting are critical in obtaining an optimum fragmentation as well as to minimize the entire cost of mining operations [11], [12]. If rock breakage in required size is not controlled, it can enhance the production cost and hamper the quarrying process due to unnecessary secondary blasting or crushing. Therefore, blasting design should take into account the findings of rock fragment assessment to cut down the mining cost and shorten the working time. Drilling and blasting in open pit mines represent 15 to 20% of the total mining cost [13].

2. Field Study and Lab Work

2.1 Field Study

To meet the objectives of the study the field study was conducted at the Dobari Colliery, Bastacola area. This mine is situated in Bharat Coking Coal field limited (BCCL), Dhanbad, Jharkhand, India. In this mine, the study of every blast was measured in overburden (Sandstone rock) benches. The study benches was 6m high which were subsequently excavated by 4.5 m$^3$ rope shovels in conjunction with 60 tonne rear dump trucks. Rock strata were fractured. It comprises of sandstone, massive sandstone, alluvium soil. The diameter of blast hole size was 150 mm. The site mixed emulsion (SME) explosive was used. The length of the blast hole size was varies between 5.0 m to 6.2 m. All the rounds were drilled on the rectangular drilling pattern with SME as explosive and sensitized emulsion as a cast booster. The blasts were initiated by shock tube system sequencing of 17 ms and 42 ms. The density of sandstone rock sample is 2.4 g/cc. In this mine, some blast design parameters like burden (m), Spacing (m), blast hole length (m), blast hole diameter (mm), total explosive (kg), charge per hole (kg), stemming length (m), delay sequence, explosive parameters, firing pattern, was measured or calculated during blasting in the bench face. After that when blasting is completed, where rock fragments were generated, images of the entire muck pile were taken by using of suitable camera. Using blast data and blasted block size images of entire muck pile, the powder factor (m$^3$/kg) and rock fragmentation sizes (mean fragment size, MFS, K50, m and maximum fragment size, K95, m) were determined. The general layout of the Dobari open cast mine is as shown in Fig. 1, general layout of the blast hole section is as shown in Fig. 2, and diagonal firing pattern of the blast 1 is shown in Fig. 3.
Fig. 1- General view of Dobari open cast mine (Study area)

Fig. 2- General layout of the blast hole section
2.2 Fragment Size Analysis using Fragalyst Software

In field, before blasting the rock, the whole blast design parameters and explosive parameters are measured. After blasting, the scaled images of whole muck pile were captured by the use of suitable camera. The images were imported in Fragalyst software. Images were delineated with the help of automatic and manual editing tools. And the delineated images were sieved to get the fragmentation distribution curve. The image of blasted muck pile with the distribution curve of the blast 1 is shown in Fig. 4.

Fig. 4- Image of blasted muck pile and the distribution curve of the blast 1
3. RESULTS AND DISCUSSIONS

The study was conducted for the 8 blasts of 3 different benches keeping the blast design parameters almost similar. Table 1 showed the data collected from the field and image analysis results.

Table 1. Details of the blast data collected from the field and obtained rock fragment size

| Field Details | Blast 1 | Blast 2 | Blast 3 | Blast 4 | Blast 5 | Blast 6 | Blast 7 | Blast 8 |
|---------------|---------|---------|---------|---------|---------|---------|---------|---------|
| Burden, m     | 2.5     | 2.5     | 2.5     | 2.5     | 3.0     | 3.0     | 3.0     | 3.0     |
| Spacing, m    | 3.0     | 3.0     | 3.0     | 3.0     | 3.5     | 3.5     | 3.5     | 3.5     |
| Blast hole length, m | 5.0 | 5.2 | 5.5 | 5.3 | 6.0 | 6.0 | 6.0 | 6.2 |
| Stemming length, m | 3.0 | 2.8 | 3.2 | 3.2 | 3.6 | 4.0 | 3.9 | 3.9 |
| Stemming/burden (T/B) ratio | 1.20 | 1.12 | 1.28 | 1.28 | 1.20 | 1.33 | 1.30 | 1.30 |
| No. of holes | 30 | 25 | 30 | 25 | 30 | 25 | 30 | 30 |
| Explosive/hole, kg | 30 | 30 | 30 | 30 | 50 | 50 | 50 | 50 |
| Total Explosive, kg | 840 | 700 | 940 | 710 | 1450 | 1230 | 1470 | 1470 |
| Brocken rock volume, m³ | 1087 | 936 | 1050 | 997 | 1990 | 1512 | 1936 | 1990 |
| Powder factor, m³/kg | 1.29 | 1.33 | 1.25 | 1.26 | 1.27 | 1.23 | 1.24 | 1.25 |
| MFS, K50, m | 0.19 | 0.17 | 0.24 | 0.20 | 0.22 | 0.28 | 0.27 | 0.24 |
| K95, m | 0.31 | 0.27 | 0.39 | 0.32 | 0.35 | 0.44 | 0.43 | 0.39 |

3.1 Relationship between rock fragment sizes (MFS, K50, m and maximum fragment size, K95, m) and stemming length to burden (T/B) ratio
Fig. 5- Relationship between Stemming length/burden (T/B) ratio and rock fragment sizes (MFS, K50, m and maximum fragment size, K95, m)

From the Fig. 5, it is evident that mean fragment size (MFS, K50, m) and maximum fragment size (K95, m) of the blasted rock increases with increasing stemming to burden (T/B) ratio. This may be due to increase in stemming that causes reduction in explosive in the blast hole.

3.2 Relationship between rock fragment sizes (MFS, K50, m and maximum fragment size, K95, m) and powder factor (m³/kg)

Fig. 6- Relationship between rock fragment sizes (MFS, K50, m and maximum fragment size, K95, m) and powder factor (m³/kg)

From the Fig. 6. It is evident that, mean fragment size (MFS, K50, m) varies between 0.17 to 0.28 and maximum fragment size (K95, m) varies between 0.27 to 0.44. As powder factor increases (1.23-1.33
m$^3$/kg) the rock fragment sizes decreases (MFS, K50, 0.45-0.18 m and maximum fragment size, K95, 0.44 to 0.27 m) and later the trends shows towards its optimization.

4. CONCLUSION

The following conclusions are drawn from the above study:

• Mean fragment size (MFS, K50, m) and maximum fragment size (K95, m) increases with increasing the stemming length to burden (T/B) ratio.
• Mean fragment size (MFS, K50, m), and maximum fragment size (K95, m) decreases with increasing the powder factor (m$^3$/kg).

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