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# Rock Mass Quality Determination in Blasting at Jalal-Abad Iron Ore Mine

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## ABSTRACT

Blasting is believed to be one of the most important operations in mining extraction. One of the main parameters which has to be considered in blasting is rock mass quality. Dynamic strengths of rocks, their spacing and orientation of joints planes and cracks as well as lithology and thickness of bedding are thought to be the most influential factors in blast design. A recognised method to combine these geological characteristics within blast design is Blasting Index (BI) which has subsequently been computed for the Jalal-Abad iron mine in Iran. Consequently, blasting patterns were designed using the following four principal methods, namely; Ash, Thumb, Anderson and Konya. Following a comparative analysis, Konya was found to provide the best correlation with regard to BI. As a result of this study it can be shown that around 30% and 70% of the specific charge and drilling metres respectively can be reduced. This can be shown to translate into reducing the drilling and blasting costs by approximately $50 million over the life of the mining operation.

***Keywords:*** *Blasting; rock mass quality; Specific charge; Jalal-Abad iron ore mine*

## 1. Introduction

The main purpose of drilling and blasting is to break and prepare the fragmented rocks for transportation and crushing purposes. The degree of rock fragmentation plays an important role in order to control and minimise the total production cost [1, 4]. The fragments produced by blasting should be small enough to be easily loaded and transported by transportation equipment. Geological characteristics and rock mechanics properties are fundamental keys in blast design. In recent years, works in the field of rock mass classification and different rock mass strength criterions have been developed. The problem of characterising a rock mass for blasting purposes is so complicated that analytical solutions are not possible, but Lilly (1986) developed a new approach called Blasting Index (BI) which considers joint spacing and orientation, rock density and hardness [3, 7]. The results of this paper show that the Konya was found to provide the best correlation with respect to the calculations for BI in the Jalal-Abad iron mine based on nearly fifty studied blasts.

## 2. Jalal-Abad iron ore mine

The Jalal-Abad iron mine situated approximately 36 km NW of Zarand, with 200 Mt iron ore resources with an average grade of 38.5% is one of the important iron deposits in Kerman Province, SE Iran [5, 6]. The deposit occurred in the intersection of Urumia-Dokhtar magmatic zone and Sanandaj-Sirjan structural metamorphic zone. There are gabbro, diorite and diabasic rocks as mass and dykes. Moreover, sedimentary rocks consisting of dolomitic limestone, siltstones and sandy-siltstones are present in the area. Main ores include magnetite and hematite which were altered and formed to goethite and limonite in the central and NW parts of the area. In addition, there are sulfidic ore minerals especially pyrite and chalcopyrite [5].
There is at least one blast every day carried out in the studied mine. Blasting parameters have been summarised in Table 1. Several problems have arisen during the investigation such as back break, high explosives and ground vibration. In addition, there are some boulders after the blasts. ANFO is

mixed with Pentaerythritol tetranitrate (PETN) and filled as column charge. Each hole contains about 0 to 12 Kg of high explosive and is charged with a primed cartridge at the bottom with Shock-tube for detonation [6].

Table 1: Blasting parameters

| **Parameter** | **Value** | **Unit** |
|---|---|---|
| Bench height | 12 | m |
| Sub-drilling | 1.5 | m |
| Spacing | 4 to 4.5 | m |
| Burden | 3 to 3.5 | m |
| Weight of ANFO per hole | 100 to 150 | Kg |
| Blast hole diameter | 165 | mm |
| Stemming length | 6.5 to 8.5 | m |

Subsequently, specific charge and specific drilling are calculated which vary between 0.7 to 1 kg/m$^3$ and 0.065 to 0.09 m/m$^3$, respectively.

## 3. Blasting Index

A blasting index (BI) developed by Lilly in (1986), correlates powder factors for blasting in mines. The blasting index is based on strength, structure, density and hardness of the rock. Equation. 1 describes the BI, Equation. 2 shows the proper specific charge and the input parameters and their ratings are given in Table 2.

$$BI = 0.5(RMD + JPS + JPO + SGI + HD) \qquad \text{Equation. 1}$$

$$Specific - charge(Kg/ton) = 0.004 \times BI \qquad \text{Equation. 2}$$

Table 2: Description of BI parameters [3, 7]

| Geomechanical parameters | Rating |
|---|---|
| Rock Mass Description (RMD) | |
| Powdery/friable | 10 |
| Blocky | 20 |
| Totally massive | 50 |
| Joint Plane Spacing (JPS) | |
| Close (< 0.1m) | 10 |
| Intermediate (0.1 to 1m) | 20 |
| Wide (> 1m) | 50 |
| Joint Plane Orientation (JPO) | |
| Horizontal | 10 |
| Dip out of face | 20 |
| Strike out of face | 30 |
| Dip into face | 40 |
| Specific Gravity Influence (SGI) | SGI=25 SG – 50 (SG in tons/cu metre) |
| Hardness, Mohs scale, (HD) | 1-10 |

More than 35 faces in the mine were surveyed and determined with respect to the above-mentioned parameters in table 2 in order to calculate BIs. BI varies from 50 to 80 however; BI equal to 60 has more frequency among the calculated values. As the extraction goes further and the mine becomes deeper, possibly, BI trends 70 in the future [2, 6]. Based on Equation. 2, proper specific charge according to Lilly model is about 0.7 Kg/m$^3$.

## 4. Blasting Design

In order to design the blasting pattern, 4 methods of the well-known blast models were selected namely; Ash, Thumb, Anderson and Konya and subsequently calculated (Table 3). The calculation has been done for the 12 m bench height and 250 mm blasthole diameter which is advisable for 7 Mt ore production per year.

Table 3: Calculation results

| Parameters | Units | Ash | Thumb | Anderson | Konya |
|---|---|---|---|---|---|
| Burden | m | 6.3 | 7.5 | 6.0 | 6.0 |
| Spacing | m | 7.8 | 9.2 | 7.5 | 7.8 |
| Stemming | m | 5.9 | 5.3 | 5.7 | 4.5 |
| Sub drilling | m | 2.8 | 2.3 | 2.7 | 2.4 |
| Total charge | Kg | 392.09 | 397.61 | 397.61 | 437.23 |
| Specific charge | $Kg/m^3$ | 0.67 | 0.48 | 0.74 | 0.78 |
| Specific drilling | $m/m^3$ | 0.025 | 0.017 | 0.027 | 0.026 |

## 5. Conclusions

Comparative analysis between the results from the blasting methods shows that the Ash and Konya have the best correlation with the results for BI. For rock fragmentation point of view, the use of Konya blasting model results proper crushed rocks in term of size. Moreover, the economical evaluation has been done to find how the proposed pattern would affect the cost. Considering the remaining mine life (roughly 30 years), decreasing specific charge (from about 1 to 0.78 $kg/m^3$) and specific drilling (from about 0.07 to 0.02 $m/m^3$) and 15% inflation each year, the discounted saved money will be about $50 million.


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## References


[1] A. Karamia, S. Afiuni-Zadehb. Sizing of rock fragmentation modeling due to bench blasting using adaptive neuro-fuzzy inference system and radial basis function. *International Journal of Mining Science and Technology*; 22, 459–463, 2012.

[2] A.B. Yasrebi, A. Wetherelt, P. Foster, J. Coggan, P. Afzal, F. Agterberg, D. Kaveh Ahangaran. Application of a Density–volume Fractal Model for rock Characterisation of the Kahang Porphyry Deposit. *International Journal of Rock Mechanics and Mining Sciences*, 66, 188-193, 2014.

[3] CL. Jimeno, EL. Jimeno, FJA. Carcedo, *Drilling and Blasting of Rocks*. Rotterdam, Netherlands: CRC Press, A.A. Balkema; 1995.

[4] F. Faramarzi, H. Mansouri, M. Ebrahimi. A rock engineering systems based model to predict rock fragmentation by blasting. *International Journal of Rock Mechanics & Mining Sciences*; 60, 82-94. 2013.

[5] M. Badel, S. Angorani, M. Shariat Panahi. The application of median indicator kriging and neural network in modeling mixed population in an iron ore deposit. *Computers & Geosciences*; 37(4) 530-540, 2011.

[6] M. Nikzad. Classification of blast fragmentation using number-size (N-S) fractal method in production blasting of Open pit mining method (Case study: JalalAbad Iron mine), *MsC thesis in South Tehran Branch, Islamic Azad University, Tehran, Iran*, 2013.

[7] PA. Lilly, An empirical method of assessing rock mass blastability. *In: Proceedings of the large open pit mining conference, Melbourne, Australia*, pp. 89–92, 1986.