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Blastability evaluation for rock mass fragmentation in Iran central iron ore mines

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ABSTRACT

In this research, we investigated the influence of rock mass properties, blast design parameters and explosive properties on blast fragmentation. Rock mass properties were evaluated in 51 blasting blocks using engineering geological mapping of 1961 meters of the scanline, experiments on intact rock samples and measuring P-wave velocity (*V*p) for 1771 meters of seismic profiles. The results indicate that increasing spacing, persistence, opening, roughness, waviness of discontinuities, and *V*p and uniaxial compressive strength (UCS) of intact rock as well as the increase of discontinuities angle with the bench face of blasting block will increase the size distribution of blasted rocks. In addition, evaluation of the influence of connector type, specific drilling and specific charge has shown that using the Nonel system will decrease the mean size of fragmentation. It is also demonstrated that increasing specific drilling and specific charge quantities will result in the increase of mean size of fragmentation.

1. Introduction

Blasting is one of the main operations in opencast mining. Blasting operation is influenced by various factors that can be classified into three categories: rock mass properties, blast design parameters and explosive properties. Burden, spacing between drillholes, stem height, drillhole inclination, diameter and length, drilling pattern, blasting direction, subdrilling and blasting sequence are blast design parameters that are controllable. Explosive materials parameters include explosive type, density, strength, resistance to moisture and heat, and specific charge, all of which are also controllable. The third group consists of the parameters related to the nature of the rock mass. These uncontrollable parameters are among the most important influencing variables in the blasting results [1–5].

When two different rock masses are subjected to identical blast geometry and energy input from explosives, they will produce quite different degrees of fragmentation. This is because the rock masses have inherently different resistance to fragmentation by blasting which is referred to as the blastability of a rock mass [3].

Parameters related to the nature of rock mass consist of physical and mechanical properties of intact rock and discontinuities. Intact rock properties include strength, hardness, elasticity, deformability, density, etc. They are dependent on rock texture, internal bonds, and composition and distribution of rock forming minerals. Discontinuity properties include orientation, spacing, persistence, opening, roughness, waviness and infilling materials created by a range of long-term geological processes. There are several different researches on the influence of rock mass and intact rock properties on blasting operations, all of which clearly indicate that the properties of blasted rock mass has a significant impact on blasting results [3,4] and [6–12].

The aim of this research is to evaluate and measure all influential parameters in blast fragmentation. For this purpose, 51 blasting blocks were selected and their rock mass properties were evaluated by measuring the characteristics of discontinuities in 1961 meters of scanline, experimenting upon intact rock samples and measuring P-wave velocity (*V*p) in 1771 meters of seismic profiles in Choghart, Chadormalu and Sechahun mines. Finally, the influence of mentioned parameters on blast fragmentation was investigated.

2. Geology of study areas

The studied areas consist of Choghart, Chadormalu and Sechahun iron ore mines. These mines are located in Bafgh block in ferriferous zone of Anarak–Bafgh–Kerman. The geographical location of the study area is shown in Fig. 1.

From the geological point of view, Choghart ore deposit is located in Precambrian formations of central Iran (Morad series).

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This series had undergone different changes such as metamorphism and metasomatism. The enclosing rocks of this ore deposit are mainly granite, quartz albitophyre and metasomatits. From the tectonic point of view, in Choghart ore deposit, three main categories of structural factors and faulting can indicate the effect of significant Panafrican, Cimmerian and Alpine events. The Panafrican structures are considered as the main factors of ore concentration and regional changes. These structures are deep faults with N–S and E–W strikes.

Sechahun ore rocks consist of Morad series rocks. In Sechahun ore deposit domain, intrusive rocks are mainly composed of diorite, granite, granophyre and syenite. In addition, the different combinations of dikes are approximately E–W strikes and high dips of 75–80°. Chadormalu ore deposit consists of two north and south anomalies. Due to metasomatic and magmatic conditions and high tectonic activities, this ore deposit has a complex geological condition. Discontinuities in ore deposits mostly have NW–SE strikes and 70–80°NW dip angles. Mineral mass was fractured by granitic and dioritic-dikes which have 15–45° dip angle and 1–20 meters thickness. In Cambrian period, ore deposit domain consists of granite gneiss, biotite gneiss and part of amphibolite facies. Ore deposit rocks included crystalline schist, fine grain schist, quartzite schist, biotite schist, quartzite, amphibolite and marbles. In Upper Cambrian period it is consisted of volcanic rocks, dolomites and sandstones.

3. Extraction operations in the studied mines

Extraction operation of iron ore in the studied mines are done by opencast mining. Extraction stages include drilling operations, blasting, loading and hauling [13]. Hole drilling is done by rotary and percussion machinery in different diameter (165, 200 and 251 mm). In these mines, blast holes are controlled in ANFO (in dry conditions) and Emulite (for aqueous conditions) as the main explosive, and the detonating cord and Nonel system are applied for initiation. Some related characteristics of extraction in the studied mines are presented in Table 1 [14].

4. Rock mass properties

Rock mass is composed of two parts of intact rock and discontinuities. Discontinuities include structures in rock mass such as joints, faults, fractures, bedding and other weakness surfaces that significantly influence the engineering and mechanical properties of rock mass [15]. The presence of one or several sets of discontinuities in a rock mass under loading and unloading leads to anisotropy. Also, in contrast to intact rocks, jointed rocks have higher permeability, less shear strength along discontinuity planes, and higher deformability and lower tensile strength in perpendicular direction of their plane. Furthermore, discontinuities lead to scale effects and the resulting intersection blocks can lead to instability problems. Therefore, in engineering studies of rock masses, both engineering properties of intact rock and discontinuities have to be considered.

Table 1
Characteristics of study mines.

Mine	Mineable ore reserve (million ton)	Bench height (m)	Bench width (m)	Bench Face Angle (°)	Overall Angle of Pit wall (°)
Choghart	177.2	10–12.5	8–10	70	38–50
Chadormalu	320	15	10	69.5	50–55
Sechahun	132	10	10	69.5	55

4.1. Measuring of rock mass properties

Line mapping method was used to measure engineering geology properties of rock mass in rock outcrops. In this method, desirable engineering properties are surveyed along the scanline on the rock outcrop. In line mapping, the length of scanline was variable from 10–100 meters. Priest and Hudson suggested that the length of scanline must be at least fifty times than that of the average spacing of discontinuities [16]. However, the International Society of Rock Mechanic has advised that the length of a scanline should normally be 50–100 meters [15] and [17]. In this method, we can choose the length of scanline based on the major changes of rock mass properties such as lithological changes, structural changes or even presence of a fault or fault zone or numerous changes in the weathering rate of rock mass. By considering these changes, we can use a new scanline for surveying rock mass properties.

In this study, discontinuities properties of 51 blasting blocks were measured in a length of 1961 meters of the scanline. Along these scanlines, properties of 7176 discontinuities were evaluated.

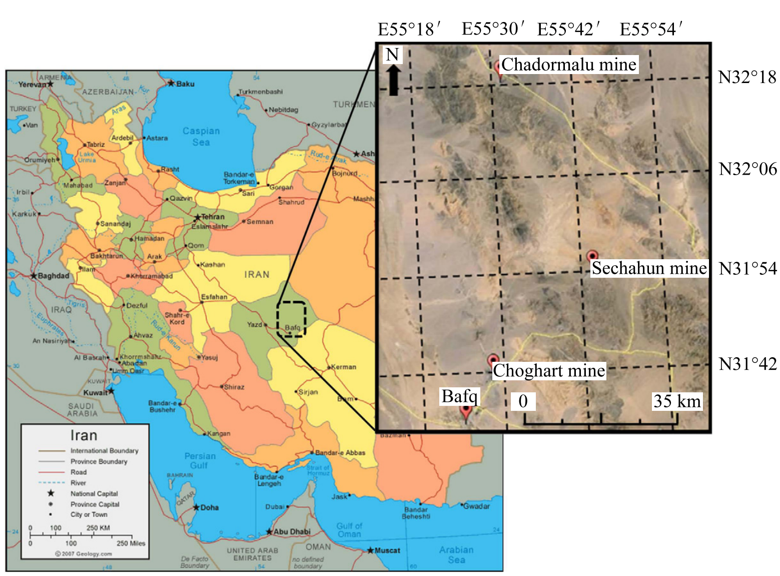

Fig. 1. Geographical location of study areas.