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Distinct element modelling of fracture plan control in continuum and jointed rock mass in presplitting method of surface mining

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ABSTRACT

Controlled blasting techniques are used to control overbreak and to aid in the stability of the remaining rock formation. Presplitting is one of the most common methods which is used in many open pit mining and surface blast design. The purpose of presplitting is to form a fracture plane across which the radial cracks from the production blast cannot travel. The purpose of this study is to investigate of effect of pre-splitting on the generation of a smooth wall in continuum and jointed rock mass. The 2D distinct element code was used to simulate the presplitting in a rock slope. The blast load history as a function of time was applied to the inner wall of each blasthole. Important parameters that were considered in the analysis were stress tensor and fracturing pattern. The blast loading magnitude and blasthole spacing and jointing pattern were found to be very significant in the final results.

1. Introduction

Drilling and blasting continues to be an important method of block production and block splitting. Drill and blast technique has a disadvantage that sometimes it produces cracks in uncontrolled manner and also produces micro cracks in the block as well as in remaining rock, if not carefully carried out. Recovery by this method is low as compared to other methods. Therefore, attempts have been made to develop controlled growth of crack in the desired direction. The control of fractures in undamaged brittle materials is of considerable interest in several practical applications including rock fragmentation and overbreak control in mining [1–3]. One way of achieving controlled crack growth along specific directions and inhibit growth along other directions is to generate stress concentrations along those preferred directions. Several researchers have suggested a number of methods for achieving fracture plane control by means of blasting. Fourney et al. suggested a blasting method which utilizes a ligamented split-tube charge holder [4]. Nakagawa et al. examined the effectiveness of the guide hole technique by model experiments using acrylic resin plates and concrete blocks having a charge hole and circular guide holes [5]. Katsuyama et al. suggested a controlled blasting method using a sleeve with slits in a borehole [6].

Mohanty suggested a fracture plane control technique using satellite holes on either side of the central pressurized hole, and demonstrated its use through laboratory experiments and field trials in rock [7–8]. Nakamura et al. suggested a new blasting method for achieving crack control by utilizing a charge holder with two wedge-shaped air cavities [9]. Ma and An conducted a numerical study to investigate the effective parameters on propagation such as nearby to free face, pre-existing stresses as well as notched and guide hole and pre-split charge holders. They concluded that when the pre-existing joint is parallel to the free face, the block behind the joint will be well fragmented due to the free face. When the pre-existing joint is normal to the free face, there is no damage in the block behind the joint. It justifies the pre-splitting technique, which is designed to prevent overbreak. They also showed that charge holder is effective in controlling the initiation and propagation of fractures. Two-slit charge holder can be used in pre-splitting operation, while three-slit charge holder can be applied in smooth blasting where more fragmentation is desired at one side of the fractured plane [10].

Nakamura performed model experiments to examine the effectiveness of the guide hole with notches [11]. Cho et al. performed experiments using a notched charge hole to visualize fracturing and gas flow due to detonation of explosives [12]. Recently model experiments using PMMA specimens and electric detonators were carried out to observe the propagation of cracks between two charge holes in blasting by Nakamura et al [13]. The applicability of the guide hole method using a circular hole having two notches

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between the charge holes was examined. Cho et al. used a numerical toll to study crack growth in notched hole and in models with guide holes [14]. They also studied fracture processes in laboratory-scale blasting of PMMA. Their study showed that predominant radial cracks propagate along different directions with different distribution patterns and the propagation direction affects the co-linearity of the fracture plane between the charge holes. They also showed that the propagation velocity of the opening crack decreased as the applied fracture energy Gf increases. Sharafisafa and Mortazavi studied fracture plane control in continuum media using numerical modelling [15]. They evaluate parameters which are effective in fracture propagation in presplitting controlled blasting such as spacing between blastholes and blast loading magnitude. Their study showed that these parameters are very significant in length and pattern of generated fractures around the blastholes as well as link between fractures to form a continuous crack.

Controlled blasting techniques produce the macrocrack in a desired direction and eliminate microcrack in the remaining rock. Macrocrack development in desired direction is required for extraction of dimensional stone and at the same time there is need to reduce microcrack development in the block and remaining rock. Blasting techniques have been developed to control overbreak at excavation limits. Some techniques are used to produce cosmetically appealing final walls with little or no concern for stability within the rock mass. Other techniques are used to provide stability by forming a fracture plane before any production blasting is conducted. On permanent slopes for many civil projects, even small slope failures are not acceptable, and the use of controlled blasting to limit damage to the final wall is often required. The principle behind these methods is that closely spaced parallel holes drilled on the final face are loaded with a light explosive charge that has a diameter smaller than that of the hole [14]. There are four methods of controlled blasting, and the one selected depends on the rock characteristic and the feasibility under the existing conditions. The four methods are line drilling, cushion blasting, smooth-wall blasting and presplitting (also pre-shear) [15].

Line drilling involves drilling holes precisely along the required break line at a spacing of two to four holes diameters, and then leaving a number of unloaded holes between the loaded holes. Line drilling is only used where very precise wall control is needed, such as corners in excavations. In another study, Sharafisafa and Mortazavi studied effect of a fault on wave propagation [16]. This study demonstrated the effect of presence of a fault on volume and length as well as direction of fractures. A major discontinuity such as a fault can arrest the fractures and as a result, fracture plane cannot fully form, which will result in incomplete presplitting blast. Rathore and Bhandari studied some effective parameters on fracture growth by blasting such as variation of explosive energy, variation of stemming, blasthole liners and so on [17]. Their result showed the variations of extent and direction of fractures with variation of mentioned parameters. For example, they concluded that by using notched hole with liner, crack was developed in desired direction and damages were controlled in extracted block and remaining rock.

When the rock is reasonably competent, smooth-wall blasting techniques can be used to advantage in underground applications. Horizontal holes are charged with small-diameter low-density decoupled cartridges strung together and by providing good stemming at the collar of the hole. Charges are fired simultaneously after the lifters. If the rock is incompetent, smooth-wall blasting may not be satisfactory [18]. Cushion and presplitting blasting are the most commonly used methods, with the main difference between the two beings that in cushion blasting the final row holes are detonated last in the sequence, while in pre-shearing the final line holes are detonated first in the sequence. Cushion blasting method is a control technique which is used to cleanly shear a final wall after production blasting has taken place. In cushion blasting method, the cushion holes are loaded with light, well-distributed charges. The sole purpose of a cushion blast is to create a cosmetically appealing, stable perimeter. It offers no protection to the wall from the production blast [14]. Presplitting consists of creating a plane of shear in solid rock on the desired line of break. It is somewhat similar to other methods of obtaining a smoothly finished excavation, but the chief point of difference is that presplitting is carried out before any production blasting and even in some cases before production drilling [4]. Presplitting utilizes lightly loaded, closely spaced drill holes, fired before the production blast. The purpose of presplitting is to form a fracture plane across which the radial cracks from the production blast cannot travel. Secondarily, the fracture plane formed may be cosmetically appealing and allow the use of steeper slopes with less maintenance. Presplitting should be thought of as a protective measure to keep the final wall from being damaged by the production blasting [18].

The presplit theory is that two simultaneously fired holes emit shock waves, which, when they meet within the web, place the web in tension, causing cracks and shearing it. Fig. 1 illustrates the presplit theory. In extremely weathered material, presplitting may have to be done at very close spacing with a very small amount of explosive. Presplit holes must be stemmed with an increased bottom charge to move the toe [19]. After detonation in presplit holes, waves generated from each hole propagate in a spherical shape and cracks are generated around holes.

Fig. 2 shows a presplitting blast project and rock shearing and forming the fracture plane in presplitting method. As can be seen from Fig. 2a, presplit blast leads to generate a fracture plane parallel to free face which is final wall of temporary slope. Fig. 2b illustrates a successful presplit blast with no unwanted damage in other sides. In order to operate a successful presplit

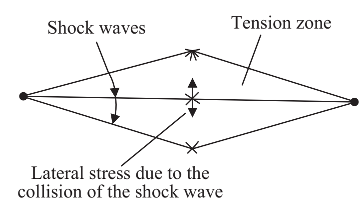

Fig. 1. Presplit principle [20].

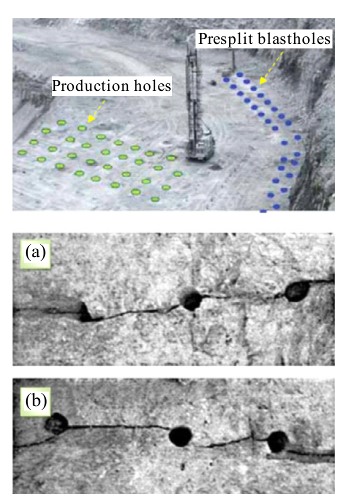

Fig. 2. Fracture patterns in the presplitting blast method (a) location of presplit holes and production holes; (b) final fracture plane after presplit blast [21].