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Application Of Air Decks In Production Blasting To Improve Fragmentation And Economics Of An Open Pit Mine

[1]Ravshanova Madina Egamberdi qizi and [2]Kushnazorov Ibrahim Saidqul o'g'li

[1]Assistant Tashkent State Technical University, named after Islam Karimov, Tashkent City, Uzbekistan.
[2]9V-17 Group student, Tashkent State Technical University, named after Islam Karimov, Tashkent City, Uzbekistan.

Abstract: *In blasting with air decks, repeated oscillation of shock waves within the air gap increases the time over which it acts on the surrounding rock mass by a factor at between 2 and 5. The ultimate effect lies in increasing the crack network in the surrounding rock and reducing the burden movement. Trials of air deck blasting in the structurally unfavourable footwall side of an open pit manganese mine has resulted in substantial improvements in fragmentation and blast economics. Better fragmentation resulted in improved shovel loading efficiency by 50–60%. Secondary blasting was almost eliminated. Use of ANFO explosive with this technique reduced explosive cost by 31.6%. Other benefits included reductions in overbreak, throw and ground vibration of the order of 60–70, 65–85 and 44% respectively. This paper reviews the theory of air deck blasting and describes in detail the air deck blast trials conducted in a manganese open pit mine in India. The blast performance data have been analyzed to evaluate the benefits of air decking over conventional blasting.*

Keywords: air deck, fragmentation, blasting, open pit mine

Introduction

In conventional blasting much of the explosive energy is wasted in the generation of undersize fragments or super fragmentation. The production of oversize fragments, on the other hand, lowers loading and transportation efficiencies of the equipment and requires secondary blasting. Melnikov and Marchenko (1971) and Melnikov et al. (1979) reported that, by introducing one or more air gaps in the explosive column, a secondary shock wave can be readily and inexpensively generated thereby increasing the duration of the shock wave action on the surrounding rock mass by a factor of 2–5. The explosive consumption was reported to be produced by 10–30% with apparent benefits in both fragmentation and movement. Fourney et al. (1981) conducted studies into fracture networks in air decks with thick Plexiglass blocks and supported the above findings. Air deck blasting has been extensively used in open pit mines in the former Soviet Union (Marchenko, 1982) and it has become very topical in Australian mines in recent years (Mead et al., 1993). In Indian open pit mines, it remains in the incipient stage and its use is yet to be commercialized. Blasting trials with air decks were conducted in the structurally unfavourable footwall side of a manganese open pit mine and the effects of the air decking technique on blast performance and economics were evaluated. Theory of air decking The technique of air decking involves the use of one or more air gaps in the explosive column as a means of optimising fragmentation for a given charge length. The theory as proposed by Melnikov and Marchenko (1971) and Melnikov et al. (1979), postulates that shock waves, when reflected within the borehole, generate a secondary shock wave that extends the network of microfractures prior to gas pressurization. The final borehole pressure produced by an explosive is, however, reduced in this case but the degree of fracture is increased as a result of repeated loading of the rock by a series of aftershocks. The three main pressure fronts (shock front, pressure front due to formation of explosive products behind the detonation front and reflected waves from the bottom of the blasthole and/or from the base of the stemming) travel within the air deck for different distances and velocities thereby creating these aftershocks. Studies of fracture networks from air-decks in thick Plexiglass models, as shown in Fig. 1 (Fourney et al., 1981) have supported Melnikov's theory (Melnikov et al., 1979). It was observed that the shock wave reflects back from the base of the stemming and reinforces the stress field. This process is repeated a number of times thereby increasing the duration of shock wave action by a factor of 2–5. With this mechanism, the fracture network appeared to expand to fragment a larger volume radially rather than immediately adjacent to the charge. Moxon et al. (1993) extended this theory and suggested that, if the air deck is placed in the middle of the explosive column, the pressure front produced due to explosive at either end of the air-deck collides at the centre of the air-deck. They proposed that this interaction should develop a reinforced stress field resulting in a more extensive radial crack pattern than if an air-deck is kept on the top of the charge (Fig. 2). Since the magnitude of the shock front depends on the explosive formulation and decreases quickly with distance in air, the degree of fracture in the air deck region will finally depend on the length of the air deck and the type of explosive. Specific surface area (SSA) The specific surface area (SSA, m2 t 21) is a measure of the utilisation of explosive energy. This was estimated using the relation given below (McCabe and Smith, 1997). SSA 5 6l P o fh Dh' (3) where l is the shape factor, P is the density (5 2.74), fh is the mass fraction of the total sample that is retained by the screen n and Dh' is the arithmetic mean of the particle diameter of Dn and Dn21. The values for the MFS and SSA are given in Table 6. In blast 5, the SSA is 60.78 m2 t 21 which is the highest of all the blasts. The RMR value near this site is 22, signifying poor rock conditions. The specific charge in the conventional blast was 0.41 kg m23 with slurry explosive whereas it was 0.56 kg m23 in blast 6 with ANFO. Thus, the explosive energy utilisation is much better in the air deck blasts than that in the blast without an air deck. Influence of bench height The trial blasts were conducted in bench heights of 6–7 m and 10–

11 m. The rock mass of the footwall side is highly jointed and foliated which gives a higher probability of oversized boulders in higher benches. Blasts in 6–7 m high benches showed good results both in terms of fragmentation and controlled throw. Further, the 1.7 m3 shovel with a boom length of 4 m did not support the choice of 10–11 m high benches. Hence, for better blast performance in the footwall side, a bench height of 6 m was the optimum. Shovel loading efficiency Time study of the shovel loading operation, both for the conventional blast and the trial blasts, revealed significant improvement in shovel loading efficiency. In a typical conventional blast, the idle run of a shovel for muck pile preparation accounted for around 30% of the total run in the best blast situations and around 60% in the worst blast situations. In the case of the trial blasts, the idle run of a shovel for muck pile preparations accounted for only 15% of the total run in the best blast situations and around 20–25% in the worst blast situations. The loading efficiency of the shovel with air deck blasts has thus shown an improvement of 50–60% over the conventional blasting practice. Overbreak Provision of an air deck in the middle of the charge effectively controlled the overbreak (Table 5) and produced a clean face along the last row of holes. This made the drilling operations trouble free for the succeeding rounds of blasting. Toe It was observed that the presence of toe in the conventional blasting caused problems in loading and blasting in the subsequent rounds. This was mainly due to the incomplete drilling lengths and the joints dipping away from the bench face. The problem of toe was completely eliminated with an air deck (Table 5). Ground vibration Ground vibration was recorded in all the trial blasts at different distances. The following ground attenuation equation was derived by regression analysis of all the ground vibration data (Fig. 8). V 5 43.94 (D/ Î Q) 20.56 (4) where V is the peak particle velocity (mm s21), D Î Q is the scaled distance (m Î kg21), D is the distance of the measuring point from the blast site (m) and Q is the maximum charge per delay (kg). The peak particle velocity (PPV) recorded at a distance of 118 m from the blast location was 17.685 mm s21 with a maximum charge per delay of 66.77 kg. Compared to this PPV of 17.685, the PPV estimated from Equation 1 for a similar maximum charge per delay at the same distance is only 9.846 mm s21 . This gives a reduction of 44.3% in the PPV with an air deck blast as compared to the blast without an air deck. This indicates that a higher percentage of the shock energy is wasted in generating ground vibration in blasts without air decks compared to the blasts with air decks. Further, it has been established previously that the shock energy of the explosive is better utilized in blasts with an air deck than blasts without an air deck. It is thus concluded that air deck blasting offers the twin advantages of higher explosive energy utilization in fragmentation and low energy utilization in producing ground vibration. Specific charge In conventional blasting with slurry explosive, a specific charge of 0.4–0.5 kg m23 was used, whereas the specific charge was slightly higher in trial blasts with an air deck. In spite of this, the explosive cost is reduced significantly due to the use of lowcost and low-density explosive (ANFO) and better utilization of available shock energy as explained previously. Throw Research conducted by the Swedish Detonic Research Founder (SVEDEFO) shows that the forward movement of muck pile in conventional charging should be 140c 2 28m, where c is the specific charge in kg m23 (Olofson, 1988). The observed throw in trial blasts with air decks is compared with the throw without air decks estimated after SVEDEFO (Table 7). It is seen in Table 7 that the throw is drastically reduced in air deck blasting which indicates that significantly less explosive energy is spent for rock throw in air deck blasting compared to blasting without an air deck. Thus, air deck blasting makes more efficient use of the explosive energy The economics of air deck blasting have been worked out by comparing the results of six trial blasts with air decking with those of conventional blasting without air decks. A comparison has been made considering the explosive cost and the operating costs of loading and transportation. The drilling cost was assumed to be the same in both cases because specific drilling remained the same. The benefits in terms of the explosive cost and the operating costs of loading and transportation are summarized in Table 9. The cost assessment on loading and transportation operations is made considering the wages and diesel heads only without taking into account the capital cost, the depreciation and the overheads, etc. Conclusions The degree of fragmentation from an air deck blast depends on the location of the air deck in the explosive column and its length. Generally the critical length of an air deck varies from 15–35% of the original charge length. An air deck placed at the middle of an explosive column is reported to produce an optimum result. The technique of air deck blasting with ANFO explosive as experimented with in the structurally unfavourable rock mass in an open pit manganese mine has shown promising results both in terms of blast performance and blast economics. Fragmentation improved significantly with minimum face bursting while secondary blasting was almost eliminated. Further, the ground vibration, the overbreak and the throw were reduced by 44, 60–70 and 65–85% respectively. Besides the above benefits, the use of air deck blasting resulted in savings on explosive cost and operating costs of loading and transportation of the order of 31.6, 36.3 and 24.6% respectively. Acknowledgements The authors are grateful to the Manganese Ore India Limited authorities for sponsoring this study and to the mine management for providing necessary facilities and extending full cooperation during the course of the field investigations. The views expressed in this paper are those of the authors and not necessarily of the organization they represent. The work reported in this paper forms part of the dissertation work of the first author for his Master of Engineering degree by research at the University of Nagpur.

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