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Enhancement of the Explosive Energy Utilization with the Application of New Stemming Contrivance

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Abstract- The effect of confinement on explosive energy utilization in rock blasting was studied by using a new stemming contrivance named SPARSH .To achieve the objectives an experiment blast was carried out using SPARSH. The experiment blast was analysed by high speed video camera. Post blast observations were also conducted to identify the blast results. Results were compared with the conventional stemming applying drill cuttings as stemming material for a part of the experimental blast. It was noticed that application of SPARSH results into increase in the explosive energy retention time, reduce ejection velocity and stemming ejection height. The combined effect of the higher retention time, the reduced stemming ejection height and the lower stemming ejection velocity manifests into a larger component of the explosive energy available for rock breakage which assists into safer economical ore liberation process.

Keywords: - stemming contrivance, explosive energy utilisation, energy retention time, stemming ejection velocity, stemming ejection height, high speed imaging.

I. INTRODUCTION

Rock breakage by blasting is the most convenient, economical and accelerated method to extraction of economic minerals. The all phases of mining operations are heavily dependent on the quality of the rock breakage process. It is imperative that the blasting energy should properly utilize in rock breakage, movement of blasted muck, and with suitable fragmentation to ensure that the loading, hauling and subsequent operation or processing are accomplished at the minimum possible cost. To accomplish this task it has been confirmed that explosive energy confined with properly within rock mass and to avoid or minimize the wastage of premature explosive energy from stemming column. Rock blasting provides an irreplaceable source of explosive energy in a very useful form like, kinetic energy (movement and throw) and fracture energy (rock fragmentation). Other parts of explosive energy are wastage in seismic energy (vibration), noise (air blast), back break, heat etc. (Sazid and Singh, 2013; Sazid et al., 2012; Sazid et al., 2011; Monjezi et al., 2010; Monjezi and Dehghani, 2008). Explosive energy components in rock blasting can be assessed by rock explosive interaction model discussed by many researchers (Lownds, 1986; Lownds and Du Plessis, 1984; Kirby and Lieper, 1985; Udy and Lownds, 1990; Scott et al., 1996; Whittaker, 1992; Saharan, 2004, Sazid and Singh, 2015). Figure 1 demonstrated that assumed partition of the explosive energy where the area under the curve between borehole pressure and volume of expanding explosive gases represents efficient explosive energy utilization.

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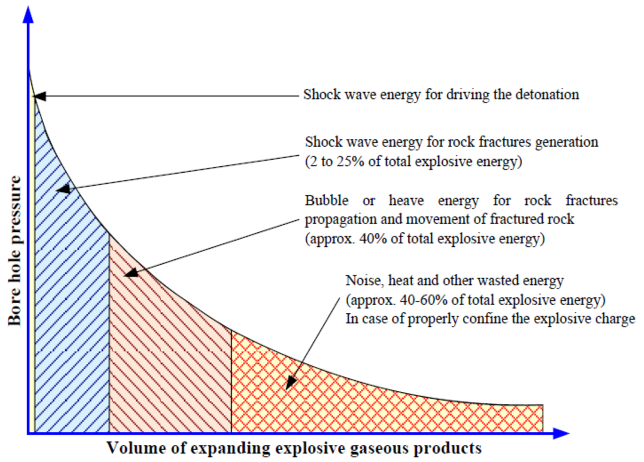


Figure 1. Partition of explosive energy during rock blasting (After Saharan 2004)

Several research studies were conducted for the improvement of positive utilization of explosive energy. Applications of de-coupling (Hudson, 1993; Worsey et al., 1981) and air-decking techniques are also found to enhance the working time of explosive energy (Mel'Nikov, 1940; Mel'Nikov and Marchenko, 1971; Liu and Katsabanis, 1996; Jhanwar, 2011; Thote and Singh, 2000; Singh et al., 2012). There is still much interest in finding ways to control and enhance the blasting energy despite of extensive application of blasting since ages. Much of advances have taken place for refinement in specifications for explosive material and blasting techniques to improvement in explosive energy utilization. Surprisingly, little efforts have been made to understand the role of effective stemming in enhancing the explosive energy utilization for engineering blasting operation. Stemming is the prime source for the confinement and the cardinal study to explain importance of the stemming is first documented by Burgoyne (1849). The role of confinement to the explosive energy within the borehole has been aptly acknowledged since a long (Snelling and Hall, 1912; Johnsson and Hofmeister, 1961; Cancec et al., 2010). Specifications for stemming material quality and quantity have not experienced much change since the principal work presented by Konya (1978) and Otuonye (1981). Despite the development of stemming contrivances over a long period from Kalambach (1874) to Gonjalez (2010) where majority of the engineering blasting operations to till date experienced early venting-off the explosive energy from the stemming collar which results into reduced effectiveness of the blasting operations (Sazid et al., 2011). The reduced explosive energy utilisation manifests into environmental detrimental effect and creation of hazardous environment due to the blasting. Perhaps, an early venting-off may be attributed for a small part of the explosive energy utilisation (about 7% to 24%) towards rock breakage process (Lownds, 1986; Lownds and Du Plessis, 1984; Kirby and Lieper, 1985; Udy and Lownds, 1990; Scott et al., 1996). Even a small increase in the efficiency of explosive energy will contribute to a significant improvement in rock breakage. Therefore, there is ample scope to further increase the effective and efficient explosive energy utilisation from a better confinement of explosive energy within the borehole which can be possible by a stemming contrivance.

This paper presents preliminary results of field experimentation of a newly developed stemming contrivance and the results are compared with conventional stemming blast from same bench. This stemming contrivance is acronym as SPARSH (Stemming Plug Augmenting Retention to Stemming in Holes). The difference of this new contrivance compared to other contrivances rests on the fact that it has a self-locking arrangement wherein the effectiveness of the locking increases with an increase in the borehole pressure due to detonation (Sazid et al, 2011, Singh et al., 2012). Thus, it is possible to achieve a greater control on the root cause of poor explosive energy utilization, i.e., an early venting-off the energy from the stemming collar. Results of the field experimentation are evaluated in terms of stemming retention time and ejection velocity calculated from high speed video imaging. It has been demonstrated from the post blast observations that the stemming contrivance significantly enhances the explosive energy utilization in terms of rock mass breakage and broken rock mass movement whereas no fracture was found in blastholes stemmed in conventional manner.

II. BRIEF ABOUT FIELD EXPERIMENT BLAST LAYOUT AND OBJECTIVES

The experimental blast site is situated in the North-West part of India in the State of Rajasthan. The blast site was very close to potable water pipeline which is very necessary things for daily usage of nearby living people. The mine management opted to reduced column charge (62.5% stemming and 37.5% blasthole length with explosive column) considering the risks involved from the blast. Further, location much closer to the pipeline was earmarked for the experimental evaluation of SPARSH. Total 85 holes of 8 m column length having diameter of 215 mm were charged in blasting pattern of 5 m burden and 7 m spacing. Bottom most part of 45 blastholes were charged with 3 m Site Mixed Slurry (SMS) explosive where top 5 m column was filled with drill cuttings as stemming column. Remaining 40 holes were also bottom charged with 3 m SMS explosive which was overlain by 2 m of stemming column. Provide 0.5 m air-deck column with the help of SPARSH and remaining 2.5 m length of the blastholes were again filled with the drill cuttings as stemming column. The details of the experiment charging column are illustrated through Figure 2.

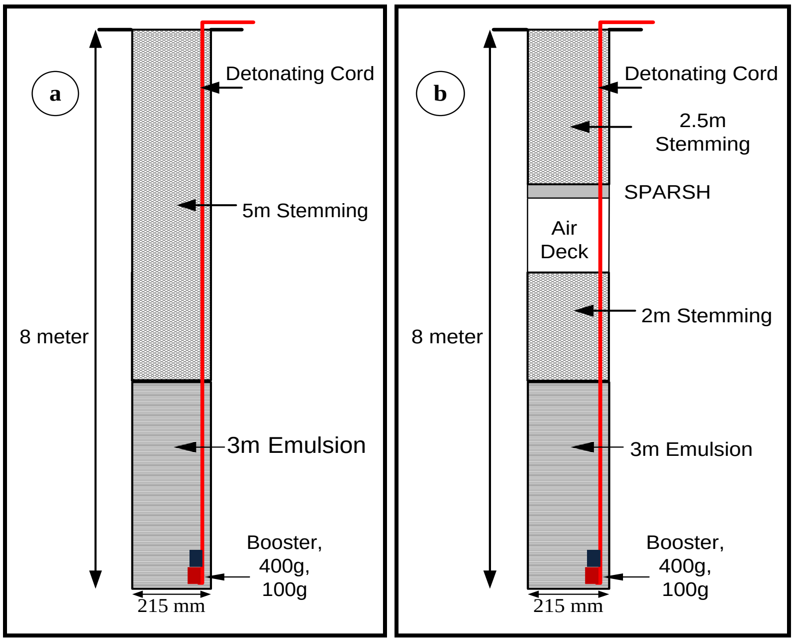


Figure 2. Blasthole charging pattern (a) Conventional stemming (b) with SPARSH

III. Results of The Experiment Blast

Recording of the experiment blast was taken with a high speed camera operating at 250 frames per second and resolution of 512*480 pixels. The video image analysis was used to calculate retention time and the ejection velocity of the blasted holes. The video image analysis indicated that application of SPARSH increased retention time of the explosive energy. The average retention time for SPARSH and conventional stemming was 76 and 14 milliseconds, respectively. More than five times increase in the retention time could be achieved with the application of SPARSH. A higher retention period of explosive energy restricted to blow out from the blastholes. In resulted reduced velocity and height of ejected material from stemming column. Comparative average stemming displacements from two sections of the experiment blast with progression of detonation are shown in Figure 3. It is demonstrated from displacement v/s time curve of Figure 3 that the SPARSH provides better confinement to explosive energy whereas the conventional stemming resulted into higher stemming displacement with a faster rate of ejection. The ejection height of the experimental blast is shown through Figure 4, where it is demonstrated that the conventional stemming and SPARSH provided ejection height of 104 m and 44 m, respectively. The application of SPARSH reduced the average ejection displacement by 60 per cent. Further, calculated ejection velocity indicates that the application of SPARSH decreases the stemming ejection velocity from 400 m/s to 250 m/s in a much shorter span of time in comparison to the conventional stemming. A larger retention time, smaller stemming ejection height and rapid decrease of the ejection velocity all together in the blasting section with SPARSH provided a greater confinement to the explosive energy. The combined effect leads to the improved explosive energy utilization in the blasting section where SPARSH was used. Figure 5 is mosaic of post blast images of the blastholes with conventional stemming where it can be observed that the pre-mature venting-off of the explosive energy could not generate any indication of rock breakage. In contrast, Figure 6 illustrates application of SPARSH resulted into fragmented muck displaced about 3 m from the in-situ rock mass bench after the blasting. Barring to a few boulders from the top column of the blastholes, the fragmented muck was easily pliable with the existing loading-hauling machinery. The vivid demarcation in the rock breakage process with the introduction of new stemming contrivance clearly indicates that the explosive energy utilization can be further enhanced with a better confinement to the explosive energy.

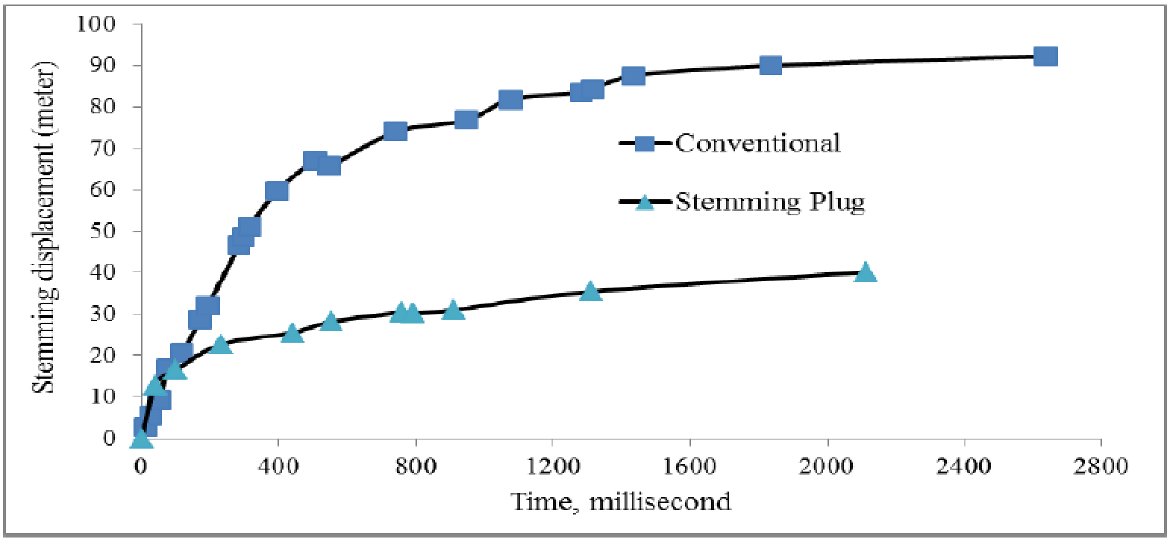
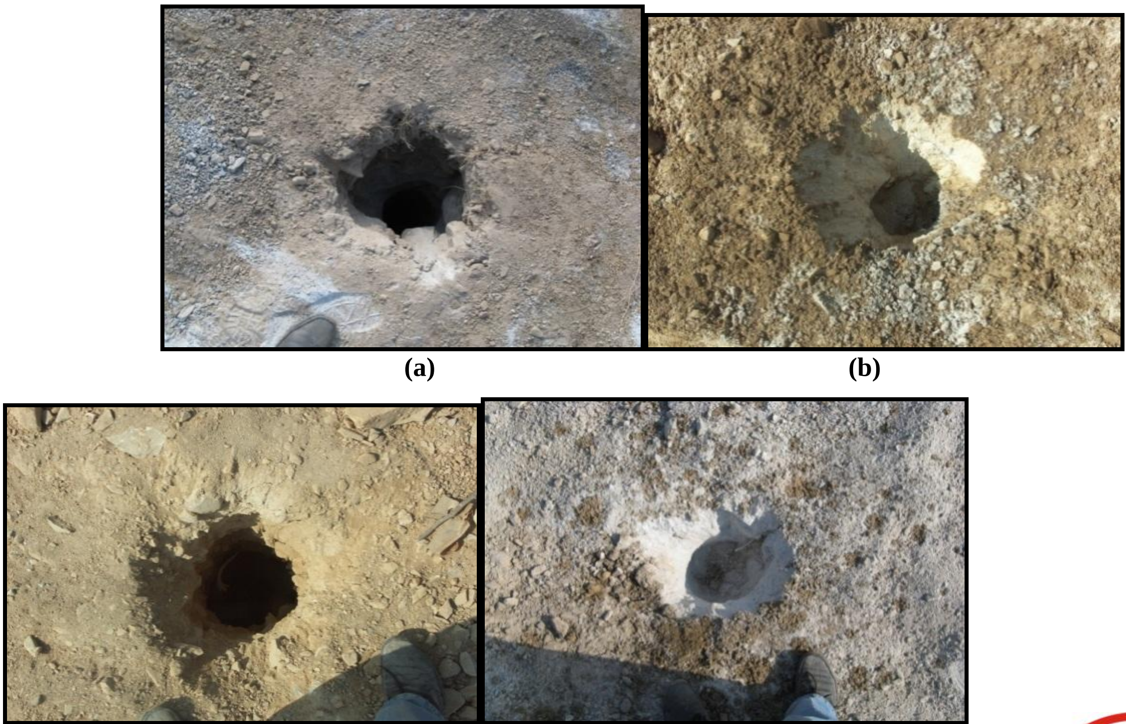
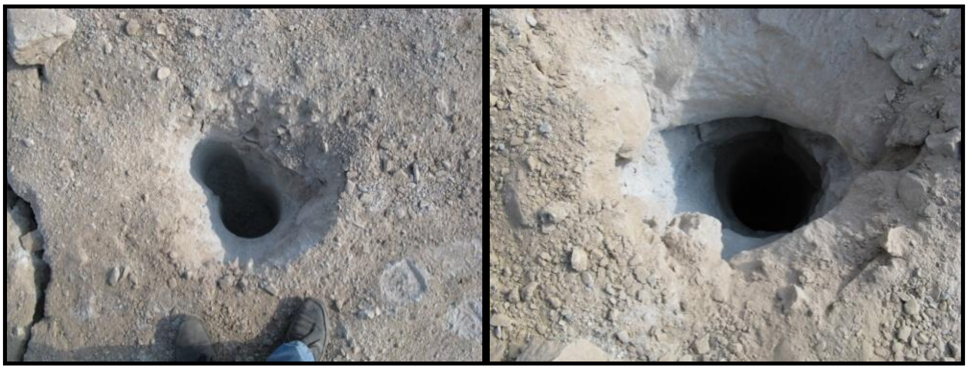


Figure 3. Stemming displacement with progress of detonation



(a) **(b)**

(c) **(d)**



(e) **(f)**

(g) **(h)**

Figure 5. Close up view of blown out holes from conventional stemming

Figure 6. Rock breakage with the application of SPARSH and the face condition

IV. CONCLUSIONS

The results of new stemming contrivance were also presented earlier published papers (Sazid et al., 2011; Singh et al., 2012). One SPARSH experiment blast results with reduce explosive charge due to sense of security are presented in this paper. The following conclusions are drawn from comparisons of conventional and SPARSH experiment blast. Major significant differences were found with the experiment blast of new stemming contrivance in terms of the proper utilization of explosive energy, i.e., rock fragmentation, muckpile throw and controls fly rocks. In reference to the conventional and SPARSH experiment blast, the SPARSH improve the five times retention time of explosive energy within rock mass. The improved retention time allows to more working of explosive energy on surrounding rock mass. This can results in substantial reduction in velocity and height of ejected material from stemming column. The reduce ejection velocity and height were observed 34% and 57%, respectively. In reference to the post blast observation, the SPARSH blast holes resulted in proper fragmentation and muckpile displacements. This can results in substantial savings in loading, hauling and subsequent operations of mining. Whereas, no fracture was found from conventional blast holes. Figures of ejected blast holes were clearly indicating the premature ejection of explosive energy as wastage in environment like fly rocks.

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