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Screened drill cuttings in blasthole for tamping of stemming to reduce generation of fly rock

For sustainability of a mine, productivity, safety and health and environmental protection are the major concern of any blast design engineer. So accordingly he designs the blast round and implement on ground level. In designing a blast stemming length and stemming material play a very important role. Drill cuttings are generally used as stemming material in the blasthole, since these are most readily available near blastholes. This type of material was not able to prevent ejection of gases from the stemming part. Therefore, study was conducted to assess the impact of dust separated drill cuttings on blasting results. From the study it was found that use of screened drill cuttings provided better interlocking in between rock particles which did not allow the gases to eject from stemming part. The screened drill cutting having size of 3-7mm provided improved blasting results in terms of reduced gas ejection, less dusty environment, less fly rock, better fragmentation, loose muckpile and reduced explosive consumption.

Keywords: *Drill cuttings; screening; blast hole; stemming; fly rock; fragmentation.*

1.0 Introduction

Blasting being the cheapest means of rock breakage continues to be the most prevalent method of rock fragmentation in the mining of ore and waste. Optimization of blast design parameters with respect to the desired blast results is the need of the hour. The blast design parameters are generally calculated on the basis of given theories and equations. However, there is no single formula for blast design. Performance of a blast depends on the accurate determination of the design parameters like blast geometry, initiation systems and the timing for the explosive rock interactions. Researches on explosives are focusing on its rational and effective use for improving the quality rock blasting. The theories and applications of explosive energy need to evolve further to cater this need successfully. The mechanism of transfer of explosive energy in rockmass for generating fractures is very complex. These complexities are the outcome of the interplay of the explosive properties, design parameters and rock properties.

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Many researchers have studied the characteristics of explosive energy distribution and its method of control. Wang (1984) proposed the energy balance theory, i.e., an explosive cratering theory of rock blasting based on explosive cratering experiments with different rocks, charging quantities and depth of charge burial. Liang (2005) studied the issue of control of explosive energy from the viewpoint of directional fracture controlled blasting. Sanchidrián et al. (2007) studied the problem of explosive energy distribution in rock blasting by analysis through laboratory model tests and numerical simulations. Tian (1999) discussed the problem of energy distribution and its control method in rock blasting.

The length of stemming is a function of many variables. Excessive stemming causes increase in stiffness accompanied with excessive confinement resulting in to host of problems. Rai et. al, (2008) reported excessive boulders in the blasted muckpile, especially from the collar zone due to excessive stemming. Based on their extensive studies, Ash (1973), Rzhevsky (1985), Konya (1996) etc. proposed the length of stemming column as function of hole diameter, bench height or burden for optimum breakage in the bench blasting. The use of coarse angular material for stemming in comparison with the fine powdered drill cuttings has also been advocated (Jimeno et.al, 1995; Konya, 1995). The coarse angular material, such as crushed rocks offer increased resistance to the premature ejection of blasthole pressure due to the interlocking properties and behaviour of angular material.

Stemming the collar region of blasthole with inert material confines and retains the gases produced due to the explosion inside the blasthole. Earlier it was largely opined that stemming serves no useful purpose but on the contrary, way back in 1912, the investigations conducted by USBM revealed the significant influence of stemming on the fragmentation and muckpile displacement results. Due to inadequate stemming, improper explosive confinement occurs, which leads to almost 50% loss of explosive energy due to premature venting of gases through the collar region of blasthole (Brinkmann, 1990). Further, inadequate stemming generates oversize at the face and perimeter zones of any blast round

(Floyd, 1999). On the other hand, adequate stemming provides proper confinement and retention of explosive gases within the blasthole to promote the rock fracturing by transmitting a major portion of shock as well as gas pressure through the broken rock mass prior to the release of stemming column. Although the length of stemming column is a function of many factors, excessively long stemming column results into excessive confinement, which becomes the genesis of numerous problems. Excessive boulders in the blasted muckpile were reported, especially from the collar zone due to excessive stemming column lengths (Jimeno et.al, 1995).

Armstrong et al. (1993) also reported the efficacy of stemming through his model scale tests. Sarma (1994) stated that early stemming ejection results in up to 35 per cent loss of explosive heave/energy. Hence, the dispute over the efficacy and utility of stemming is absolutely over with general acceptance that early stemming ejections (which results in premature gas venting through collar region) affect the fragmentation and displacement adversely to generate a tight muckpile. Armstrong and Moxon (1993), on the basis of their lab scale trials, suggested the gas retention, in the blasthole, for a time period equivalent to, or, greater than the initial burden movement time (time period elapsed between the detonation and when the burden material just begins to move). He suggested a burden movement time of 5-9 ms/m of burden for common overburden material. Floyd (1999) also indicated that improper explosive confinement due to inadequate stemming etc. produces oversize in the face and perimeter zones of the blasted patch.

The optimum length of stemming column has been expressed in terms of burden by Ash (1973) as: T = 0.5 - 0.6 B, Where, T = stemming length (m), B= burden (m)

As per Konya (1996) the type of stemming material significantly affects the stemming adequacy. He suggested the use of angular material in contrast to the finely powdered drill cuttings. This was because coarse angular material, such as crushed rock offers less resistance to the ejection due to interlocking, effects, whereas as indicated by Konya (1996) drill cuttings do not lock into the blasthole but function much the same as a viscous fluid. He also suggested that angular materials prevent the sympathetic detonation and pre-compression of charge inside the blasthole. The coarse angular material, such as crushed rocks offer increased resistance (Mario et al., 2005; Kojovic, 2005) to the pre-mature ejection of blasthole pressure due to the interlocking properties and behaviour of angular material. Mario et al (2005) reported through the detonation velocity measurements in holes that 16/32 fraction is the best suited material for stemming in technical construction quarries. This size produced lowest shock-wave velocity within the stemming. Usage of this fraction allows reduction of stemming length without loss of explosive energy. This result in increase in explosive charge and resulting in lesser number of holes for the same amount of blasted material.

As per Kojovic (2005) the practice of using aggregate stemming in production blasting has typically been justified in terms of the improvements in fines generation, consistent with the benefits of confining more explosive energy in the rock during blasting

The stemming of blasthole collars in surface mines with an inert material redirects blasting energy to the rock more efficiently; thus the energy is utilized more effectively in breaking the rock Cevizci and Özkahraman (2012). In this procedure, high efficiency of blockage is important since the blast gases should not be allowed to escape due to loose stemming material. Therefore, more efficient stemming with better confinement increases the generation of fines. Also, better rock breakage can be obtained. On the other hand, there is an increased scatter distance, giving rise to a looser muck pile that can be more easily loaded and transported (Ozkahraman, 2006).

Blasting results showed that coarse angular crushed rock is better than fine drill cuttings for stemming. Dobrilovi'c et al. (2005) studied stemming material consisting of broken limestone and found that the +16-32 mm fraction was the best-suited material. In this study, a new stemming material was investigated with the aim of increasing the blast energy directed to the rock. For this purpose, quick-setting molding plaster was used as a stemming material (Cevizci, 2012).

Drill cuttings are the most common stemming material used in open pits and quarries, since they are most readily available at blast sites and are cheap. However, dry drill cuttings eject very easily from blast holes without offering much resistance to the explosion. Therefore, blasting tests were carried out in quarries by using screened drill cuttings as stemming material, and performance measurements carried out by image analysis of fragmented rock piles.

2.0 Objective of the study

The main objective of the study is to assess the effect of screened drill cuttings on explosive gases ejection, fly rock and rock fragmentation.

3.0 Field study and research methodology

To accomplish the objective field studies and field data acquisition was conducted at two limestone mines. These mines are having the similar geology and rock strata conditions. The section of mines comprised benches being 10m high. The loading operation was performed by the backhoe of 5-6 cum. The blasted muck was loaded on 65 tonne rear dump trucks. The blasted material was feeded in the crusher which can adopt 0.75-1.2m sizes of fragments. The drilled holes of 115/165mm sizes were blasted using ANFO explosives, Emulboost/kelvex-600 cartridge as primer with shock tube initiation system. In one mine the charged explosive was stemmed by the drill cuttings (as shown in Fig.1) while for the other mine the stemming was done by the rock chips (3-7mm) produced by the drill cuttings after separation of dust (as shown in Fig.2). The general drilling and charging pattern used in mines are shown in Figs.3 and 4.

Fig.1 Drill cuttings used as stemming material used in charged holes

Fig.2 Screened drill cuttings used as stemming material used in charged holes

The blasts were recorded using the video camera to assess the gas ejection from stemming part. After blasting a series of high resolution photographs were captured along with a proper scaling object on the blasted muckpiles to cover the entire excavation history of each blast. The image analysis software was deployed to the delineated images to get the fragmentation distribution curve as shown in Fig.5.

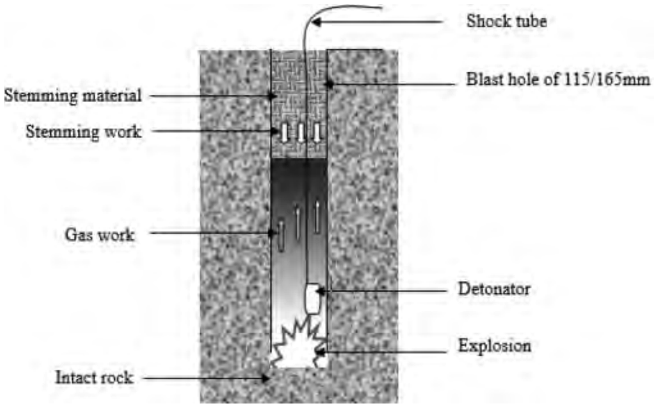

Fig.4 Blast hole section

4.0 Result and discussions

A total of 20 blasting rounds were conducted at two limestone mines at different benches having similar geological conditions (Tables 1 and 2). Other parameters such as explosive, initiating system and blast design parameters were also kept similar, to investigate the influence of stemming material on gas ejection. The holes of 10 blast rounds were stemmed without screening of the drill cuttings and the holes of another 10 blast rounds were stemmed with screened drill cuttings having chip sizes of 3-7mm.

Inferences of 10 blast results (without screening of drill cuttings): Fig.6 clearly indicates the effect of gas ejection from the holes. It means the explosive energy was not properly utilized in breaking and forward movement of fragmented rock therefore, resulted uneven fragmentation sizes. After fragmentation analysis of the broken rock it was found that mean fragment sizes very from 0.35-0.56m. Large number of boulders were separated from collar region and

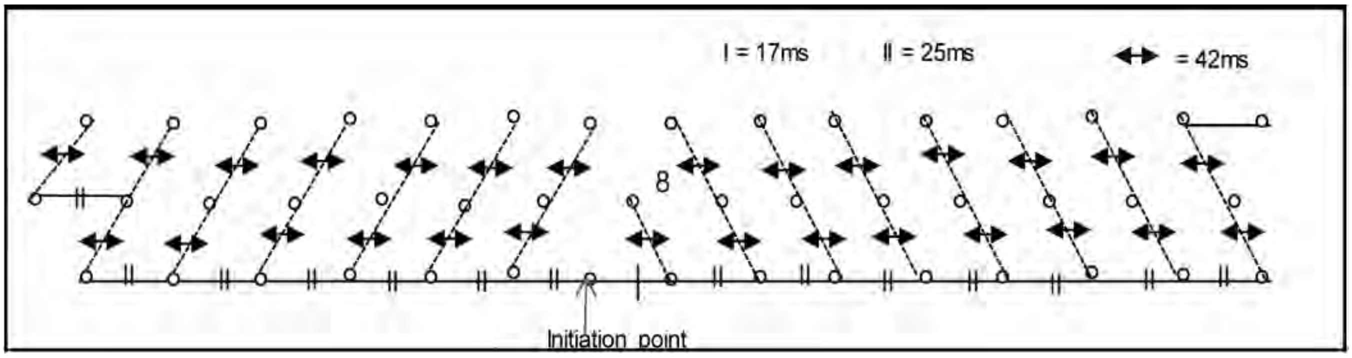

Fig.3 Drilling and firing pattern

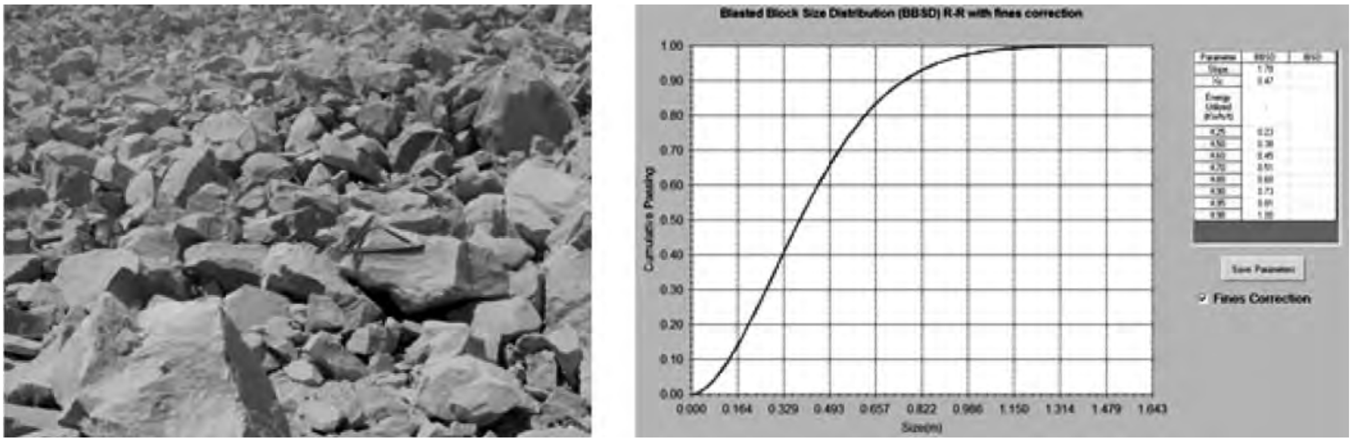

Fig.5 Field captured image for fragmentation analysis

inside the muckpile. Almost 5-7% of the blasted material was treated under secondary breakage which resulted the extra cost of excavation. The throw, drop and spread of the muckpile was restricted. The muck was congested resulting in more digging effort for the excavator. Although more explosive was used to reduce the boulder generation in reduced burden and spacing (powder factor was 5.83-6.84 t/kg). More fly rocks were generated and reached up to 50-70m distance. There was huge dust generated which polluted the environment also.

Inferences of 10 blast results (with screening of drill cuttings): Fig.7 clearly indicates the importance of screened drill cuttings as stemming material. The use of screened drill cuttings made less effort to stem the hole. The fragmentation sizes were uniform and mean fragment sizes were 0.16-0.36m. The boulder generation was less therefore, the secondary breakage was almost 1% of the total broken material. There was increased throw, drop and spread of material that resulted in loose muckpile. No dust, fly rock was observed during blasting as there was almost negligible gas ejection from the stemming part. The powder factor (10-15t/kg) was more than the earlier case due to expansion of burden and spacing in blast designed pattern.

5.0 Conclusions

The following conclusions are drawn from the study:

1. Use of screened drill cuttings provided better interlocking in between rock particles which did not allow the gases to eject from stemming part therefore, improved the explosive energy utilization.
2. To reduce stemming ejections from stemming part, use of

TABLE 1: BLAST DATA FROM FIELD STUDIES AT MINE-A

	Parameters	BS-1	BS-2	BS-3	BS-4	BS-5	BS-6	BS-7	BS-8	BS-9	BS-10
1	Bench height (m)	12	12	12	12	12	12	12	12	12	12
2	Burden (m)	5	5	5	4.5	5	5	5	5	5	5
3	Spacing(m)	6	6	6	6.5	6	6	6	6	6	6
4	Depth of holes (m)	13.43	10.48	11.91	12.91	12.16	5.76	11.36	11.89	10.86	12.15
5	No. of holes	85	60	112	40	66	107	42	45	49	62
6	No. of rows	05	04	04	6	6	6	6	4	6	4
7	Explosive per hole (kg)	168.13	124.90	153.18	138	151	63.41	131.13	135.09	126.35	152.26
8	Total explosive (kg)	14291.37	7494.13	17155	5522	9990	6784	5507	6078	6191	9412
9	Front row burden (m)	2.5	2.5	2.5	2.5	2.5	2	2.5	2.75	2.5	2
10	Throw (m)	15	16	16	15	17	16	15.5	12	16	14
11	Drop (m)	2.5	2.5	4.0	3.2	2.5	2	2.5	1.75	1.5	2
12	Spread (m)	56	40	55	40	52	45	55	48	52	50
13	End break length (m)	3.0	2.5	1.5	2.0	1.5	1.5	2	1.0	2	1.75
14	Total broken rock (t)	85631	47175	100031	37769	60206	46200	35775	40144	39900	56475
15	PF (t/kg)	5.99	6.30	5.83	6.84	6.03	6.81	6.5	6.6	6.44	5.98
16	Mean fragment sizes (MFS)	0.45	0.27	0.39	0.35	0.56	0.31	0.42	0.51	0.22	0.25
17	Fly rock distance	Ranges from 35-75 m									

TABLE 2: BLAST DATA FROM FIELD STUDIES AT MINE-B

	Parameters	BW-1	BW-2	BW-3	BW-4	BW-5	BW-6	BW-7	BW-8	BW-9	BW-10
1	Bench height (m)	10.0	9.75	10	10	9.5	10.0	9.50	10.0	9.75	10.0
2	Burden (m)	4.5	4.5	4.5	5.0	5.0	4.5	4.5	4.5	4.5	4
3	Spacing (m)	6.5	6.5	6.75	7.0	7.0	6.5	6.5	6.5	6.5	6
4	Depth of holes (m)	10.5	10	10.25	10.25	10.0	10.25	10.0	10.5	10.0	10.2
5	No. of holes	20	10	10	07	10	10	10	11	10	20
6	No. of rows	2	2	2	2	2	2	2	2	2	2
7	Explosive per hole (kg)	60.25	57.75	55.25	57.39	50.25	57.75	52.75	59.34	55.25	62.5
8	Total explosive (kg)	1205	577.5	552.5	401.75	502.5	577.5	527.5	652.75	552.5	1255
9	Front row burden (m)	4.5	4.5	4.75	5.0	4.5	4.5	4.5	4.5	4.5	3
10	Throw (m)	10.0	15	10	12.0	10.0	15.0	10.0	10.0	12	15
11	Drop (m)	2.5	1.5	1.5	2.5	1.5	2.5	2.0	1.0	2.0	1.5
12	Spread (m)	30	20	20	25	20	30	20	20	20	25
13	End break length (m)	1	1.5	2.0	1.0	1.0	1.0	2.0	1.5	2.0	2.0
14	Total broken rock (t)	15356	7312	8015	6125	8750	7496	7312	8445	7312	12600
15	PF (t/kg)	12.75	12.66	14.50	15.24	17.0	12.97	13.86	12.9	13.23	10.04
16	Mean fragment sizes (MFS)	0.36	0.27	0.22	0.32	0.37	0.16	0.50	0.25	0.28	0.32
17	Fly rock distance	No fly rock was generated									

Fig.6 Stemming ejection generated fly rock due to use of without screened drill cuttings

Fig.7 No stemming ejection, proper face movement, no fly rock

screened drill cuttings of 3-7mm sizes as stemming material reduced the dust generation, fly rocks and improved the fragmentations of rock, throw and spread of muckpile.

References

1. Armstrong, L. W., Moxon, N. T. and Sen, G. C. (1993): The effect of confinement on fragmentation and movement, Proc. Int. Symp. Rock Fragmentation by Blasting (Fragblast 4), Vienna, 5-8 Jul., pp : 353-560.
2. Armstrong, L. W., Moxon, N. T. and Sen, G. C. (1993): The effect of confinement on fragmentation and movement, Proc. Int. Symp. Rock Fragmentation by Blasting (Fragblast 4), Vienna, 5-8 Jul., pp : 353-560.
3. Ash, R. L. (1973): The influence of geological discontinuities on rock blasting, Ph.D. thesis, Univ. of Missouri, USA.
4. Brinkmann, J. R. (1990): An experimental study of the effects of shock and gas penetration in blasting, Proc. 3rd Int. Symp. on Rock Fragmentation by Blasting, Brisbane, Australia, pp : 55-66.

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