A new stemming application for blasting: a case study

Uma nova aplicação para tamponamento no processo de detonação: um estudo de caso

Halim Cevizci
Suleyman Demirel University.
Mining Engineering Department.
Isparta, Turkey.
halimcevizci@sdu.edu.tr

Resumo

Aparas e pó de perfuração são, geralmente, utilizados em pedreiras e minas a céu aberto, como o material de tamponamento mais comum, uma vez que são mais facilmente disponíveis nas frentes de desmonte. O tamponamento com gesso mostrou-se de melhor uso do que o com detritos de perfuração, devido ao aumento do confinamento dentro dos furos e melhor utilização da energia explosiva no desmonte do maciço. A principal vantagem do novo método é a redução do custo do desmonte. Em uma pedreira de calcário, os custos de detonação por unidade de volume de rocha desmontada foram reduzidos em 7%. Isto foi obtido através do aumento da carga e distâncias de espaçamento. Além disso, a melhor fragmentação foi obtida, usando-se o método de tamponamento com gesso. Ensaios de detonação mostraram que o uso do gesso produziu material mais fino do que os métodos convencionais. Em ensaios sob mesmas condições, a geração de matacões acima de 20 cm de tamanho foi de 42,6% do total, comparado com 48,7% no método convencional, usando-se espaçadores e tamponamento de aparas de perfuração.

Palavras-chave: Tamponamento com gesso, tamponamento, detonação, fragmentação, calcário.

Abstract

Drill cuttings are generally used in open pits and quarries as the most common stemming material, since these are most readily available at blast sites. The plaster stemming method has been found to be better than the drill cuttings stemming method, due to increased confinement inside the hole and better utilization of blast explosive energy in the rock. The main advantage of the new stemming method is the reduction in the cost of blasting. At a limestone quarry, blasting costs per unit volume of rock were reduced by 7%. This is obtained by increasing burden and spacing distances. In addition, better fragmentation was obtained by using the plaster stemming method. Blast trials showed that plaster stemming produced finer material than the conventional methods. In the same blast tests, +20 cm size fragments reduced to 42.6% of the total, compared to 48.7% in the conventional method of drill cuttings stemming.

Keywords: *Plaster stemming, stemming, blasting, fragmentation, limestone.*

1. Introduction

The stemming of blast hole 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, 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 (Tamrock, 1984). 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. Apart from the work of Cevizci (2012), there is no previous work found in the literature citing the usage of this material. Blasting tests were carried out in quarries by using both the suggested new stemming method and classical stemming material, and performance measurements carried out by image analysis of fragmented rock piles.

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 blastholes without offering much resistance to the explosion because drill cuttings are not such a strong plug (Figure 1). With the plaster stemming method, more of blast energy is wasted and lost to the atmosphere because the plaster stemming method provides better fragmentation. Sometimes the plaster plug does not eject from the hole during explosion (Figure 2). Cevizci (2012) carried out blasting tests by changing the blasting parameters of open pit blasts and obtained better results with the plaster stemming method in two different limestone quarries and one clay quarry. These blasting trials were carried out on the same benchmarks and under same rock conditions. The new method employs a plaster prepared as a thick paste, which hardens in less than 25-30 minutes after application. The hardened plaster creates a very strong plug, therefore the stemming column length can be reduced and the explosive column length increased. This increased explosive column results in better rock breakage than similar holes stemmed with dry drill cuttings. Also, this increased utilization of the hole's length reduces specific drilling costs due to increased burden and spacing distances. Blasthole drilling constitutes a major cost in blasting operations. Another advantage of the new method is better fragmentation, with more induced cracking in the rock mass.

In one series of blast tests, blasting costs per unit volume of rock were reduced to 16% by increasing burden and spacing distances (Cevizci, 2012). Also, better fragmentation was obtained by using the plaster stemming method. Blast trials showed that plaster stemming produced finer material. In the same blast tests, +30cm size fragments reduced to 5.4% of the total, compared to 37.7% in the conventional method of drill cuttings stemming. With this method of stemming, vibration and air shock values increased slightly due to more blast energy being available for rock breakage, but these increased values were small and under the permitted limit for blast damage criteria (Cevizci, 2012).

Peak particle velocity (PPV) is known to be a function of site conditions (i.e. geological conditions) and scaled distance, $SD = D/W^{1/2}$, for surface blasting; where D is the distance from the blast face to the vibration monitoring point and W is weight of explosive per delay (Devine et al., 1966).

At the study (Cevizci, 2012) using the plaster stemming method, 61.3 kg explosive per delay was used compared to 58.7 kg in the drill cuttings stemming. This increase in explosive charge caused an increase in PPV value from 12.0mm/s to 17.8 mm/s, whereas it should cause only a 0.4 mm/s increase in PPV value according to calculation from the theoretical formula. The vibration and air shock values measured at the Bozanonu limestone quarry test trials with both the drill cuttings stemming and the plaster stemming were under the safety limits specified in the limit criterion. At the top-level bench, small quantities of fly rock were generated, but this did not constitute a major problem. In addition, the plaster stemming round resulted in a slightly more scattered muck pile owing to more blast energy directed to the rock, but this did not create a big problem either. Loading of the muck pile was easier due to the looser particles.

Also at another limestone quarry, a blasting test with plaster stemming was

Figure 1
Drill cuttings are easily ejected from hole collar.

Figure 2
A plaster plug is not ejected from the hole during explosion at a basalt quarry.

performed and measurements were taken at 39 m in the locations where vibration and air shock occurred, as shown in Figure 3 (Cevizci & Akcakoca, 2011).

At Bastas limestone quarry, 25 cm of drill cuttings were placed between the explosive and the plaster paste (Cevizci, 2012). Length of plaster column was 45 cm. The top 55 cm of the drill hole was filled with drill cuttings. With a plaster stemming round, total length of stemming was 1.25m and no fly rock was generated at the top level bench, similar to the drill cuttings stemming round test trial. Also, the scattering of the muck pile with the plaster stemming round was similar to scattering of the drill cuttings stemming round.

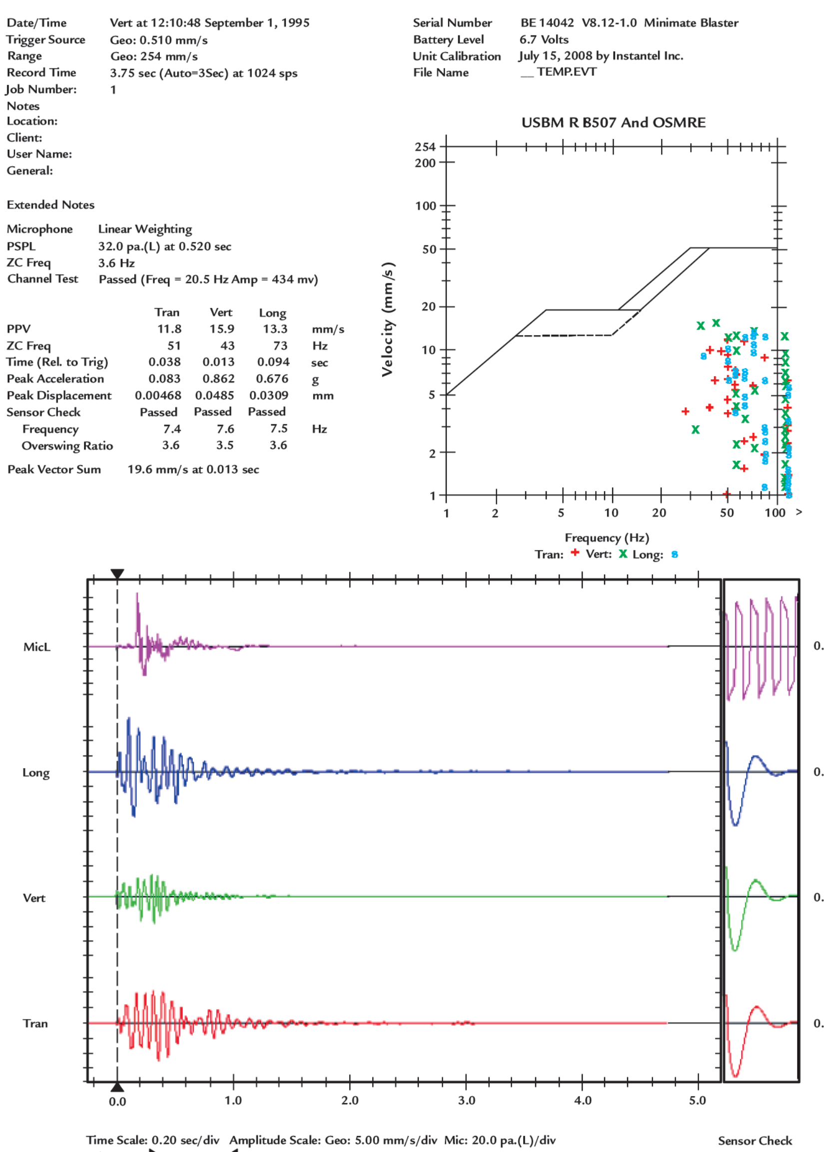

Figure 3
Measured vibration and noise levels in the plaster stemming test at Bastas limestone quarry.

2. Method

The study was carried out at the Gumusgun limestone quarry of Kartas Company. The quarry is located at Gumusgun village, northwest of Isparta city. A summary of the properties of materials at the blast site, blast patterns, measurements of blast tests, and features of the bench faces is shown in Table 1. Both fast-setting molding plaster and drill cuttings were used as stemming material at different lengths in similar blastholes on the same quarry bench. A thick milky molding plaster was prepared by mixing ten units of plaster powder and seven units of water in a barrel, and charged into the blastholes as shown in Figure 4. This wet paste hardens in 25-30 minutes. The design of the stemming, using the tests at Gumusgun limestone quarry is shown in Figure 5.

Wet plaster should not be placed in contact with ANFO, which is water-sensitive, thus 25cm of drill cuttings were placed between the explosive and the plaster paste. Plaster column length was 45 cm. The top 30 cm of the drill hole should not be filled with plaster, since this section of the hole collar is deformed and cracked during drilling (Figure 6). No benefit is expected from filling this section with plaster, and therefore it was filled with dry drill cuttings after the plaster had hardened instead of leaving it empty. This had the advantage of protecting the hole from loose stones dropping in.

Table 1
Summary of properties of materials at blast site, blast patterns and measurements of blast tests.

Blast tests	Dip direction/ angle of dip/ angle of blast direction relative to strike direction of discontinuity	Block size indices (cm)	RQD (%)	Stemming length (m)	Burden (m)	Spacing (m)	Bench height (m)	Index of uniformity	K_{50} (cm)	-10 cm size fraction (%)	Specific charge (kg/m^3)	Specific drilling m/m^3
Gumusgun (drillcutings stemming)	90/55/90	48	75	2	1.85	2	10	1.25	19.5	31.3	1.19	0.29
Gumusgun stemming)	90/55/90	48	75	1	1.95	2.1	10	1.5	15.5	40.1	1.16	0.27

Figure 4
Pouring of plaster paste into hole collar.

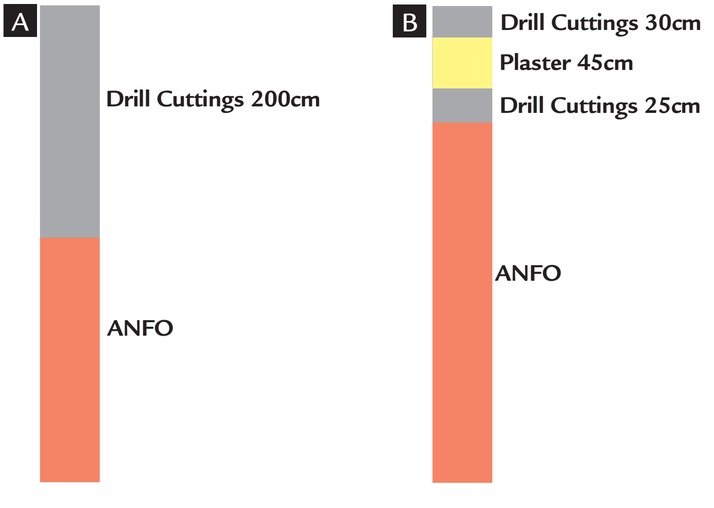

Figure 5
Blast hole Stemming at Gumusgun limestone quarry.
(A) Stemming with drill cuttings.
(B) Stemming with plaster.

Figure 6
Cracked hole collar
and hardened plaster

3. Blast trials and results at Gumusgun limestone quarry

Two test blasts were carried out at Gumusgun limestone quarry. The first round was carried out by using drill cuttings stemming. The second round was carried out by plaster stemming. In both two rounds, all of the 89 mm diameter holes were drilled with Tamrock drillers. Compared to blasting with drill cuttings stemming, burden and spacing distances were approximately 4% larger at plaster stemming method. Nobelex 100G dynamite was used as primer at the bottom of holes. Only one primer initiated with Nonel cap in each hole, which was considered enough for detonation. Extra 625 g of dynamite was also used without cap in the middle of ANFO column. The firing was started with one electric cap. At the surface 42ms and at the hole bottom 500ms Nonel millisecond caps were used.

Drill cutting stemming method is globally used in open pits and quarries. Therefore the stemming blast holes with drill cuttings procedure is a standard procedure and details of this procedure is not given in the paper; instead the new and more efficient plaster stemming is more emphasized. For comparison of two stemming procedures, test blasts were carried out in the same location. Therefore, the rock structure and strength were similar. In both rounds ANFO, with double primer containing of 625g dynamite was used. A quick hardening molding plaster was used for plaster stemming.

The evaluation of blast trials

The blasting results of two stemming methods were compared. Muck pile fragmentation was evaluated using Split Desktop image-analysis software and verified standard "compare photo" method. The rock piles from the blasting tests at Gumusgun limestone quarry are shown in Figure 7 and Figure 8. The cumulative percentage of retained size at the Gumusgun limestone quarry blasting tests is given in Table 2.

The first round was carried out using drill cuttings stemming with 92 holes. The length of the stemming was 2 m. The second round was carried out by plaster stemming with 77 holes. The length of the stemming was 1 m. Each blasthole was filled with 42.6 kg ANFO initiated with one primer with 0.625 kg in weight in the case of the drill cuttings stemming method. For the plaster stemming method, the quantity of ANFO was 46.3 kg per blasthole. The total length of ANFO column in the plaster stemming method was 100 cm greater than for the conventional method of drill cuttings stemming.

The blasted area was 338 m^2 for the drill cuttings stemming trial, and blasted volume was 3380 m^3 in situ. The specific charge was found to be 1.19 kg/m^3 and the specific drilling was 0.29 m/m^3. The blasted area was 312 m^2 for the plaster stemming blast trial and yielding the blasted volume was 3120 m^3 in situ. The specific charge was 1.17 kg/m^3 and the specific drilling was 0.27 m/m^3.

The total length of holes for the plaster stemming trial at Bozanonu limestone quarry was 76.4 m less than for the drill

Figure 7
Rock pile from blast round with drill cuttings stemming at Gumusgun limestone quarry.

Figure 8
Rock pile from blast round with plaster stemming at Gumusgun limestone quarry.

Table 2
Comparison of cumulative percentage of retained size (oversize) from blast trials with plaster stemming and drill cuttings stemming.

Fragment size (cm)	Gumusgun drill cutting stemming (%)	Gumusgun plaster stemming (%)
100	0.0	0.0
70	1.8	1.9
50	8.9	6.7
40	17.2	15.6
30	31.3	27.8
20	48.7	42.6
15	59.2	50.4
10	69.9	60.8
5	82.4	72.5

cuttings stemming round. This resulted in 9% less drilling per unit volume rock. The cost saving for drilling calculated was $825.5 (76.4 m x10.8 $/m). At this site, specific drilling and specific charge decreased because a larger burden and spacing were applied with the plaster stemming method. In order to fragment the same volume of rock as for the plaster stemming round, an additional hole length of 76.4 m should be drilled for the drill cuttings stemming round. The profit per unit volume was $0.31 and total profit by using plaster stemming was $967.2 (Table 3).Therefore, the plaster stemming trial was found to be more economic, as well as giving better fragmentation. For instance, the +20 cm size fraction dropped from 48.7% to 42.6%. Therefore, better fragmentation is obtained with $967.2 profit. Also, the amount of -10 cm size material was increased from30.1% to 39.2%. This has benefits in crushing and grinding.

Table 3
Comparison of cost of blasting of plaster stemming with drill cutting stemming.

Cost item	Drill cutting stemming ($)	Gypsum plaster stemming ($)
Cost of ANFO	3271.8	2990.9
Nonel caps (surface + bottom)	612.9	515.8
Initiating electrical cap	0.5	0.5
Dynamite	363.9	306.2
Gypsum plaster and labor cost	-	50.3
Drilling cost	10672.6	8981.3
Fragmented rock (m^3)	3380	3120
Unit cost ($/$m^3$)	4.43	4.12
Specific charge, kg/m^3	1.19	1.17
Specific drilling, m/m^3	0.29	0.27

4. Conclusion

In the method presented in this study, the inefficiency of the drill cuttings method of stemming is overcome by using plaster stemming. With the old method of stemming, loosely placed drill cuttings do not effectively confine the high-pressure stress produced by blasting. The study clearly shows how gases escaping from the drill hole, without efficient confinement, waste blasting energy. With the plaster stemming method, the pressure of the explosive is used successfully due to the more efficient confinement of the blast because better fragmentation was obtained.

Stemming heights were 1 m greater in the old drill cuttings stemming method than with the plaster stemming method. These long stemming columns caused problems in blasting, since the upper collar region was not broken properly, creating large boulders (Cevizci & Ozkahraman, 2012). This region, called the hard cap rock region, is not effectively broken with the classic drill cuttings stemming method. Generally, as the stemming column increases in length, more boulders are produced, which are dangerous and costly to move.

Additionally, the new method offers a more profitable solution. The cost of drilling for one meter of hole length is almost $10.8. With plaster stemming, more of the hole length is better utilized by increasing the loaded length of the hole, resulting in better breakage at the hole collar. The increased length of loading in the hard cap rock region improves the cap rock breakage, thus reducing the creation of oversized boulders and increasing both efficiency and profit. It was observed that a plaster stemming column 0.45 m in length provided a more robust sealing than 2m of drill cuttings used in the classical method.

Carrying out the plaster stemming in the field does not take a lot of time and is not difficult or expensive. At present, hand loading is used. We are developing a machine for preparing the plaster solution that incorporates a charging unit.

Recently, this stemming method has found acceptance by some quarries. It was reported from these quarries that the new method meets their needs for aggregate production with minimum cost.

However, plaster stemming method cannot be used in a quarry where holes are filled with water, as in the case of ANFO.

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6. References

BOSHOFF, D., WEBBER-YOUNGMAN, R.C.W. Testing stemming performance, possible or not?. ***The J. of The South African Inst. of Min. and Metall.,*** p. 871-874, December, 2011.

CEVIZCI H., ÖZKAHRAMAN, H.T. The effect of plaster stemming to blast fragmentation at clay quarrıes. In: WORLD MINIG CONGRESS & EXPO, WMC-2011, 22. Istanbul, Turkey. v. 1, p. 551-554, 2011.

CEVIZCI, H. A newly developed plaster stemming method for blasting. ***The J. of The South African Inst. of Min. and Metall.***, December. p. 1071- 1078, 2012.

CEVIZCI, H., ÖZKAHRAMAN, H.T. The effect of blast hole stemming length to rockpile fragmentation at limestone quarries. ***International Journal of Rock Mechanics and Mining Sciences***, v. 53, p. 32-35, 2012.

DOBRILOVIC, M., ESTER, Z., JANKOVIC, B. Measurement in blast hole stem and influence of stemming material on blasting quality. In: Rudarsko-geološko-naftnizbornik v.17, Zagreb. p. 47-53, 2005.

KUZU, C. The importance of site-specific characters in prediction models for blast-induced ground vibrations. ***Soil Dynamics and Earthquake Engineering***, v. 28, p. 405-414, 2008.

OZKAHRAMAN, H.T. Fragmentation assessment and design of blast pattern at Goltas limestone quarry, Turkey. ***International Journal of Rock Mechanics& Mining Sciences*** 43, p.628-633. 2006.

TAMROCK. Handbook on surface drilling and blasting. Painofaktorit, Finland, 1984. 310 p.

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