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The Environmental and Ecological Effects of the Plaster Stemming Method for Blasting: A case study

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Abstract

This study was carried out at a limestone quarry of the Kartaş Company at the Bozanönü village in the Isparta region in 2010. Two blast trials, one with a classical drill cuttings stemming method and new plaster stemming method were carried out and the environmental and ecological effects were measured in terms of vibration and air shock and observed flying rock. The results were evaluated in terms of environmental and ecological values. In the one series of blast tests, the blast cost was reduced to 16 % by increasing the burden and spacing distance for the unit volume rock. In this way, 21% more blast area and the 21% more rock was obtained with the same hole-drilling. It means that lesser drilling and lesser blasting results in lesser environmental and ecological effects for obtaining the unit volume rock.

Blast trial with plaster stemming produced less oversize material. For instance, +30 cm size fragments reduced to 5.4 % compared to 37.7 % in the conventional method of classical drill cutting stemming. In the next process, both the product can be broken and ground more profitable and especially the dust problem and other grinding and breaking induced environmental and ecological damage will be reduced. Therefore, it is expected that the new stemming method will commonly be preferred in the future. Using the new plaster stemming method, in spite of the 88 m measuring distance, vibration, and air shock values increased in the Peak Particle velocity (PPV) value from 12.0 mm/s to 17.8 mm/s and in the air shock value from 132 dB to 132.9 dB by directing more blast energy to rock breakage. Firstly in spite of it being seen as a disadvantage, it is not a disadvantage because of the total work (lower specific charge and specific drilling). In other words, we can obtain the same rock with lesser drilling and lesser explosives. In addition, these increased values were small and under the permitted limit of blast damage criteria in spite of the short measuring distance. Within the blasting area especially the birds, mammals, plants, as well as other living organisms can be affected. In terms of reducing the bad effects of blasting on the biological diversity, the new method provides successful and encouraging results because of a lower specific charge and specific drilling.

Keywords: Air shock, blasting, biological diversity, ecology, plaster stemming, vibration.

Patlamalarda Alçı Sıkılamanın Çevresel ve Ekolojik Etkileri Üzerine Bir Araştırma

Özet

Bu çalışma Isparta ili, Merkez ilçe, Bozanönü köyünde, Kartaş A.Ş.'ne ait kireçtaşı ocağında 2010 yılında gerçekleştirilmiştir. Çalışmada, normal taş tozu sıkılama ve yeni alçı sıkılama yöntemi ile iki ayrı patlatma yapılmış ve bu patlatmaların çevreye yaptığı etkiler titreşim ve hava şoku olarak ölçülmüş, fırlayan kaya etkisi de gözlemlenmiştir. Ölçülen değerler çevresel ve ekolojik açıdan irdelenmiştir. Yeni alçı sıkılama yönteminde, dilim kalınlığı ve delikler arası mesafe % 10 artırlarak, aynı basamakta, aynı sayıda delik ile %21 daha fazla alan ve dolaysıyla % 21 daha fazla kaya parçalanmış ve birim hacim için %16 kâr elde edilmiştir. Bu da, aynı miktar kayacı parçalamak için daha az delik delme ve patlatma dolaysıyla da çevresel ve ekolojik olarak daha az zarar anlamına gelir.

Alçı sıkılamalı atımda, tüm boyutlar için elek üstü oranları azalmıştır. Örneğin klasik taş tozu sıkılama yöntemine gore; +30 cm boyutlu malzeme oranı % 37.7'den % 5.4' e düşmüştür. Elde edilen ürünün sonraki aşamada kırılması ve öğütülmesi de hem daha kârlı olacak hem de, çevreye daha az zarar verecektir. Bu yüzden yeni alçı sıkılama yönteminin gelecekte yaygın olarak tercih edilmesi beklenir. Yeni yöntemde patlatma enerjisinin daha verimli kullanımından ötürü, patlatmadan 88 m uzakta yapılan ölçümde, yeni alçı sıkılama yönteminde, titreşim değeri maksimum parçacık hızı (PPV) 12.0 mm/s'den 17.8 mm/s ye ve hava şoku değeri 132.0 dB'den 132.9 dB'ye çıkmıştır. Bu durum ilk bakışta dezavantaj gibi görünse de, toplam işe göre değerlendirildiğinde gerçekte avantaj olduğu anlaşılmaktadır (daha düşük özgül şarj ve özgül delme oranları). Bir başka deyişle daha az delme ve patlayıcı ile aynı kaya elde edebiliyoruz. Ayrıca, bu artan değerler, çok yakın mesafeden ölçüm yapılmasına rağmen, izin verilen limitlerin altındadır. Tüm canlılar özellikle kuşlar, memeliler, bitkiler ve diğer canlı organizmalar patlatmadan etkilenebilir. Yeni yöntem, biyolojik çeşitliliğin patlatma kaynaklı olumsuz etkilerinin azaltılması açısından daha düşük özgül şarj ve spesifik delme oranı sağladığından ümit vericidir.

Anahtar Kelimeler: Alçı sıkılama, biyolojik çeşitlilik, ekoloji, hava şoku, patlatma, titreşim.

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INTRODUCTION

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

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. Thus, a great percentage of blast energy is wasted and lost to the atmosphere. Cevizci (2010) studied blasting parameters of open pit blasts and obtained better results with the plaster stemming method in three different limestone quarries and one clay quarry. 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 hole-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 (Cevizci 2012).

Blasting and ecology

The first mining works, before blasting, is to remove the birds and mammals from the area (Öztürk and Tabur 2013). The damage to these species is very small, because, the first blasting operation, is firing the detonation caps (Cevizci et al. 2013). This event by itself causes serious noise and causes birds to fly from the site. Detonation cord is better than an electric detonator in terms of warning. However, for bugs and reptiles, escaping the blasting is difficult and they can be exposed to serious damage. On the migration routes, especially during the migration period, blasting operations must be reduced or blasting operations stopped completely (Bernis 1983). Blasting must never take place at an area that is of vital importance in terms of ecology. Asphalt roads are useful for mining operations but a disadvantage in terms of saving biological diversity (Korkmaz et. al. 2012). Because, unpaved roads are better than asphalt roads for ecology (Özçelik 1995)so therefore, asphalt roads must be limited. The more asphalt roads there are, the more traffic there is (Özçelik 2000). In this way, anthropological problems can occurred. According to each bird species, nesting is different. Some birds like the magpie and woodpecker nest in trees and some birds like the seagull nest on the ground. If blasting or other mining operations are made in an area that contains no trees, then birds like the magpie and woodpecker will have no problems. Blasting or other mining operations must not be carried out an area in which endangered species live. For endangered species, the population number is a big problem. However, for the non-endangered bird species, they can build their nests in other areas. Saving the nesting area for reptiles which can be under rocks and or in rocky terrains; as well as the reptiles, invertebrates would also have a difficult time moving. So there for blasting or other mining operations must not be allowed in an area in which endangered invertebrates and reptiles live (Do and Lineman 2012).

Near residential and not so near residential area, a Nonel detonation system must be the preferred blasting system (Tamrock 1984). Because blasting with the Nonel detonation system, the environmental effects are lower. In addition, the Nonel detonation system is vitally important for the worker's health and safety also (Özkahraman 2009). Blast induced flying rock can damage all living things. However, the damage risk is lower for birds than for reptiles, mammals, and bugs. Blasting or/and other mining and civil operations must not be carried out in an area in which endemic plants are growing. This is especially vital and important for local endemic plants. Blast induced dust is a big problem for some living things such as plants and the pollination process. On the other hand, underwater blasting causes pressure waves and the pressure waves generated causes injuries to fish (Fukiyama et al 1985). The damage can change distance and direction of the blast point. In addition, blasting can also cause damage in terms of hydrogeological effects. Groundwater quality is commonly affected by blasting.

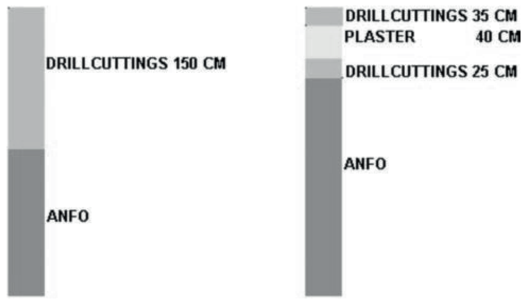
MATERIAL AND METHODS

The study was carried out at the Kartas Company's Bozanönü limestone quarry. Fast-hardened molding plaster was used as a new stemming material instead of drill cuttings. Both stemming materials, of different lengths, were used in similar holes at the same quarry bench. The quarry is located at Bozanönü village north-west of the city of Isparta. Vibration and air noise levels were measured with an Instantel Minimate Blaster for both stemming methods.

A thick milky molding plaster was prepared by mixing ten units of plaster powder and seven units of water in a barrel, and then charged into the blastholes 40 cm in length. Thirty-five cm long drill cuttings were used on top of the plaster column and 25 cm at the bottom of the plaster column giving a total of a 1 m long stemming length (together with the plaster column, Fig.1).

Thus, this application gives better utilization of a drill hole. Because, in the case of the plaster stemming method it provides a one and half meter long extra explosive column. Thus using more explosive energy which gives better results and improved efficiency.

Two blast rounds, five meters apart, were carried out with the plaster stemming and the classic conventional drill cuttings stemming, each consisting of one row with seven holes. The length of the stemming was 1.5 m. In the case of the drill cuttings stemming method, each blasthole was charged with 58.7 kg ANFO and the detonation initiated with two primers of 0.625 kg in weight. With the plaster stemming method, the spacing of the holes and burdens was increased by 10 per cent, and the quantity of ANFO was 61.3 kg per blasthole. The ANFO column in the plaster stemming method was 0.5 m longer than the with the conventional method of drill cuttings stemming. A total of 28 primers were used in 14 holes in both blast rounds. Detonation was initiated from the bottom of the holes. An extra 0.625 kg of dynamite was used without a cap in the middle of the ANFO column to ensure the success of blasting. Nonel cap delays were used with the Nonel tubes, with a delay of 42 ms at the surface and 500 ms at the bottom of the hole. Vibration and air noise levels for both stemming methods were measured with an Instantel Minimate Blaster placed 88 m away from the blastholes.



(a) Stemming with drill cuttings (b) Stemming with plaster

Fig. 1. Blast hole stemming at the Bozanönü limestone quarry.

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 the weight of explosive per delay (Devine et al. 1966).

Therefore, in 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 12.0 mm/s to 17.8 mm/s, whereas, it should only have caused a 0.4 mm/s increase in the PPV value according to the calculation of the theoretical formula (see Fig. 2 and Fig. 3). In addition, the air shock increased from 132.0 dB to 132.9 dB (see Fig. 2 and Fig. 3). The vibration and air shock values measured at the Bozanönü 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.

RESULTS

The results of the measured vibration and noise levels are shown in Fig. 2, where the classical drill cuttings method of stemming was used for blasting a group of seven holes. The results of the measured vibration and noise levels are shown in Fig. 3, where the plaster stemming was used for blasting a group of seven holes. Fig.2 and Fig.3 show the 3 direction (transverse, vertical, and longitudinal) maximum peak particle velocity, maximum air pressure, and frequencies. Fig.2 and Fig.3 also shows the 3 direction velocity and air pressure according to the time. Also, Fig.2 and Fig.3 show the graph of the 3 direction velocity according to the frequencies.

Vibration and air shock values increased slightly by directing more blast energy to rock breakage. However, these measured values (Table 1) were under the permitted limit of blast damage criteria (Table 2). The measurements were taken were only taken at a distance of 88 m.

DISCUSSION

In this study, the environmental and ecological effects of the new "Plaster Stemming Method" was investigated and compared with the environmental and ecological effects of the classical drill cuttings stemming method. In the classical drill cuttings stemming trial, the PPV is 12.0 mm/s. The components of vibration (3D) are transverse PPV 6.22 mm/s at 14 Hz, vertical PPV 11.9 mm/s at 19 Hz, and the longitudinal PPV 9.78 mm/s at 23 Hz. With the new plaster stemming trial, the PPV is 17.8 mm/s. The components of vibration are transverse PPV 12.8 mm/s at 13 Hz, vertical PPV 8.76 mm/s at 21 Hz, and the longitudinal PPV 17.8 mm/s at 14 Hz. The vertical component of vibration is lower and the frequency is higher which it is an advantage in the plaster stemming method but longitudinal and transverse components are higher and frequencies are lower which is a disadvantage. But these increased values were small and under the permitted limit of blast damage criteria in spite of the short measuring distance (88m).

Firstly, we can express this is a significant increase in terms of vibration and that this is a disadvantage but these increased values are under the permitted limit of blast damage criteria in spite of the short measuring distance. In fact, according to the study, we can break 21% more rock with the preferring plaster stemming method with the same drilling and blasting. In other words, we can break 21% more rock with the plaster stemming method because of 10% more burden distance and 10% more spacing distance. However, we must use more ANFO due to a shorter stemming length column and more explosive charge column. It means that we can break the same volume of rock with 17.76%

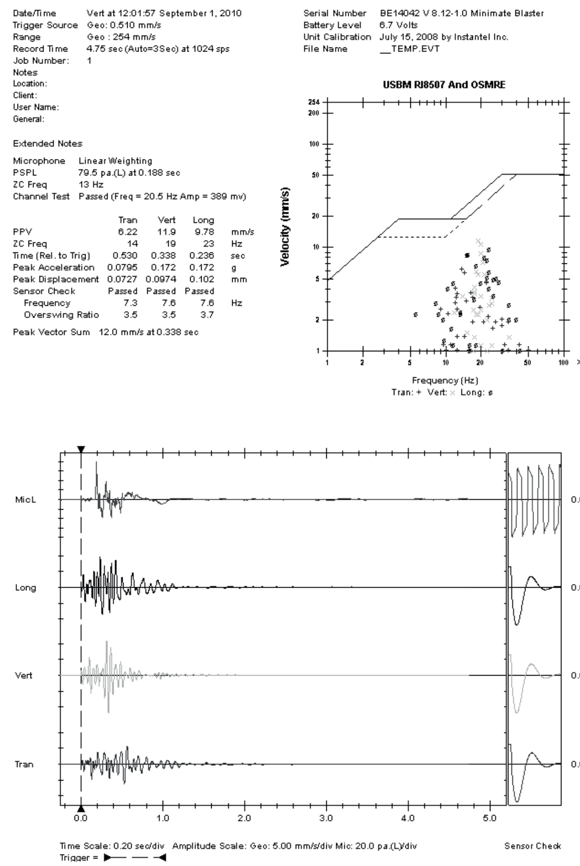


Fig. 2. Measured vibration and noise levels in the drill cuttings stemming test at the Bozanönü limestone quarry.

lesser drilling and blasting. This is a significant advantage in terms of profitability and the environmental and ecological damages. On the other hand, it means lesser fuel consumption which means lesser exhaust gases for drilling. It is a significant change in terms of environmental pollution. At the same time, less drilling is most important for reducing cost. Because, blast hole drilling constitutes a major cost in blasting operations. In addition, better fragmentation is obtained. For instance, +30 cm size fragments reduced to 5.4 % compared to the 37.7 % in the conventional method of classical drill cutting stemming. Because of the high cost for the grinding and breaking process the product can be broken and ground easily realizing a more significant profitability. Also especially the dust problem and other grinding and breaking induced environmental and ecological damage will be reduced.

At the top level bench, small quantities of fly rock were generated, but this did not constitute a

Table 1. Particle velocities and frequencies measured at the Bozanönü limestone quarry according to the stemming method.

Stemming method	Tran. Particle velocity (mm/s)	Fr. (Hz)	Vert. Particle velocity (mm/s)	Fr. (Hz)	Long. Particle velocity (mm/s)	Fr. (Hz)	Peak Particle velocity (mm/s)
Drill cuttings	6.22	14	11.9	19	9.78	23	12.0
Plaster	12.8	13	8.76	21	17.8	14	17.8

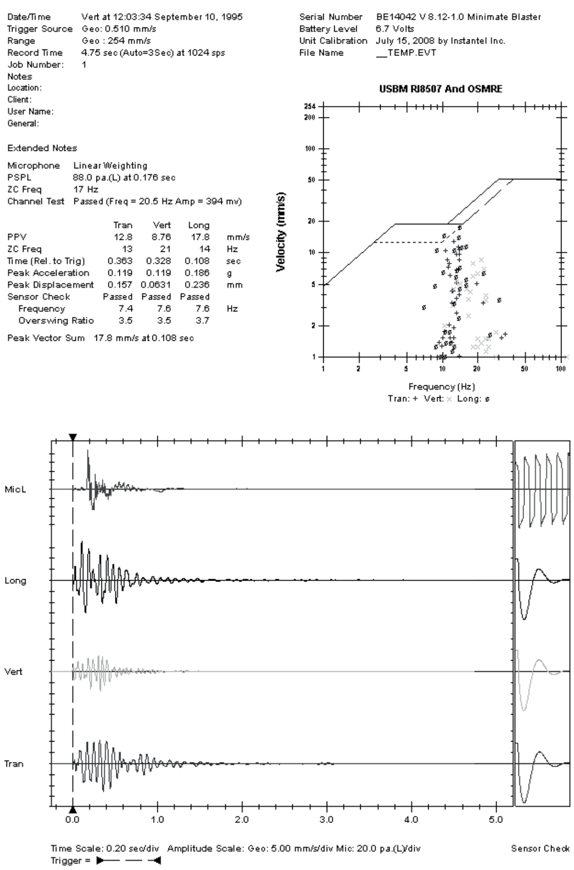


Fig. 3. Measured vibration and noise levels in the plaster stemming test at the Bozanönü limestone quarry.

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. On the other hand, in the plaster stemming, if the total length of stemming including the top and bottom drill cuttings is more than 100 cm, the muck pile scatter distance is the same as for the drill cuttings stemming. It was found that the total length of the plaster stemming method should be 125 cm–150 cm (Cevizci and Akçakoca 2011).

All mining processes and blasting effect the ecology of the environment. On the other hand, all mining processes as well as blasting are vitally important and useful for human life also.

Table 2. Maximum tolerance levels of blast vibrations at mines and quarries (By Turkish Law).

Vibration Frequency (Hz)	Maximum Allowable Vibration Level (Peak-mm/s)
1	1
4-10	19
30-100	50

When near residential and not so near residential areas, the Nonel detonation system must be preferred. Because blasting with the Nonel detonation system, the environmental effects are lower. Blast induced flying rock can damage all living organisms. However, the damage risk is lower for birds when compared to reptiles, mammals, and bugs. Blasting or/and other mining and civil operations must not be carried out in areas which contain endemic plants . It is especially, of vital importance for local endemic plants. Blast induced dust is a big problem for some living things such as plants and the pollination process.

The high-stress is produced by plaster stemming due to effectively confining the gases inside the holes. In the case of the drill cuttings stemming method gasses escaped and the blast energy is wasted by the exhausting gases escaping from the drill hole by inefficient confinement. Whereas, this blasting power is used successfully by molding plaster stemming due to more efficient confinement. On the other hand, the measured pick particle velocity values were higher when compared to the drill cuttings stemming method. This finding is due to less exhaust fumes escaping via the collar of the hole. The initial shock waves generated by better confinement with the moulding plaster trials were responsible for this increased efficiency of blast energy used in rock breakage.

CONCLUSIONS

Consequently, using the plaster stemming method, we can obtain the same rock with less blasting according to the classical drill cuttings stemming method. Therefore, ecological destruction is reduced significantly and in terms of reducing the bad effects of blasting on th biological diversity, the new method provides successfully and encouraging results. Blast induced flying rocks can cause damage to all living organisms. In this study, using the plaster stemming method, we could obtain the same rock with approximately 18 % lesser blasting according to the classical drill cuttings stemming method. In this way, ecological destruction is reduced significantly.

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