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NEW APPROACH ON BLASTING FOR EXCAVATION

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Abstract

In this study, efficiency of a new method of stemming with plaster was investigated in blast holes and compared with conventional method of stemming with "dry drill cuttings". Drill cuttings is generally used in open pits, quarries and other blast operations as the most common stemming material since it is the most readily available in blast sites. However, dry drill cuttings ejects very easily from blast holes without much resistance to blast energy. The plaster stemming method investigated in this study is 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 blasting tests were carried out in one clay quarry and one limestone quarry. ANFO was used as a main blasting agent and holes were blasted with Nonel caps. To compare the results obtained with both method of stemming, blasting tests were done at the same locations. Fragmentations after the trial blasts were measured with Split Desktop software. It was found that plaster stemming provided finer fragmentation. The conventional method of drill cutting stemming gave worse fragmented rock pile than round with plaster stemming. This finding shows that the plaster stemming method can be used in quarries which are a better alternative. Also muckpile volume is larger in the case of plaster stemming. As a result, powder factor is reduced giving better economy in explosive consumption.

Keywords: Plaster stemming, stemming, blasting, fragmentation, Split – Desktop software

1. Introduction

Stemming blast hole collar in surface mines with an inert material redirects blasting energy to the rock more efficiently so, the energy is utilized more effectively in breaking rock. But in this procedure, high efficiency is important since the gases should not be escaped due to loose stemming material. Therefore making more efficient stemming with better confinement improves the fines generation. Thus better rock breakage is obtained. Also throw distance is increased giving looser muck pile, which can be more easily loaded and transported.

Fragmented limestone and clay are used in cement production in great quantities. The cheapest way to fragment clay or limestone rock mass is by blasting. Blasted clay or limestone is send to crushers to reduce its size. So producing fragments as fine as possible reduces the work of crushers thus the cost of breaking is reduced as well as the cost of loading (Mac Kenzie, 1966, Ozkahraman, 2006).

Drill cuttings is the most common stemming material used globally in open pits and quarries since it is most readily available in blast sites and it is cheap. But, dry drill cuttings ejected very easily from blast holes with explosion without much resistance.

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Thus, a great percentage of blast energy is wasted and lost to the atmosphere. Cevizci (2010) was studied blasting parameters on open pit blasts and obtained better results with plaster stemming. Blast hole stemming by plaster means preparation of a plaster with water as a thick white solution like a mud but this solution is hardened in 25 minutes. Thus, stemming length is also reduced and explosive column is increased. This increased explosive column gives better rock breakage than similar holes filled with dry drill cuttings. Also this increased utilization of hole length reduces drilling costs, since hole drilling contribute a high cost in blasting operations. Another advantage which new method provides is better fragmentation and product with more induced cracks inside. Dobrilović et al. (2005) studied the best stemming material made of broken limestone and found that 16/32 mm fraction was the best-suited material. But the quick setting plaster as a stemming material has not used before. Zhu et al. (2008) have concluded that strong confinement can efficiently block explosive products (gases) escaping from the borehole, thus it can intensify rock damage extent, which means enhances blasting efficiency. Boshoff and Webber-Youngman (2011) developed new approach about testing stemming performance.

2. Method

The study was carried out at clay quarry of Goltas Company (Figure 1) and Bastas cement factory limestone quarry (Figure 2). Summary of properties of materials at blast sites, blast patterns and measurements of blast tests are shown in Table 1. Fast-hardened moulding plaster was used as a new stemming material instead of drill cuttings. Both stemming material at different length was tried at similar holes at the same quarry bench. A thick milky moulding plaster was prepared by mixing ten unit moulding plaster and seven unit water and poured in hole. This wet paste plaster hardens in 25-30 minutes. The moulding plaster was mixed with water inside a barrel and a thick white colored paste was obtained.

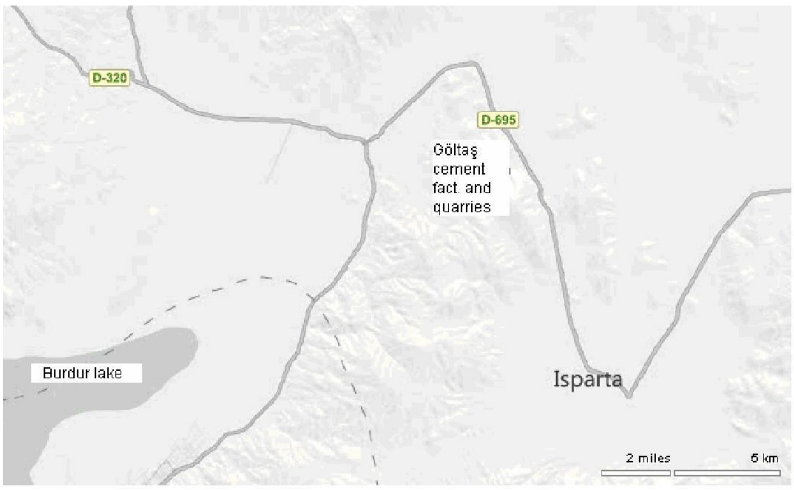


Figure 1. Location of Göltas company’s clay quarry

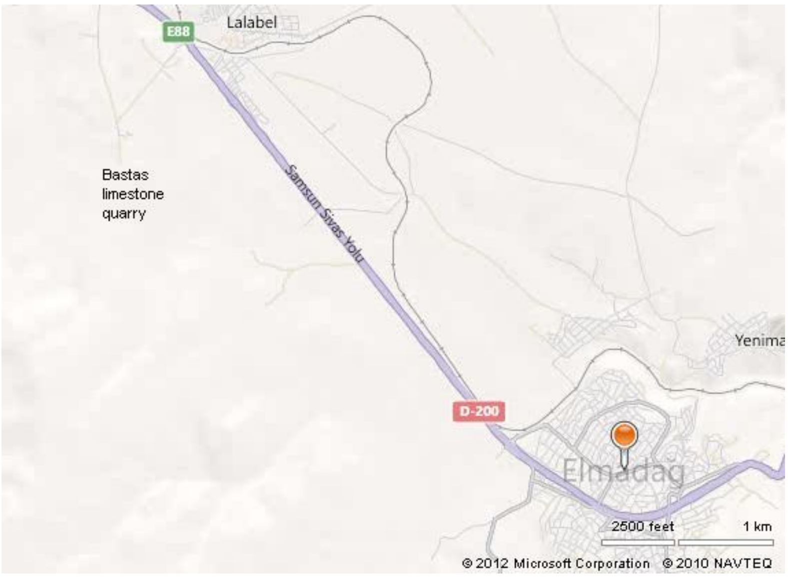


Figure 2. Location of Bastas cement factory's limestone quarry

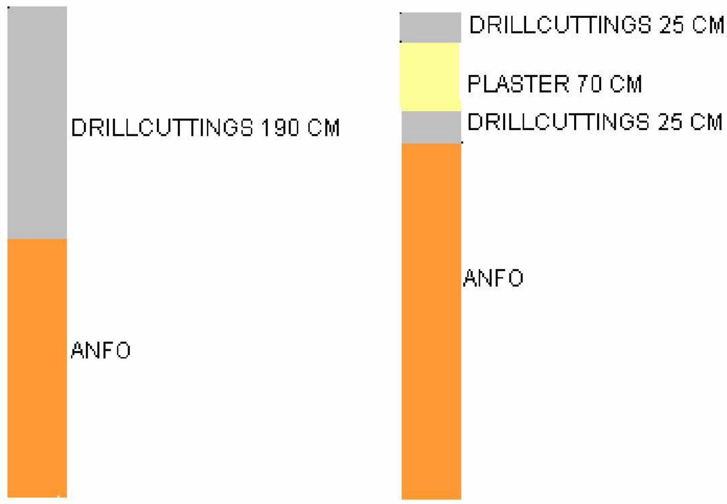
3. Blast tests at Clay Quarry of Goltas Cement Factory

A thick milky moulding plaster was prepared with using water and poured 70 cm in length. A 25 cm long drill cutting was used on top of plaster column and 25 cm at the bottom of plaster column giving a total of 1.2 m long stemming length (Figure 3), (together with plaster column). A wet plaster should not effect ANFO, thus 25 cm long drill cuttings was found to be a sufficient length which will not effect ANFO which is water sensitive. 25 cm length on top of drillhole should not be filled with plaster since this section of drill hole collar is deformed and cracked during drilling. No benefit is expected from this section with filling with plaster. So this section was filled with dry drill cuttings instead of leaving empty after plaster hardening phase. This application has a advantage of protecting hole from stones dropping inside the hole from above. Thus this application gives better utilization of corresponding 1.9 m long drill cuttings length. The results obtained gave improved efficiency (Cevizci, 2010).

53 holes of 3.9 m in average length with 127 mm diameter were drilled with Atlascopco drillers. Nobelex 100G dynamites were used as primer at the bottom of holes. One primer initiated with Nonel cap in each hole was considered to be enough for detonation This application was used in lieu of classic 1.9 m long drill cutting stemming method. The firing is started with one electric cap. At the surface 42 ms and hole bottom 500 ms Nonel millisecond caps were used with Nonel tubes. Nonel tubes grantees any misfires and the round was fired with electrical blasting maching. This wet paste plaster was hardened in 25-30 minutes. The moulding plaster was poured in water and a thick white colored paste was obtained inside barrel. This paste was charged inside holes as shown in Figure 4 according to the design given in Figure 3. The total length of plaster column was 70 cm which was totally 70 cm more than classic conventional method of drill cutting filling. The ANFO column should not be wetted therefore it is protected from wet paste of plaster with 25 cm long drill cuttings inserted on top of the ANFO column as seen in Figure 3. The hardening time was 25-30 minutes. The rest of stemming length was 25 cm long which was filled with drill cuttings at the top of hole collar.

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

Blast Tests	*Dip direction/ angle of dip/ angle of blast direction relative to dip*	*Block size index*	*RQD (%)*	*Stemming length (m)*	*Bench height*	*Average Burden (m)*	*Average Spacing (m)*	*+ 30 cm Size Fraction (%)*	*Delay (surface/ bottom)*	*Specific charge (kg/m³)*	*Specific drilling (m/m³)*
Goltas clay (drill cuttings stemming)	210/50/30	24	70	1.9	3.6	2.5	2.5	22.9	42/500	0.39	0.14
Goltas clay (plaster stemming)	210/50/30	24	70	1.2	3.6	2.5	2.5	8.3	42/500	1.07	0.14
Bastas limestone (drill cuttings stemming)	225/40/225	52	65	3.5	12	2.3	2.5	46.8	9/500	1.0	0.21
Bastas limestone (plaster stemming)	225/40/225	52	65	1.25	12	2.4	2.65	30.6	9/500	1.13	0.20



a) Stemming with drill cuttings b) Plaster stemming

Figure 3. Blast hole stemming at Goltas Company's clay quarry

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Figure 4. Application of plaster paste to hole collar

3.1. The Evaluation Of Blast tests at Clay Quarry of Goltas Cement Factory

Blasting was carried out with larger holes which was 127 mm in diameter and stemming length was 0.70 m in length filled with moulding plaster. The length of holes drilled was 3.9 m. The fragmentation of muckpile generated after blast tests was evaluated with Siplit – Desktop software (Table 2). The percentage of +30 cm size fraction is used for comparison. It's found that in moulding plaster stemming it was reduced from 22.9 % to 8.3% compared to drill cutting stemming. Since the product is used in, cement making and is crushed. The finer size generation with blasting with plaster stemming reduces cost of crushing by saving energy consumption. Creating more confinement with plaster plug gave more blasting energy. Weight per cent retained cumulative oversize at Goltas cement factory clay quarry and Bastas cement factory limestone quarry blasting tests is given Table 2.

4. Blast tests at Limestone Quarry of Bastas Cement Factory

A thick milky moulding plaster was prepared with using water and poured 45 cm in length. A 55 cm long drill cutting was used on top of plaster column and 25 cm at the bottom of plaster column giving a total of 1.25 m long stemming length (together with plaster column). Blasting was carried out with holes which was 102 mm in diameter and stemming length was 45 cm in length filled with moulding plaster. Totally 13 holes of 13 m in average length with 102 mm diameter were drilled with Frukawa drillers.

Two test blasts were carried out at Bastas cement factory limestone quarry. First round was carried out by using the drill cuttings stemming with 7 holes, in which length of stemming was 3.5 m. Second round was carried out by plaster stemming with 6 holes.

Table 2. Comparison of Cumulative per cent of retained size (over size) at blast trials both at the plaster stemming with the drill cuttings stemming

Fragment size (cm)	Goltas cement factory clay (%)		Bastas cement factory limestone (%)	
	Drill cuttings stemming	Plaster stemming	Drill cuttings stemming	Plaster stemming
200	0.0	0.0	2.1	0.0
150	0.0	0.0	9.4	0.0
100	0.0	0.0	18.8	0.3
70	0.8	0.0	26.1	5.3
50	5.7	0.2	34.4	14.7
40	11.9	1.9	40.0	22.1
30	22.9	8.3	46.8	30.6
20	38.2	27.9	55.0	39.0
15	47.2	42.2	59.0	44.7
10	56.7	56.8	64.5	51.9
5	69.6	74.1	72.2	62.1

Each blast hole was filled with 59.0 kg ANFO initiated with primer with 0.5 kg in weight in the case of the drill cuttings stemming method. At the plaster stemming method, quantity of ANFO was 72 kg per blast hole. The total length of ANFO column at the plaster stemming method was 2.25 m longer than classic, conventional method of filling with drill cuttings. Total of 13 primers were used in 13 holes in both blast rounds. The holes were initiated detonation from the bottom. At the surface 9 ms and at the hole bottom 500 ms Nonel cap delays were used with Nonel tubes. Weight per cent retained cumulative oversize at Bastas cement factory limestone quarry blasting tests is given Table 2.

4.1. The Evaluation Of Blast tests at Limestone Quarry of Bastas Cement Factory

The blasted area was 34.3 m^2 at the drill cuttings stemming trial. Therefore blasted volume was 411.6 m^3 in-situ. Specific charge was found to be 1.0 kg/m^3 and the specific drilling was 0.21 m/m^3. The blasted area was 31.7 m^2 at the plaster stemming blast trial giving a blasted volume of 380.9 m^3 in-situ. The specific charge being 1.13 kg/m^3 and specific drilling was 0.2 m/m^3

The total length of holes at the plaster stemming trial at Bastas cement factory limestone quarry was 3.9 m shorter than the drill cuttings stemming round for whole obtained rock, giving 5 per cent less drilled holes for the plaster stemming round. Because burden and spacing were increased. Therefore, using the plaster stemming method provided lower drilling cost but higher blasting cost for unit volume. The profit per cubic volume was $ 0.07 and total profit by using plaster stemming was $26.7. On the other hand, the plaster stemming trial was found giving better fragmentation. For instance, +30 cm size material was dropped from 46.8 per cent to 30.6 per cent. With the plaster stemming round, there were no fly rock at the top level bench, similar to the drill cuttings stemming round test trial. Also, scattering of muck pile with the plaster stemming round was similar to scattering of the drill cuttings stemming round.

5. Conclusion

With this study, the inefficiency of the drill cuttings method of stemming is solved with the plaster stemming method. In the old stemming method, the high-pressure stress produced by blasting is not effectively confined by loosely placed drill cuttings. The blasting energy is wasted by exhausting gases escaped from drill hole by inefficient confinement. Whereas, this power is used successfully by the plaster stemming due to more efficient confinement.

In the new developed method, the vibrations and air shocks occurred was under the permitted damage levels. But the measured PPV and air shock values were higher compared to the drill cuttings stemming method. This finding is due to (proves the theoretical consideration of) less exhaust fumes are escaped to the air via the collar of the hole. The initial shock waves generated by better confinement with the plaster stemming trials are responsible for this increased efficiency of blast energy used in rock breakage. Stemming height was 2-3 m longer in old the drill cuttings method than the plaster stemming method. And this long stemming column caused problems in blasting since this top upper collar region were not broken properly causing big boulders. This region called hard cap rock region is not effectively broken at the classic drill cuttings stemming method. Generally, as the stemming column increases, the more boulders are produced which are dangerous and costly to move.

Blasting experiments carried out in-situ proved the theory that the plaster stemming makes better confinement in blast holes, especially in short holes, where explosive column length is short giving lower explosive charge. In such cases, the plaster stemming method offers great benefits in breaking rock more effectively.

The new method offers more profitable solution. The cost of drilling for one meter of hole length is almost $10.8. With the plaster stemming up to almost 3 m hole length is better utilized by increasing loaded length of hole, giving better breakage at the hole collars. Higher length of loading in hard cap rock region, improves the cap rock breakage thus reducing oversized boulders, this increases efficiency and profit in total. It is observed that a 0.45 m length plaster stemming column provided a more robust sealing than holes filled with 3.5 m long drill cuttings stemming length used in the classical method.

Energy utilization rate increased with the plaster stemming due to creating effective confinement with better clogging. Also, a better fragmentation, increasing vibration levels, flying rocks and air shock levels are all indicators for the increase in the rate of energy usage.

Carrying out the plaster stemming in the field do not take a lot of time and is not difficult and expensive. In addition, plaster length more than 50 cm increases the hardening time creating a disadvantage (Cevizci and Ozkahraman, 2011). So, length of plaster column must be 30 – 50 cm. On the other hand, in the plaster stemming, if total length of stemming including the top and bottom drill cuttings is more than 100 cm, muck pile scatter distance was same to scatter distance of the drill cuttings stemming. It is found that total length of the plaster stemming method should be 125 - 150 cm, otherwise if it exceeds 150 cm muck pile fragmentation becomes worse.

Blasting tests with plaster increases overall rock fragmentation and reduces secondary breakage costs and overall downstream costs. The high velocity shock wave travels up the path of least resistance (the drill hole), is slowed down for milliseconds (ms) by plaster stemming, forcing the explosive energy, and gases out into the rock mass. Higher length of loading in hard cap rock region, improves cap rock breakage thus reducing oversized boulders that are dangerous and costly to move. Therefore plaster-stemming application should be used in open pit and quarry blasting for clay**,** limestone and other materials. Similar studies with plaster stemming were carried out in limestones where applied plaster distance were 30-50 cm. These plaster distances were determined as the best suitable for the blast configuration. If the distance is increased more than 50 cm then the hardening time found to be too long.

In this study, new developed plaster stemming method is investigated and studied examples at open pits. Plaster stemming method provides more profitability. This advantage is valid for channel blasting and all construction blasting too.

Kaynaklar

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