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Application of Stemming Plugs and A Case Study in A Limestone Quarry

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ABSTRACT: Stemming is one *of* the major effective parameters of open pit blasting. "Stemming plugs" are the new technological development on the increase of blasting efficiency without changing the feature of explosives. They are used in the stemming zone of the blast hole to increase the containment of the explosive gasses. This yields an increase in explosive energy transmitted to rock mass, resulting in better fragmentation. In this study, the results of some limestone quarry bench blasting performed with domestically produced plugs have been discussed. The video-camera shots of experimental blasting with stemming plugs will provide a better understanding over the mechanism of them.

I INTRODUCTION

/. / The effect of stemming on blasting efficiency

The drilling and blasting operations in open pit mining and quarrying are two important cost elements, which must be considered to reduce with new technological developments. Beside of the cost of blasting, another important effect of blasting to be considered is the fragmentation of blasted rock. It has a very big influence both on the performance of loading equipment and on the cost of primary crushing if the blasted pile is a raw material of a consecutive process.

The accepted procedure for directing the explosive energy into the surrounding rock mass is the chemical reaction that produces high volume of gasses. Detonation velocity of explosive provides high energy within the blast hole, until the production gasses is kept inside the blast hole. The stemming provides the capture of the energy to transmits into rock mass. Stemming material is generally inadequate to fully contain explosive gasses if used with the optimum charge height for maximum blast efficiency. The stemming length is usually increased in an attempt to compensate for the loss of explosive energy. This results in usually with oversize material at the top of the drill hole. Inappropriate stemming height will allow the explosive gasses to vent, creating fly rock and air blast problems as well as reducing the effectiveness of the blast (Long, 1996).

Too much stemming will result in poorly fragmented rock near the top. It is generally accepted that the shock from the initial detonation of explosive in a blast hole is responsible for the cracking, spilling and weakening of the rock around a blast hole. The following rapid expansion of gasses provides the heave and resultant fragmentation. Thus, confining the gasses in the hole for as long as possible is important in maximizing the blast efficiency. One way to provide better stemming column is to use classified aggregate and other way is to increase the height of stemming column filled with some primer parts inside. All the methods are about to utilize the crushing effect of the explosive for maximizing blast efficiency and minimizing the cost (Miller, 1997).

1.2 Theory of stemming plugs

Stemming plugs were first developed in University of Missouri in 1994 in order to protect explosive gasses escaping from the blast hole. The main purpose is to block the chemical output gasses those are effective source of fragmentation in blasting within the blast hole. Stemming plugs are placed in the stemming zone of the blast hole to increase the containment of the explosive gasses. The resultant increase in explosive energy is transmitted to the rock mass and is utilized to fragment the rock more efficiently.

Stemming plug ıs a cone shaped device constructed of high impact polystyrene. The circumferential wall of the conic shape ends with a placement part at the top as seen in Figure 1. It can easily be compressed under any load to change its shape. This characteristic of the plug is used for placing the plug firmly in the hole when any load coming from stemming material applied over it. The plug is inserted in the borehole over the explosive charge. First of all, one third of the total stemming material is placed in the hole over the explosive column to provide cushion effect against the heat produced by chemical reaction. This protects plug from rapid deformation due to excessive heat and pressure (Fitzgibbon, 2001).

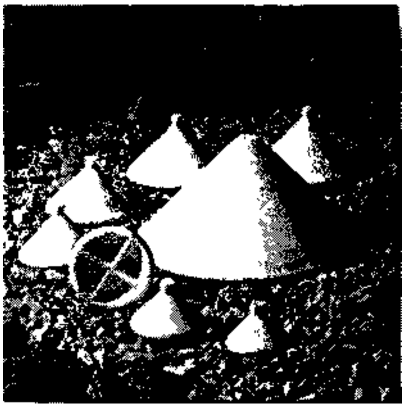


Figure I. A general view of stemming plugs (w\v w..stemlile.com.au)

Then the next step is to put rest of total stemming material over the plug. The plug should be as firm as to resist the burden from stemming material above it, but at the same time it should expand to close the gap with hole wall to restrain necessary friction when the explosive column is initiated. This provides necessary caption forces to keep high-pressure explosive gasses inside the stemming zone giving a better fragmentation effect. The working mechanism of the plugs is given in Figure 2.

Figure 2. The mechanism of the stemming plugs (w\\w.stumtite.com.au)

When the explosive column is initiated, the energy created from rapid chemical reaction drives the stemming plugs upwards into the stemming column, the typical path of least resistance and engages the stemming material in the borehole wall. At the same time, the expansion occurs on the plugs providing a better friction resistance to keep its position in the hole (www.stemtite.com.au).

In order to install the plugs in the hole, it is lowered onto the first part of stemming material functioning as buffer with an appropriate insertion tool that is a wooden stick a holding mechanism at the end. After ensuring that the plug is properly seated, at least one borehole diameter of stemming material is added on the plug to disengage the insertion tool from it. Plugs are designed to occupy approximately 90% of the actual borehole diameter to allow space for plugs to freely down detonation wires and compensate for drill bit wear.

Another type of stemming plug called as Mocap has been in use for surface and underground blasting. They can be functional in both horizontal and vertical drilling. The function of the Mocap is same as stemming plugs; only the difference between both is the shape and easy installation properties. It is pushed into the hole to the top of explosive charge with the closed end facing the drill hole. The shape of Mocap stemming plug is shown in Figure 3.

Figure 3. Mocap stemming plugs (www.accurateblasting.cuni/explosives/mucap.html)

The test on Mocap showed that they provide longer time to stemming movement and lower stemming ejection velocity means more blast energy is retained in the borehole, giving better fragmentation, less fly rock and noise reduction. In the stemming movement test Mocap plugs are 100% better than regular stemming and 77% better than hard plastic cones shapped plugs. (www.accurateblasting.com/explosives/inocap.html)

2 CASE STUDY AT A LIMESTONE QUARRY

In order to examine the disclaimed advantages of stemming plugs, several blast tests were organized on a limestone quarry that provides raw material to a cement factory around Izmir, Turkey. One important aspect expected from blasting is the proper fragmentation of the limestone, since the pile is fed directly to the primary crusher of the cement factory. As it was mentioned before, particle size distribution has big influence over the cost of consecutive process, so that it is a general approach to use explosive energy in the fragmentation process as much as possible to reduce the work of primary crushers. For this reason, in limestone quarry of a cement factory, the burden and spacing distances are kept closer than it is in overburden removal for open pit mining.

At the beginning of the study, it was planned to obtain original stemming plugs from the firm that distributes, but we failed to provide them. It was later decided to produce the plugs with our own design from polystyrene block by shaping with lathe. The conical angle and the thickness of the plug are selected in a way that it provides enough stiffness to bear the .stemming over it and also to expand with the explosive gasses pressure.

The diameter of the blasting holes in the quarry is 6 inches (15.24 cm). The biggest diameter of the plugs was selected as 14 cm with 30° conical angle and on the top of it a special holding part for insertion purposes was designed (Figure 4).

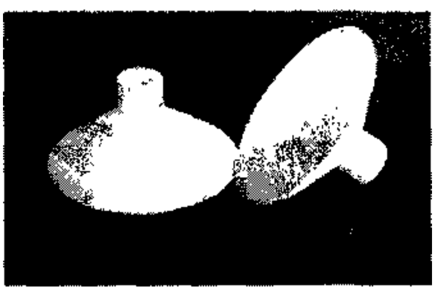


Figure 4. Produced stemming plugs

The method of field experiments can be described as follow. There were total of 6 blasts organized by changing the blast components such as burden, spacing and height of stemming column. All blasts were shot by a digital camera from a safe distance to see the behavior of explosive column, stemming ejection with or without stemming plugs. The ground vibration that was the indicator of energy propagation was also measured, hence it is a well-known effect that if the explosive energy is not used properly in blasting, it comes out as noise and vibration. Each camera recording was loaded to a personal computer and detailed analysis was performed on every 1/16 of the second because the frames per second of the digital camera is 16 pictures in a second. Each image analysis performed on the blasting provided data to plan next blast with different pattern.

The first experimental blast was organized to see the behavior of the moving mass without using stemming plugs with original blast pattern that has been using in the quarry. Table 1 gives the information about blast 1, 2 and 3. There were total of 8 holes fired in blast i. The cross sections of the holes with and without plug are given in Figure 5.

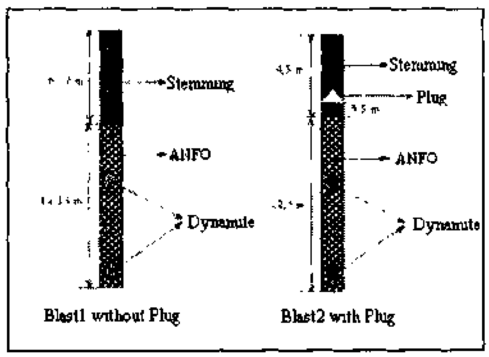


Figure 5. Cross section of the holes for blast I and blast 2

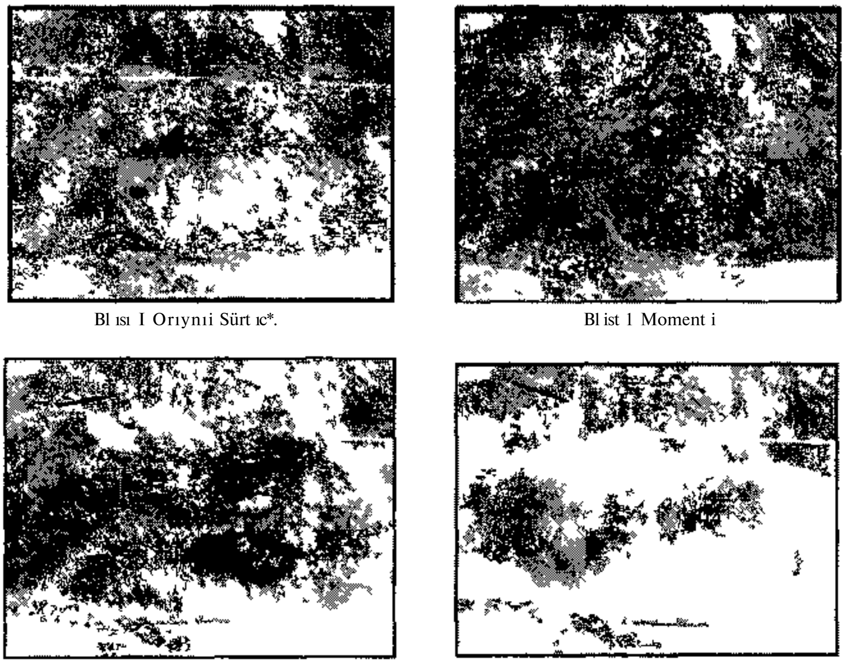
When the camera shots taken from blast 1 investigated (Figure 6), it can be seen that for the original blast pattern, there were stemming ejections in two of eight holes. In this blast, eight different delay times were applied for the holes and 2[IKl] and 8[lh] holes produced stemming ejections, due to increased burden in front of them resulting from irregular bench face. Increasing burden caused an additional bearing on the hole, so that explosive gasses produced higher pressures on stemming. As blast 1 was organized to see the effect of the common blasting that has been used over years in the quarry, it showed that increased burden caused a stemming ejection and this process was recorded by the digital camera.

Tıblel Blast p îttein toi blast 1 blast 2 and bhst 1

		Bhst 1	Bhst 2	Blast 1
Nunibei ot hole		8	8	8
Amount ot explosive (Without plug)	(kg/hole)	200	200	220
Amount of explosive (With plug)	(kg/hole)		204	241
Pi unci	(kg/hulc)	4 44	4 44	4 44
Buiden	(m)	s()	5 0	6 6
Spicing	(in)	4 5 - 5	4 7 - 5 2	5 8 62
Cimei t set up dist tnce	(in)	15s	US	165
Beııelı height	(m)	IS 6- 16 0	16 s	16
Hole leıiglıt	(in)	iy	17	18
Hole diametei	(mm)	152 4	165	16s
Stemming lenghl	(m)	6 - 7	4 5	1 5
Chugtcolomn	(m)	12 M	11 5	14 5

Although the length of stemming column changes between 6 and 7 m toi all 8 holes tor 19 m ol hole length two holes pioduced stemming ejection that was the ındıcatoı ot pıessuıe on the stemming column It was so big that even ^0% ot stemming height over dull hole did not woik propeily

The camera shots obtained horn blast I aie given in Figuie 6 Stemming ejection could be identified fiom the picture on the lelt coinci ot Figuie 6 The name ol moment is given so that pictuies are taken by lree/mg the \ideo movie in différent time inteivals to see the blasting event in detail The tiagmeniation lesulted fiom blast 1 is given in Figuie 7 It gives an idea in compaiing the performance ot blast with othei blast results



Bl ısı I Orıynıi Sürt ıc*.

Bl ist 1 Moment i

B ast 1 Moment 2

Blast 1 Moment

Figuit 6 Digit ü edmeıa views foi bl ist 1

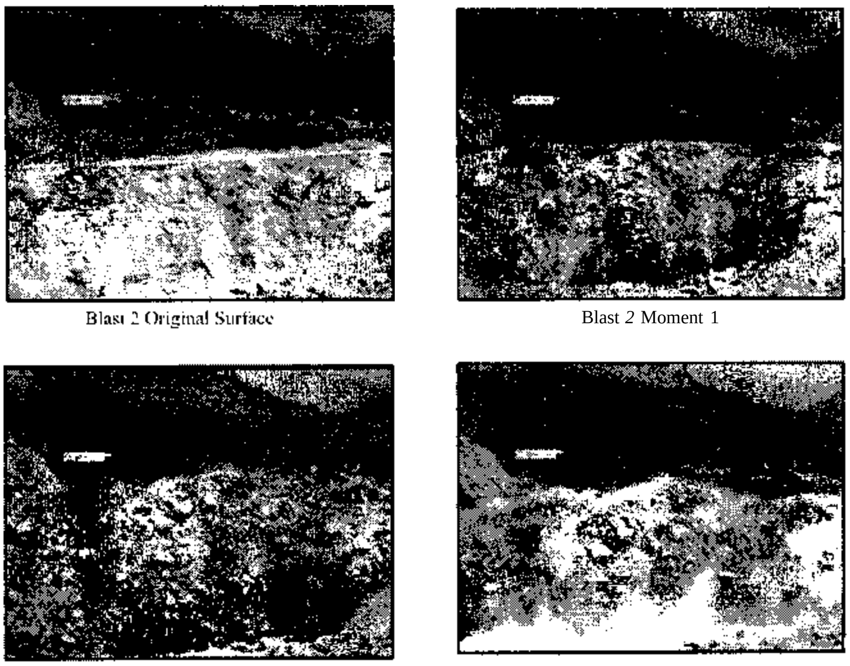
Fi sure 7. The fraamentation for blast I.

The second blast was carried out with eight holes (Figure 8). Plugs were used in three of them with decreasing stemming column height to see whether any ejection would occur or not. Total hole length was 17 m and the height of stemming column was kept as 4,5 m for the holes those contain stemming plug.

Decreasing stemming column height, another saying increasing charge column made the expectation of stemming ejection high, nevertheless there was no ejection seen for these holes. Additionally a better fragmentation had been seen for the holes with plugs.

As it was stated before, as the length of stemming column increases, it ends up with larger blocks at stemming zone due to lack of breaking energy. The case is given in Figure 9. It is apparent that holes those were fired without plug on the right hand side of the picture contain oversize blocks on visible part of the pile. The source of these blocks was the length of stemming column for the holes without stemming plugs.

The only concern about the blast 2 was the back cracks occurred as a result of increased charge column. Since the burden and spacing were kept constant for this blast with increased charge column, the excessive energy caused back cracks on the top of the benches (Figure 10).



Blast 2 Original Surface

Blast 2 Moment 1

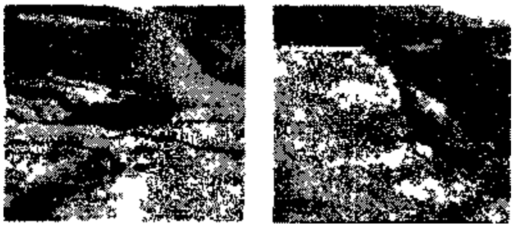
Blast 2 Moment 2

Blast 2 Moment 3

Figure 8. Digital camera views for blast 2.

F-iguie 9 The fragmentation foi blast 2

These back cracks show that some ot the explosive energy that must be ctlective in size ıeductıon pıocess, is lost In oıdeı to use this energy in tiagmentation the buiden or spacing lengths should be inueased as well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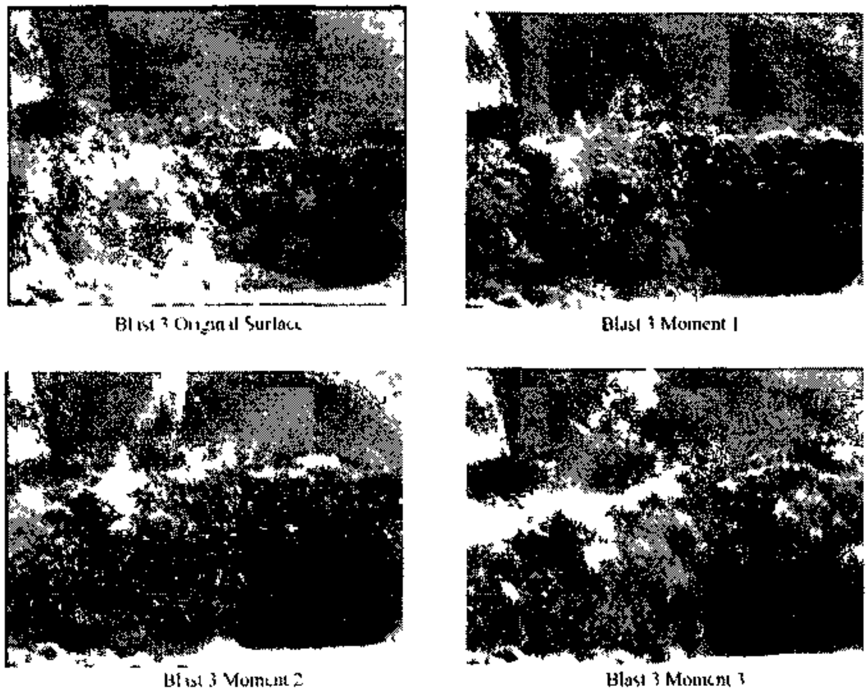
The next toui experimental blasts wcie tned with increased burden and spacing by using stemming plug in halt ot the holes The stemming height was reduced to 20% ot the whole hole length, that was the lowest value the quarry had been used so tar, but the expectation ot stemming rejection tailed in each blast This gives a very pıomısıng lesult on the technical benefit ot using stemming plugs Decieased stemming column meant higher explosive column to produce a better tiagmentation tor stemming zone


Bl ıst 3 Oııgın ıl Surlacı

Blast 3 Moment I

Bl ıst 3 Momınt 2

Blast 3 Momcnt 3

Figuıe 11 Digital camcıa views foı blast 3

Only blast 3 has been given out ot tour blasts tor the rest ot experiments in this papei Figure 10 shows the digital cameia pictures tor blast 3 Even veiy small value ot stemming column height kept the explosive gasses inside the blast hole, but an ejection occurred in the holes without plug due to the increased burden

Success ot the blast with stemming plug can be assessed by carefully consideration ot fragmentation or to study îequired size distribution of the muck pile In the experiments we earned out the size distnbution ot the muck pile had been obtained by image analyzing and anothei simple method like ovei size block counting or the peiloimance ol the loading machine Theie were almost no difference between the blast with plugs and without plugs as lar as luel consumption of the loading machinery and the number ol oversize blocks were considered (Figure 12)

Figure 12 The fragmentation for blast 3

Calculating the specific charge used in these examples can assess etlectiveness ol plugs Specific chaige is the amount of explosive that is used to blast I m of material The change of the specific chaige between the holes with and without plugs aie given below

Blast without stemming plugs

The volume of broken lock per hole (m)
4 "im x 4 5m x 18m =364 5 m /hole
Total amount ot explosive pei hole
(165/2)'x 3 14 x MSOx 09 gı/cm' = 238 kg/hole

specific chaige = 0 653 kg/ m

Blast with stemming plugs
The volume ot broken lock per hole 0^)
6m x 6m x 18m =648 m /hole
Total amount ot explosive per hole
(165/2)- x 3 14 x 1650 x 0 9 gr/cm3 = 271 kg/hole

specific chaige = 0 418 kg/ m'

3 CONCLUSION

The specific charge of the limestone quairy blasting has been leduced tiom 0 653 kg/m' to 0 418 kg/m which is still above the usual values toi limestone The amount ol explosive depends not only on the geomechanic propeities ot ıock to be blasted but also the stiuctural body ot the lock as well The voids ciacks discontinuities and joints are the main deteiminislic stiuctuies in blasting This amount of reduction obtained only by using stemming plugs is important as tar as blasting cost ot the company is concerned

The lollowmg suggestions and results can be given at the light ot the studies done in this project

- Stemming plugs woiked veiy well in the holes wheie theie were some problems lesulting in shoiter stemming column
- Foi the blast in which stemming plugs were used with increased burden and spacing theie was not much differences in particle si/e distribution ot the blasted pile This results in a leduction ot total hole length to be drilled to pioducc the same amount ol blasted material
- Reduction on stemming ejection leduccs the noise and fly ıock

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