Rocklock Improves Blasting Efficiencies in Aggregate Quarries

ROCKLOCK STEMMING PLUG FIELD STUDY - AGGREGATE TESTING	
APPLICATION	Two aggregate quarries in Southwest Pennsylvania
TESTING	Rocklock stemming plug vs. stemming only
BLAST DESIGNS	Site 1: 69-hole production blast - half using Rocklock and half using stemming only; Site 2: Five production blasts in a 12 x 12 ft. parallel pattern with the blasts 1 and 5 using stemming only and blasts 2 through 4 incorporating Rocklock
ROCKLOCK SIZES	6.75 in diameter at Site 1; 6.0 in diameter at Site 2
RESULTS	Regardless of whether using shock-tube or electronic detonators, Rocklock retains explosive gasses longer than using stemming material alone. Rocklock improved muckpile uniformity and overall blast performance at both sites.

ABTI continually evaluates the performance of Rocklock stemming plugs to ensure optimum performance. We recently commissioned independent consultants to conduct two separate field studies at quarries in southwestern Pennsylvania, exhibiting different geological characteristics. Site 1 in Connellsville featured the use of 6.75-in diameter Rocklock plugs in a blast detonated by non-electric shock tube system, while Site 2 in Somerset used the 6-in diameter Rocklock and electronic detonators.

The scope of both studies focused on quantifying the effectiveness of Rocklock stemming plugs to better contain explosive energy than stemming alone and, therefore, improve rock fragmentation and overall blast performance.

Typically, the loss of energy through stemming ejection reduces the performance of the blast. By improving the effectiveness of stemming material in the blast hole, Rocklock enhances explosive energy containment within the rock mass to yield a more controlled and efficient blast event.

Throughout both studies, high levels of field controls were adhered to during the drilling and blasting process. These field controls were monitored and applied as they relate to: bench preparation, pattern layout, blast hole drilling, blast hole loading procedures and post blast data collection.

All blasts were filmed with a high-speed digital video camera, filming at the rate of 1,000 frames per second, which allowed field technicians to quantify the burden containment offered by Rocklock plugs. Following each blast, the fragmentation composite of the post-blast muckpiles were quantified using optical fragmentation analysis techniques.

TWICE THE RETENTION TIME

Consultants tested Rocklock on 69-hole production blast at quarry Site 1. The blast consisted of 2 rows drilled to a depth of 58 feet with a diameter of 6.75 in and to a pattern of 17 ft burden by 19 ft spacing. During this test, half of the holes were loaded using the Rocklock plug, while the other half were loaded using only crushed stone as stemming material.

Technicians loaded the holes with an average 875 pounds of a bulk emulsion explosive and used a non-electric shock tube system for detonation. Blast timing was designed to open the blast in the center of the rock face, and, in a chevron array, the blast holes were individually detonated.

A portion of the center holes were equipped with signal indicators, so the precise firing time of these individual detonation signals could be recorded by the high-speed video. These signals gave visual indication of burden movement and relative confinement levels within different sections of the blast.

In addition to showing actual firing times, analysis of the high-speed video provided visual references of gas retention time, stemming ejection times, the apparent initial burden movement vertically and overall vertical throw of the blast event. The table below identifies the above times relative to the starting detonator (Time Zero). The time between the signal flash and the first visible movement of the surface as stemming ejection or surface swell is referred to as Retention Time or Tmin.

Rocklock stemming plugs delivered a gas retention time of more than twice as long than the non-plugged holes. **Average retention time for crushed stone stemmed holes was only 5.88 ms, compared to 12.75 ms for holes stemmed with Rocklock and crushed stone.**

The longer the explosive energy is confined within the rock mass, the more these gasses penetrate into the cracks and break the rock. Any loss of gas pressure through stemming ejection or venting will directly affect the overall fragmentation of the blast and the heave of the muckpile.

Rocklock delivered a higher degree of fragmented rock with a more uniform size distribution

A digital image analysis system provided aggregate fragmentation data from the blast. The images were gathered during the excavation procedures at locations throughout the muckpile to ensure the merged findings would be representative of the true level of blast induced fragmentation. The merged fragmentation data yields results showed the portion of the test blast using Rocklock stemming plugs was composed of a higher degree of fragmented rock with a more uniform size distribution.

Rocklock blasts resulted in a 2% reduction in the average mean size of rock from 4.88 to 4.79 inches and an 8% decrease in the D90 (90%passing) screen size from 9.14 in to 8.41 in. These numbers typically can be directly related to reductions in excavation and crushing costs.

FACE ROW

Hole Number Stemming Mat.	1 stone only	2 stone only	3 stone only	4 stone only	5 stone only	6 plug stone	7 plug stone	8 plug stone	9 plug stone
Firing Time ms ΔT ms	115 ms 25 ms	90 ms 25 ms	65 ms 27 ms	38 ms 38 ms	0 ms start	55 ms 55 ms	77 ms 22 ms	104 ms 27 ms	134 ms 30 ms
Initial Movement, ms	123 ms	95 ms	70 ms	44 ms	2 ms	68 ms	87 ms	117 ms	144 ms
Retention Time, ms	8 ms	5 ms	5 ms	6 ms	2 ms	13 ms	10 ms	13 ms	10 ms

BACK ROW

Hole Number Stemming Mat.	10 stone only	11 stone only	12 stone only	13 stone only	14 plug stone	15 plug stone	16 plug stone	17 plug stone
Firing Time ms ΔT ms	288 ms 36 ms	252 ms 20 ms	232 ms 35 ms	197 ms start	247 ms 50 ms	276 ms 29 ms	309 ms 33 ms	344 ms 35 ms
Initial Movement, ms	297 ms	261 ms	239 ms	199 ms	259 ms	294 ms	317 ms	362 ms
Retention Time, ms	9 ms	9 ms	7 ms	2 ms	12 ms	18 ms	8 ms	18 ms

ROCKLOCK & ELECTRONICS DETS: A HIGHER LEVEL OF BLAST OPTIMIZATION

Testing at Site 2 occurred over a series of five production blasts. Blasts 1 and 5 established a baseline by using stemming only, while blasts 2 through 4 incorporated usage of Rocklock plugs. To ensure comparative data integrity, the five production blasts were symmetrical to one another in terms of geometry and loading parameters, and each blast was initiated with electronic detonators.

With two of the blasts, technicians spotted the camera to the surface of the bench directly above the first hole detonated in the face row. Surface electronic detonators were programmed with the same firing time as the corresponding in-hole detonators of the explosive column below. These surface detonators were inserted into a box and placed directly above the blast-hole collar.

Replay of the high speed video allowed the consultant to determine the amount of time elapsed (Dt) between the explosive detonation and the vertical heave and gas venting above the borehole. Any increase would indicate a higher level of energy containment, enabling the expanding gasses to penetrate deeper into the micro-fractures of the rock mass, increasing fragmentation.

For this series of tests, five rows of 6-in diameter holes were drilled on a 12' X 12' parallel pattern to a bench depth of 68 ft. To ensure proper toe burden dimensions, set back markers were placed prior to the detonation of each blast.

Prior to loading the holes with 40% a bulk emulsion blend, they were re-measured to verify the correct depth and the presence of water. If water was encountered, the holes were pumped before loading the explosives. The holes in the front row of each blast were stemmed with 12 - 15 feet of drill cuttings, while the rest of the holes were stemmed with 5 feet of cuttings.

Post-blast muckpile delineation and size distribution analysis was conducted using a digital image analysis system. The images were gathered during excavation at locations throughout the resulting muckpiles to ensure the merged findings would be representative of the true level of blast-induced fragmentation. This analysis indicated that a large percentage of oversize rock originates from the cap rock above the level to which the explosives could be safely or efficiently loaded to maintain proper confinement levels.

No Plug Blasts	Mean Size (in)	D_{90} (in)	D_{75} (in)	Roslin - Rammler Uniformity Coefficient
Blast 1	4.08	6.59	4.51	1.96
Blast 5	4.33	7.08	4.69	1.63
Combined Data	**4.21**	**6.84**	**4.60**	**1.80**
Plugged Blasts	**Mean Size (in)**	**D_{90} (in)**	**D_{75} (in)**	**Roslin - Rammler Uniformity Coefficient**
Blast 2	3.86	6.44	4.40	1.90
Blast 3	3.28	5.37	3.70	1.14
Blast 4	3.61	6.24	4.14	1.15
Combined Data	**3.58**	**6.02**	**4.08**	**1.40**

Rocklock Stemming Plugs	% difference in avg. Mean size	Decrease in D_{90}	Decrease in D_{75}
Combined	**15% smaller ↓**	**9% ↓**	**11% ↓**

From the data files, technicians generated a merged analysis report to show the size distribution and uniformity of each of the five resulting muckpiles. **The report verified that the Rocklock post-blast muckpiles were composed of a higher degree of fragmented rock with a more uniform size distribution**, as show in the above tables.

Rocklock delivered a 15% reduction in the average mean size of rock and a 9% decrease in the D90 (90%passing) screen size, reducing it to 6.02 in. There was also an 11% decrease in the D75 size from 4.60 inches to 4.08 inches with Rocklock. These numbers typically can be directly related to reductions in excavation and crushing costs.

Video of the surface swell above the opening hole indicated that Rocklock contained the expanding gasses roughly an average of 17% longer than the non-plugged holes. This analysis was conducted to determine the time in milliseconds between the detonation of the explosive column and the initial indication of first movement or swell of the bench in the vertical direction.

IMPRESSIVE RESULTS

Both Pennsylvania Rocklock stemming plug trials resulted in performance benefits in terms of improved fragmentation and overall blast performance, regardless of using shock tube or electronic detonators. At Site 1 in Connellsville, Rocklock increased the effectiveness of the stemming to better retain the expanding gas pressure pulse of the blast, exhibited in a more controlled bench swell and reduced stemming ejection. At Somerset Site 2, Rocklock delivered a 15% decrease in the mean size in the post-blast muckpile.

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