Performance Testing of the VARI-STEM® 4.5 inch Hole Plugs September 24, 2003

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Introduction

This study was designed to quantify the effectiveness of the 4.5-inch diameter MOCAP VARI-STEM hole plugs. On September 24, 2003 Douglas Bartley of DBA Consulting and representatives of the Wampum Hardware Company met at a J.S. Faulkroad and Sons Stone quarry in McCalisterville, PA to conduct field tests to determine the effectiveness of the VARI-STEM hole plugs using different types of top stemming material.

The test consisted of a production stone blast with 50% of the holes stemmed with standard crushed stone. Two-thirds of the remaining 50% of the holes were stemmed with a VARI-STEM plug and crushed stone. The last one-third of the remaining 50% of the holes were stemmed with a VARI-STEM Plug and only Drill Cuttings**.

The testing was designed to answer the following questions:

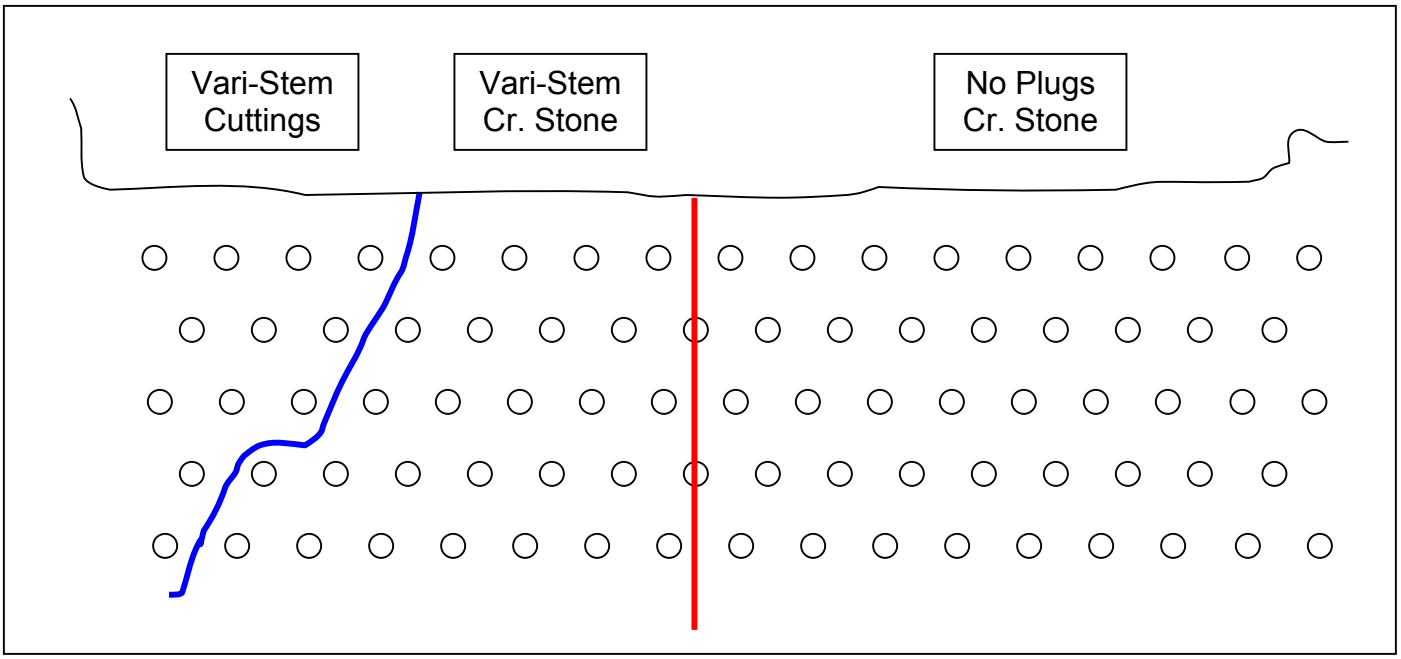
- Do the VARI-STEM plugs retain expanding gasses from the explosive detonation in a manner to improve overall blast performance?
- If so, what is the level of gas energy confinement in terms of time and burden movement?
- Is there a measurable difference in blast performance and energy confinement using the VARI-STEM plug implemented with dry drill cuttings or sand as top stemming in place of crushed stone?

** Due to the geology in the area, the resulting drill cuttings had the consistency of a fine sand, rather than dust or talc.

The following is a discussion of the test procedures and the results as determined by DBA Consulting.

On September 24, 2003 an 86-hole production blast was detonated at the J. S. Faulkroad and Sons, McCalisterville Quarry. This blast consisted of 5 rows of 14 holes drilled to a depth of 50 feet with a diameter of 4.5 inches. The holes were drilled to a pattern of 8'X8' (Burden X Spacing). The blast holes were loaded with an average 330 pounds of a blended Iremix bulk explosive. The timing of the blast was designed to open the blast in the center of the rock face and in a chevron array the blast holes would be individually detonated. The blast was detonated using a non - electric shock tube system.

The blast was filmed using a Redlake Motion - meter, a high-speed digital video camera filming at the rate of 1,000 frames per second. Each of the face holes in the blast was equipped with signal indicators as the blast holes were being loaded. These signal indicators flash when the detonator within the hole is fired. The precise firing time of these individual detonation signals were then recorded by the high-speed video along with the visual indication of burden movement and relative confinement levels within different sections of the blast.



The analysis of the high-speed video has provided data showing the actual firing times of the face holes relative to their designed or nominal firing times. The video also provided visual time references as to the retention time of gasses, stemming ejection times, the apparent initial burden movement vertically and overall vertical throw of the blast event.

The following table identifies the above times relative to the starting detonator (Time Zero). This electric detonator was used to start the non-electric shock tube system. The data below shows that the actual firing times of the detonators ranged from 13 ms premature to 52 ms late.

	Hole 1	Hole 2	Hole 3	Time Zero Signal	Hole 4	Hole 5	Hole 6	Hole 7	Hole 8	Hole 9	Hole 10	Hole 11
Signal Time ms	2760	2764	2787	3431	2831	2799	2775	2743	2720	2693	2676	2637
Nominal ms	2747	2772	2797		2864	2839	2814	2789	2764	2739	2714	2689
Off Nominal ms	-13	8	10		33	40	39	46	44	46	38	52
Designed ms	50	25	0		67	92	117	142	167	192	217	242
Actual ms	37	33	10		100	132	156	188	211	238	255	294
Stemming Material	Stone	Stone	Stone		Varistem Stone	Varistem Stone	Varistem Stone	Varistem Stone	Varistem Cuttings	Varistem Cuttings	Varistem Cuttings	Varistem Cuttings
1st Movement	2710	2721	2763		2720	2695	2634	2620	2590	2540	2520	2495
Retention Time	50	43	24		111	104	141	123	130	153	156	142

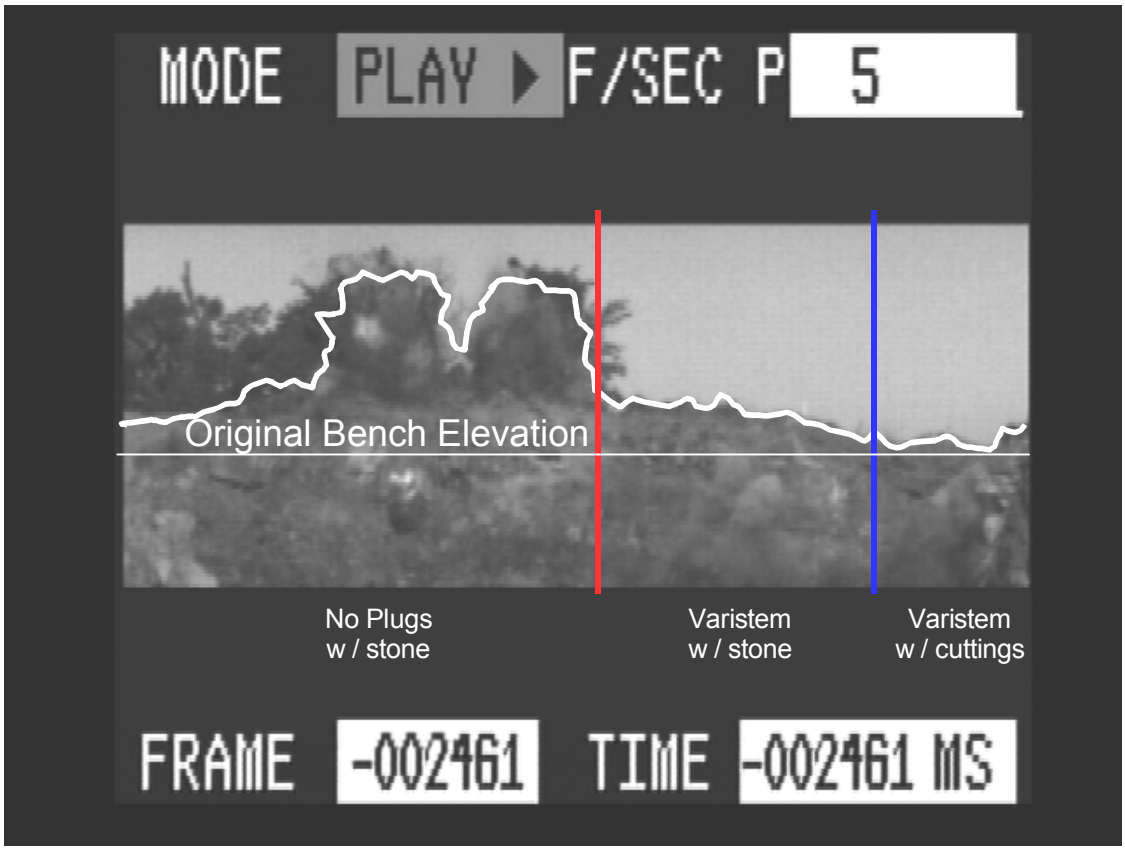
The time between the signal flash and the first visible movement of the surface as stemming ejection or surface swell is referred to as Retention Time or T_{min}. The VARI-STEM plugged holes all yield retention times at least 2 times longer than the non-plugged holes. The average retention time for the VARI-STEM holes with crushed stone was 120 ms. The average retention time for the holes loaded with a VARI-STEM plug and stemmed with drill cuttings was 145 ms.

Vari-Stem	Avg. T_{min}	Difference
Stone (4 holes)	120 ms	
Cuttings (4 holes)	145 ms	+ 20%

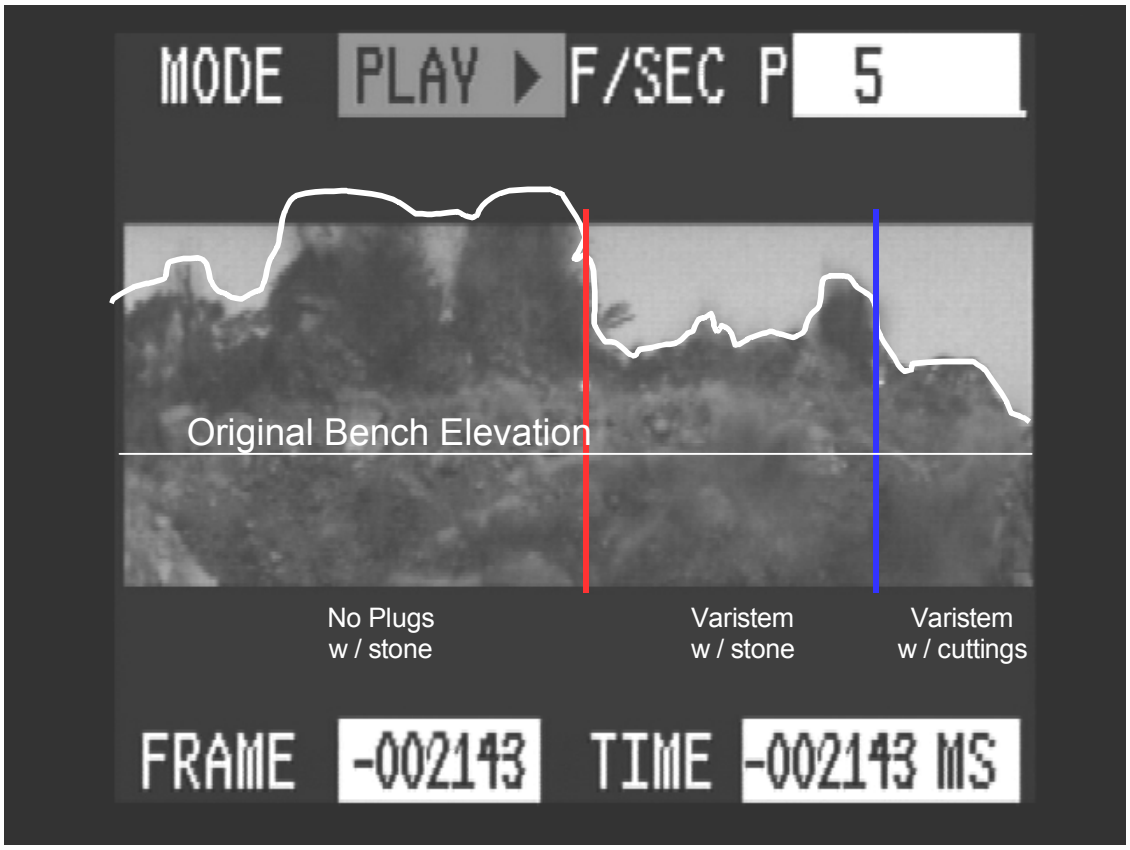
The video recording shows a very discernable contrast between the vertical burden movement of the plugged and non-plugged holes during the first 600 milliseconds of the blast event. It is during this time that the explosive energy should be confined within the rock mass to best utilize the expanding gasses to penetrate into the cracks and break the rock. Any loss of gas pressure through stemming ejection or venting will directly effect the overall fragmentation of the blast. The following images show a progression of burden movement during the time period from 300 ms into the blast to 600 ms into the blast. The vertical red line marks the separation between plugged and non-plugged holes. The left side of the image is the non-plugged portion of the blast. The right side (plugged side) does not exhibit stemming ejection within the period and predominant movement is uniform bench swell. To the right of the blue line is the area that cuttings were used as top stemming. The trees in the color photo

below give the appearance of greater than actual burden movement. The white lines drawn on images show the outline of vertical throw.

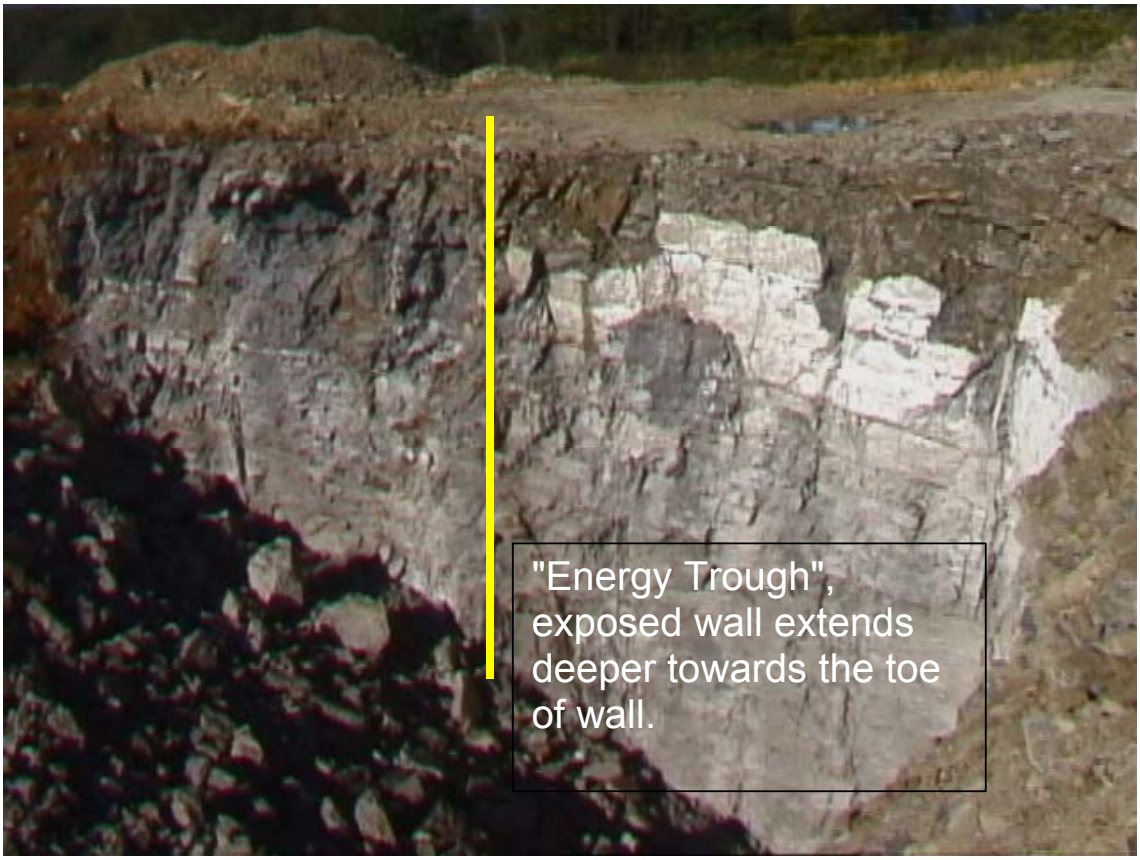
326 ms



644 ms



The preceding data indicates a visible difference in the energy containment of the blast through the use of the VARI-STEM plug. This energy containment within the rock mass seemed to provide for increased horizontal movement into the pit. The following photo shows a dramatic difference in the "Energy Trough" on the right side of the blast equipped with hole plugs.



All the above information from the blast detonated on September 24, 2003 indicates a dramatic improvement in the energy containment through the use of the VARI-STEM hole plug. This was a single test and the data should be confirmed through a broader series of testing procedures. However, this data combined with other similar VARI-STEM testing data supports the conclusions that the implementation of hole plugs does improve blast performance.

Respectfully Submitted,

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