Fragmentation Optimization Techniques using the Varistem 5.5 inch Hole Plug at the Holcim Cement – St. Genevieve Quarry

Introduction

This study was designed to determine if the implementation of the Varistem Hole Plug developed by MOCAP, Inc. will facilitate the pattern expansion of an already optimized blast design (that does not include hole plugs) without a reduction in the current blast performance in terms of the blast induced rock fragmentation.

The testing procedures were designed to:

- Determine the baseline fragmentation levels of current blast design
- Quantify the fragmentation differential of the current blast design including Varistem hole plugs

If the implementation of the Varistem hole plugs show a sufficient positive increase in the fragmentation levels compared to the baseline fragmentation, the testing procedures would proceed with an expanded pattern design using hole plugs.

- Determine the fragmentation of an additional one (1) foot of spacing expanded pattern design using hole plugs
- Determine the fragmentation of an additional two (2) feet of spacing expanded pattern design using hole plugs

Test Site

The testing procedures were conducted at the Holcim Cement Company's new plant in Ste. Genevieve County, Missouri along the Mississippi River and about 55 miles south of St. Louis. This greenfield state-of-the art St. Genevieve Plant produces approximately 4 million metric tons of cement per year (or 12,000 mtpd), making it the largest cement-producing plant in the nation and the world's largest single-kiln clinker production line. The pyroprocessing system includes a new-generation clinker cooler and in-line preheater with low NOx and CO calciner.

The St. Genevieve Quarry is currently mining a Platen Limestone formation to provide the necessary limestone raw material for the production of cement. This limestone is obtained from two active benches within the quarry. They are named P1 and P2. The P2 bench is the lower bench that was used in this study. The P2 bench contained a more massive formation with less weathering. The drilling and blasting oerations at the St. Genevieve Quarry are designed and managed by the Holcim Cement Company engineers. The drilling operations are conducted

entirely by Holcim Cement using two types of drilling apparatus and designs. Typically, the developmental blasting is designed using a 5.5” hole diameter and the Platen production blasting is conducted using a 7” hole diameter drill. However, for the purposes of these testing procedures, the 5.5” drill bit diameter was used entirely within the (P2) Platen formation.

The same blast design was maintained throughout the testing procedures. The initiation system used for the test blasts was the Digishot ectronic System developed by the DYNO corporation. This implementation of this electronic system was very crucial as it eliminated any impacts on fragmentation caused by inaccuracies in hole detonation.

The blast hole loading oerations are conducted by the DYNO explosives company representatives based in Hermann, MO. The blaster in charge, Mr. Steve Horstman, was very contientious in making sure the blast holes were loaded as per the design and all measures were taken to maintain high levels of field control and safety throughout the loading and detonation procedures.

The Tests

A total of three (3) test patterns were conducted during this study and are described as follows.

- **Pattern 1B (Shot #14, P2 - Hill 1)** – This blast was fired on August 24, 2010. The blast pattern for this blast was 13’X15’ (BXS) . This blast was a two row of 28 hole per row design and the blastholes were drilled to a depth of 47 feet with 4 feet of sub-drill. The stemming height of 7 feet was maintained for the blastholes. The stemming heights were increased if necessary in any front row hole with a damaged crest to contain energy and control burden movement. The blast holes were loaded with DYNO-Mix bulk ANFO. The average explosives weight in each blast hole was 372 pounds and the powder factor in pounds of explosives per cubic yard (LBS/BCY) was 1.15. This blast was detonated using the DYNO EZ-det pyrotechnique initiation system. The blastholes from the center of the bech to the north were all loaded using the 5.5” Varistem plug.

- **Pattern 1A (Shot #16, P2 - Hill 1)** – This blast was fired on September 14, 2010. The blast pattern for this blast was 14’X18’ (BXS) . This blast was a three row of 22 hole per row design and the blastholes were drilled to a depth of 49 feet with 2 feet of sub-drill. The stemming height of 7 feet was maintained for the blastholes. The stemming heights were increased if necessary in any front row hole with a damaged crest to contain energy and control burden movement. The blast holes were loaded with DYNO-Mix bulk ANFO. The average explosives weight in each blast hole was 396 pounds and the powder factor in pounds of explosives per cubic yard

(LBS/BCY) was 0.90. This blast was detonated using the DYNO Digishot electronic initiation system. The blastholes from the center of the bench to the south end of the blast were loaded using the 5.5" Varistem plug.

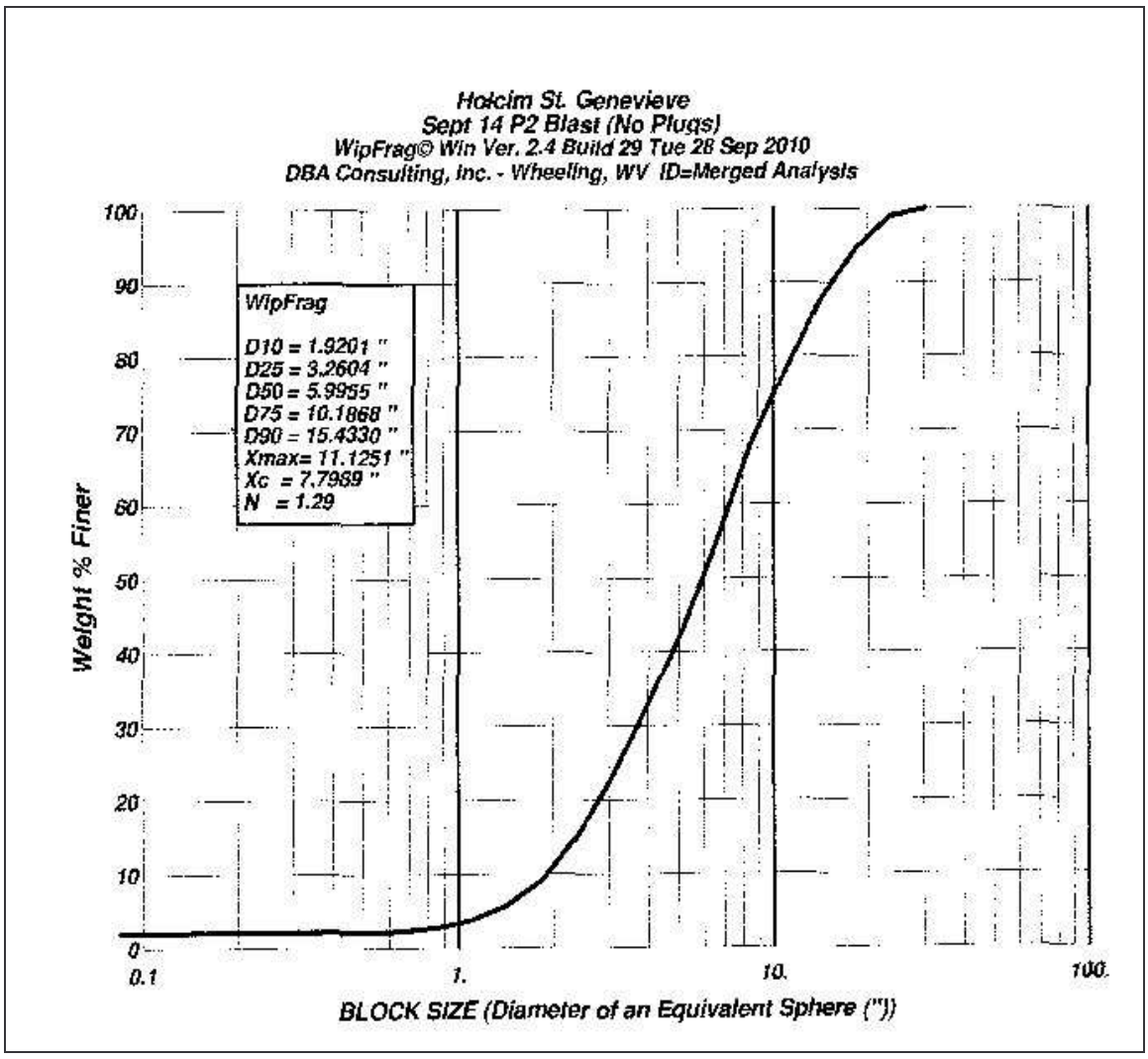
- **Pattern's 2 and 3 (Shot #572053, P2 - Hill 1)** – This blast was fired on November 2, 2010. This blast was the expanded pattern test blast. The blast pattern for this blast was divided into two sections. The northern section of the blast incorporated a 14'X20' (BXS) pattern. The southern half of the blast incorporated a 14'X19' (BXS) pattern. This blast was a three row of 25 hole per row design and the blastholes were drilled to a depth of 49 feet with 1 feet of sub-drill. The stemming height of 7 feet was maintained for the blastholes. All of the blast holes were loaded with a Varistem hole plug. The stemming heights were increased if necessary in any front row hole with a damaged crest to contain energy and control burden movement. The blast holes were loaded with DYNO-Mix bulk ANFO. The average explosives weight in each blast hole was 349 pounds and the powder factor in pounds of explosives per cubic yard was 0.69 lbs/cy. This blast was detonated using the DYNO Digishot electronic initiation system.

Fragmentation Analysis

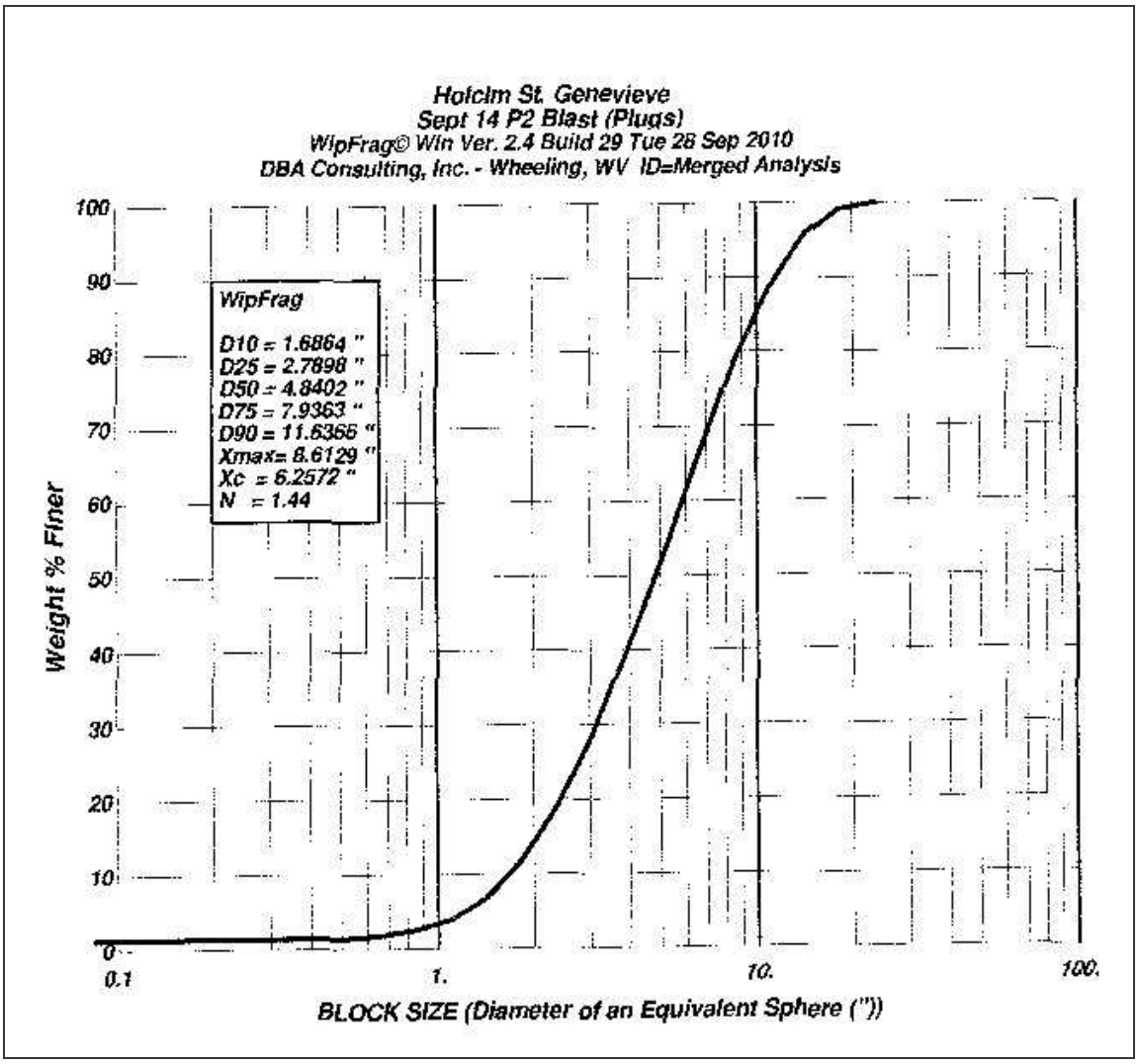
The fragmentation data during this study was processed using a digital image analysis system. The images were gathered using a Kodak Z1285 high resolution (12 Mega-pixel) digital camera, transferred to the computer hard drive and loaded into the image processor for delineation and size distribution analysis. The digital images were gathered at consistent locations during the excavation procedures of muckpiles to insure the merged findings would be representative of the true level of blast induced fragmentation. The collection points were within the back 2/3 of the muckpile. The front 1/3 of each muckpile contained large amounts of oversize rock due to the pre-conditioning of the face from the previous blast event. This volume of rock was not included in the analysis as it is not truly representative of the fragmentation experienced by the virgin rock of the second and third row of blast holes deeper into the blast.

During the analysis of the images, the data files were saved in the system and used to create a merged analysis report. This report is very representative of the size distribution and uniformity of each of the resulting muckpiles during the testing procedures.

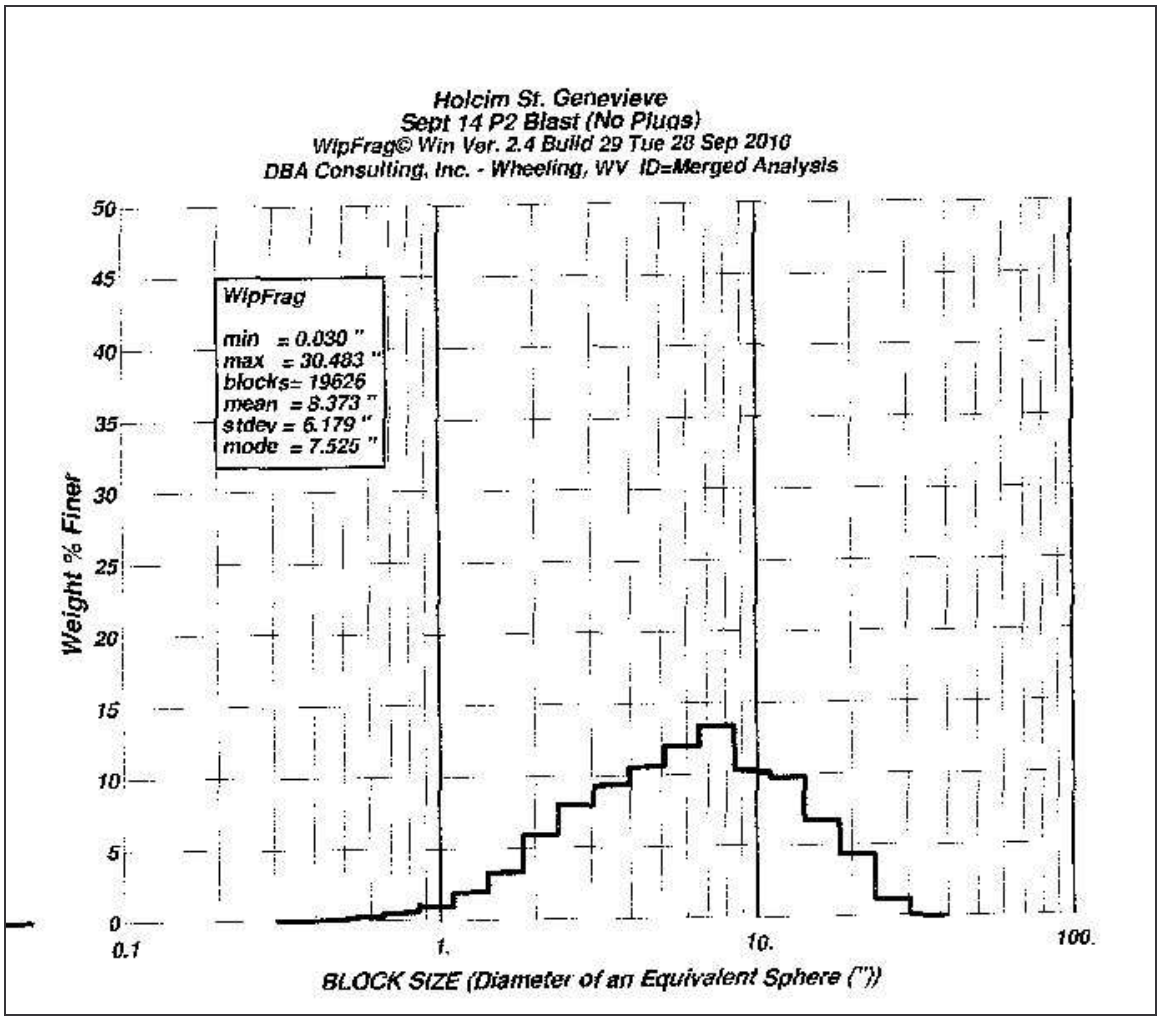
The fragmentation analysis of the Pattern 1: Test Blast #16 detonated on September14, 2010 are as follows.



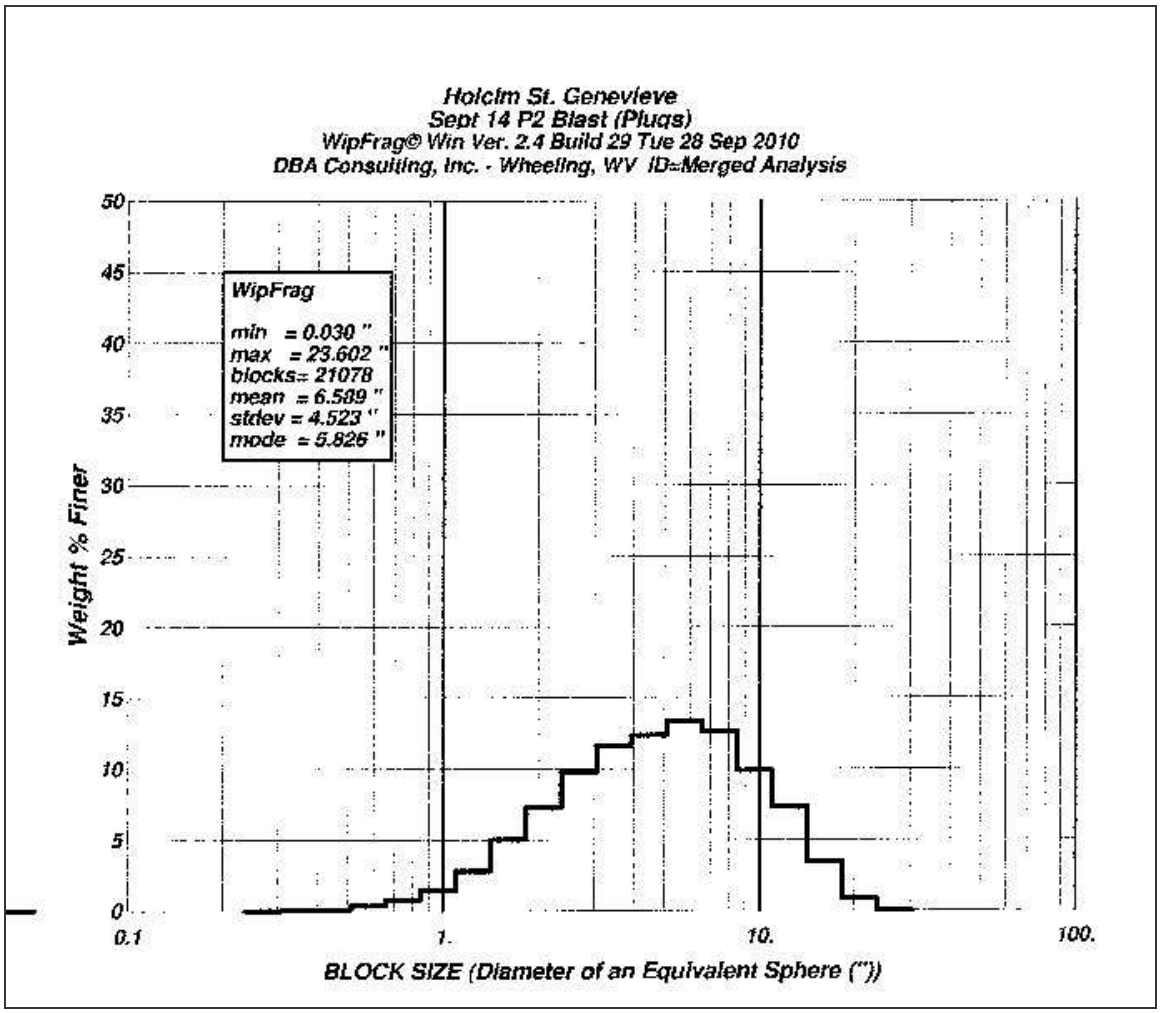
Distribution curve of fragmentation analysis with no plugs used in blast holes.



Distribution curve of fragmentation analysis with Varistem plugs used in blast holes.



Histogram curve of fragmentation analysis with no plugs used in blast holes.



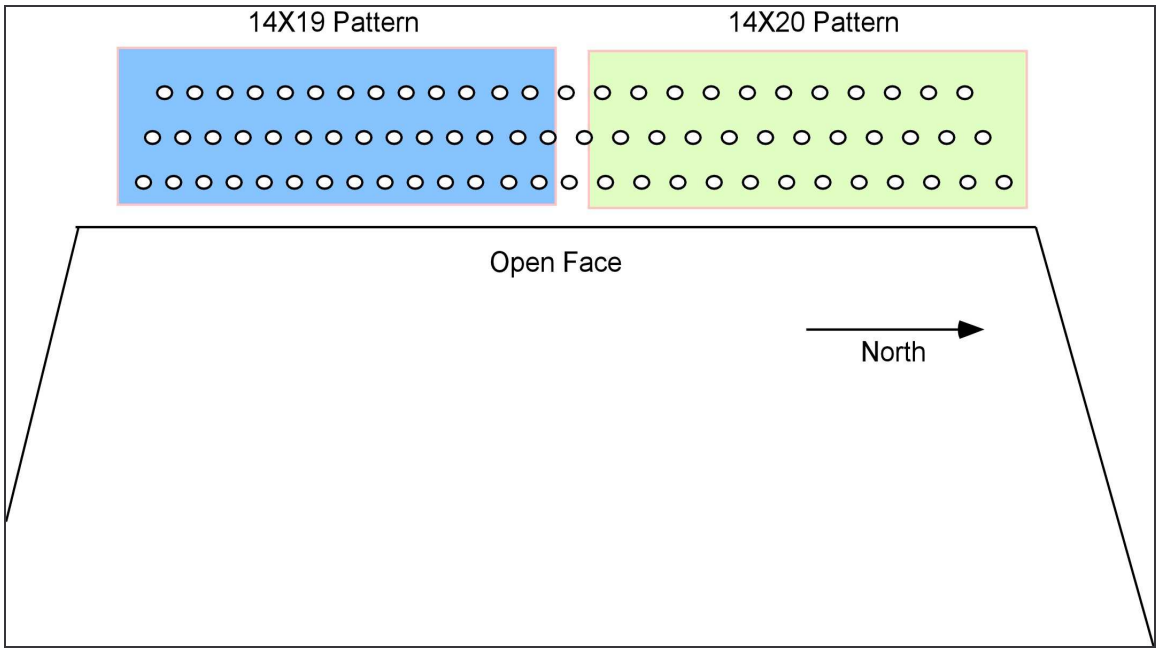
Histogram curve of fragmentation analysis with Varistem plugs used in blast holes.

A review of the fragmentation data is as follows. A positive differential percentage denotes a higher level of fragmentation. The D_{10} through D_{90} values represent a percent passing size in inches. The “Mean” is an arithmetic mean of the fragment sizes in inches.

Pattern 1	D_{10}	D_{25}	D_{50}	D_{75}	D_{90}	Mean	N
No Plugs	1.9201	3.2604	5.9955	10.1868	15.4330	8.373	1.29
Plugs	1.6864	2.7898	4.8402	7.9363	11.6366	6.589	1.44
Differential	+ 13.8%	+16.8%	+23.8%	+28.3%	+32.6%	+27.0%	+11.6%

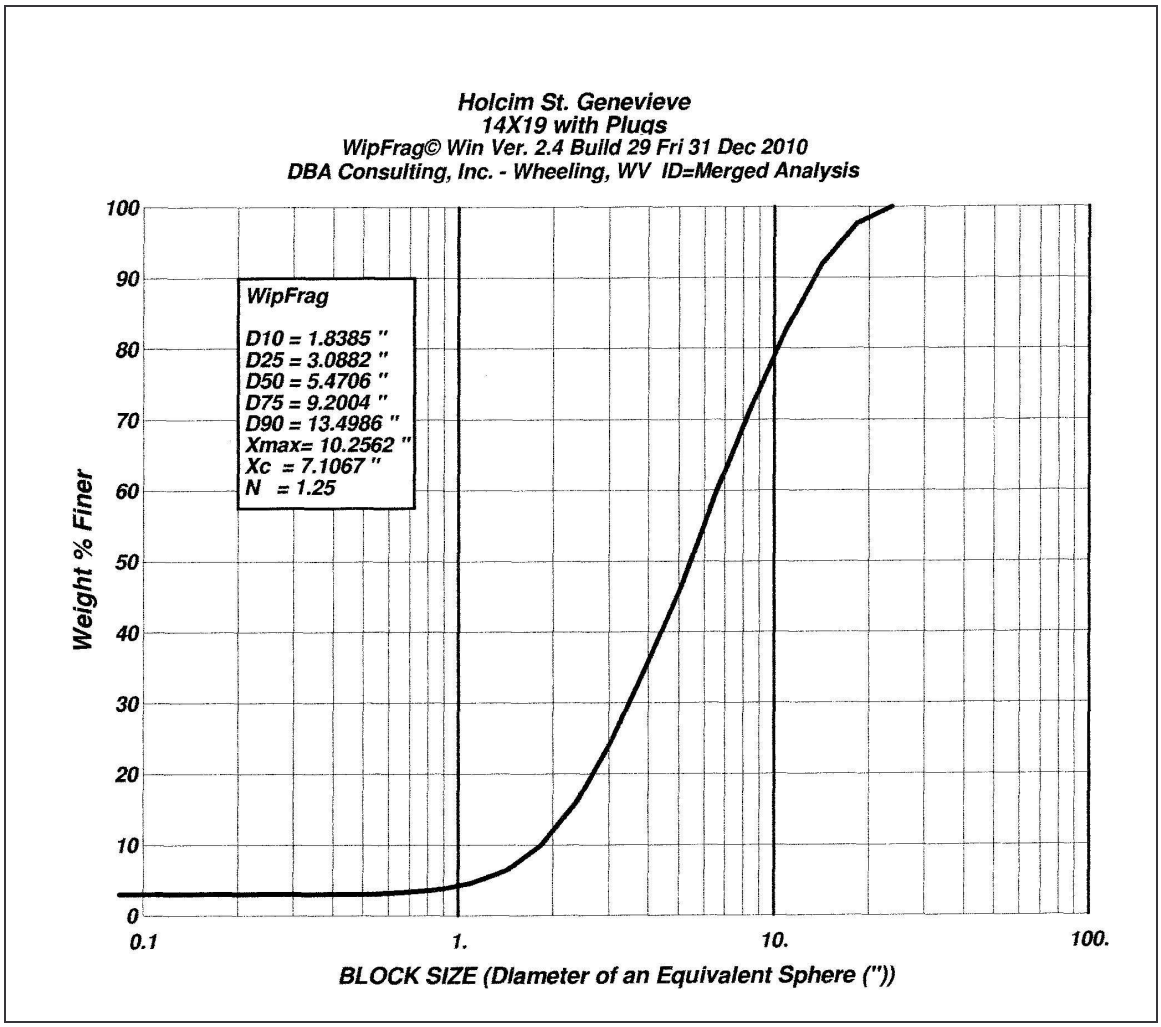
The Pattern 1: Test Blast Number 16 detonated on September 14, 2010 shows a substantial increase of fragmentation in the holes that were loaded with a Varistem hole plug. The increased fragmentation ranges from 13.8% in the D_{10} finer material sizes to 32.6% in the D_{90} coarser sized material. The decrease in the mean size of 6.589 inches from 8.373 inches represents a 27% improvement in fragmentation. These values of increased fragmentation performance are similar to other previous studies conducted in limestone quarries using the Varistem hole plug.

The following are the fragmentation analysis for the Pattern 2 and 3: November 2, 2010 blast that implemented a pattern expansion. The pattern was expanded from the standard pattern of 14'X18" (BXS) to patterns of 14'X19" (Pattern 2) and 14'X20' (Pattern 3). The following image is a representation of the November 2, 2010 test pattern layout.

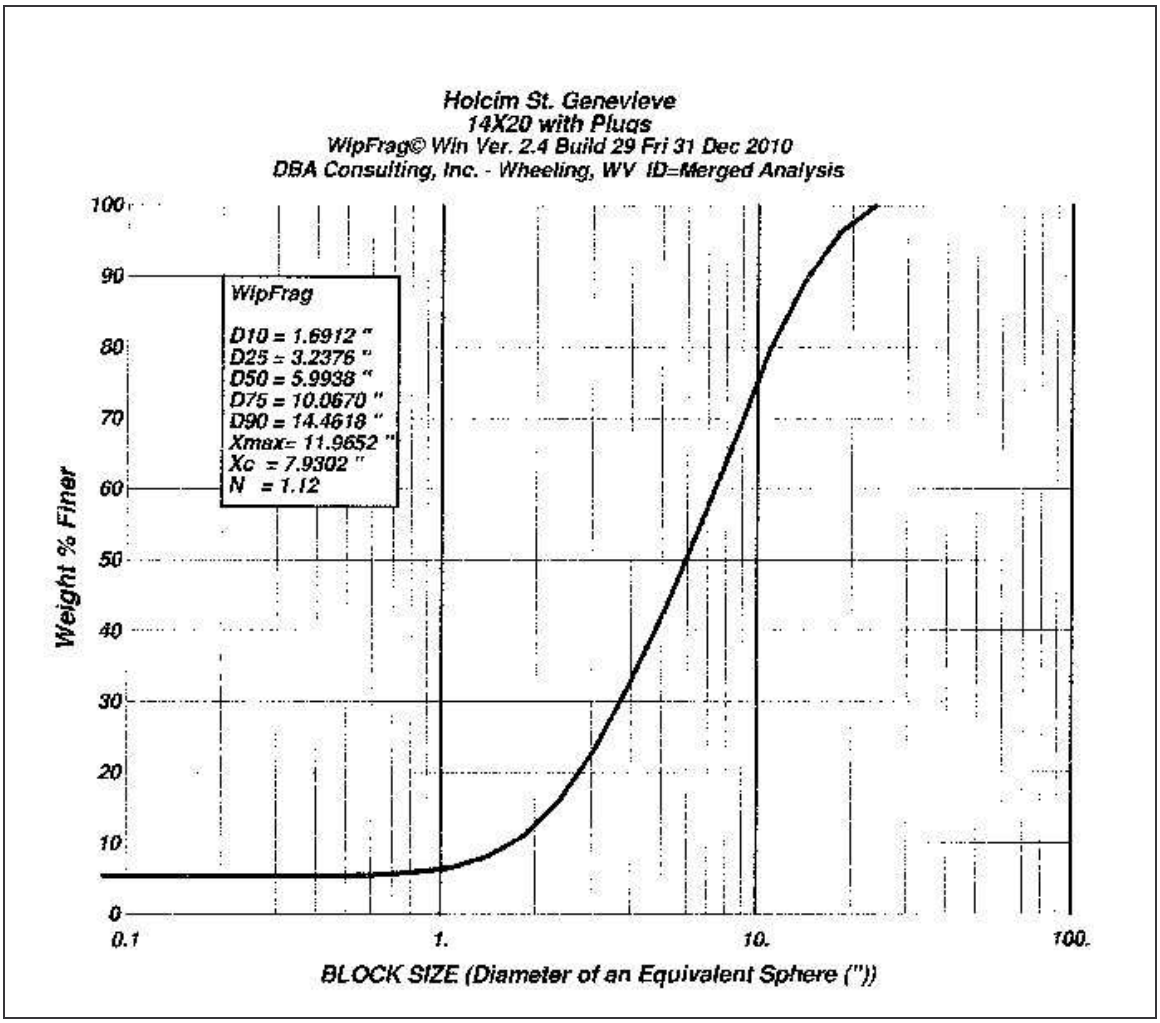


All of the blast holes in this blast were loaded using the Varistem hole plug. The fragmentation analysis was completed by sampling the muckpile at locations containing the rock from the second and back row of the blast. This was done to exclude the oversize material that typically originates from the face row of a blast from the pre-conditioning of the prior blast.

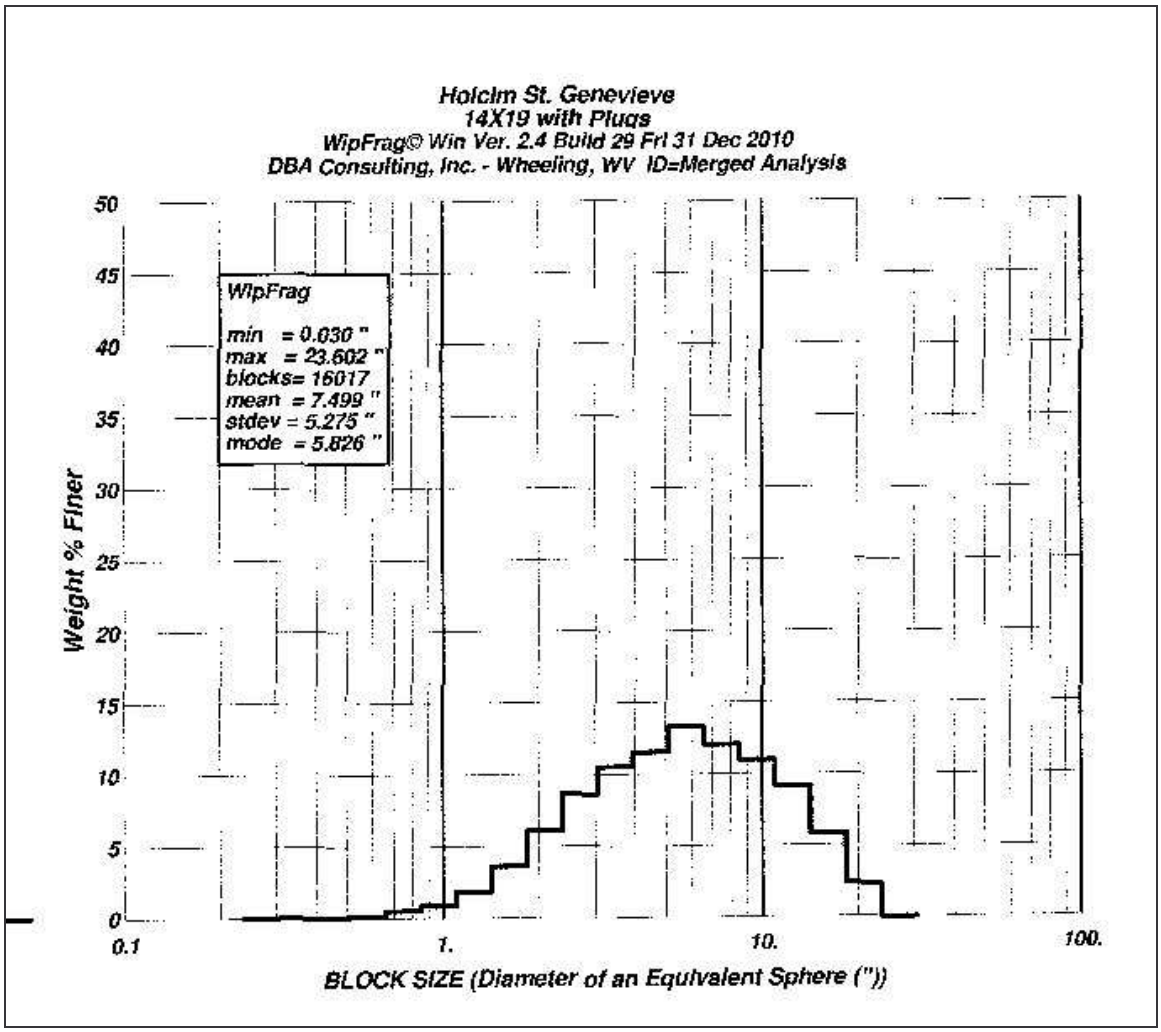
The fragmentation analysis of the Test Blast # 572053 detonated on November 2, 2010 are as follows.



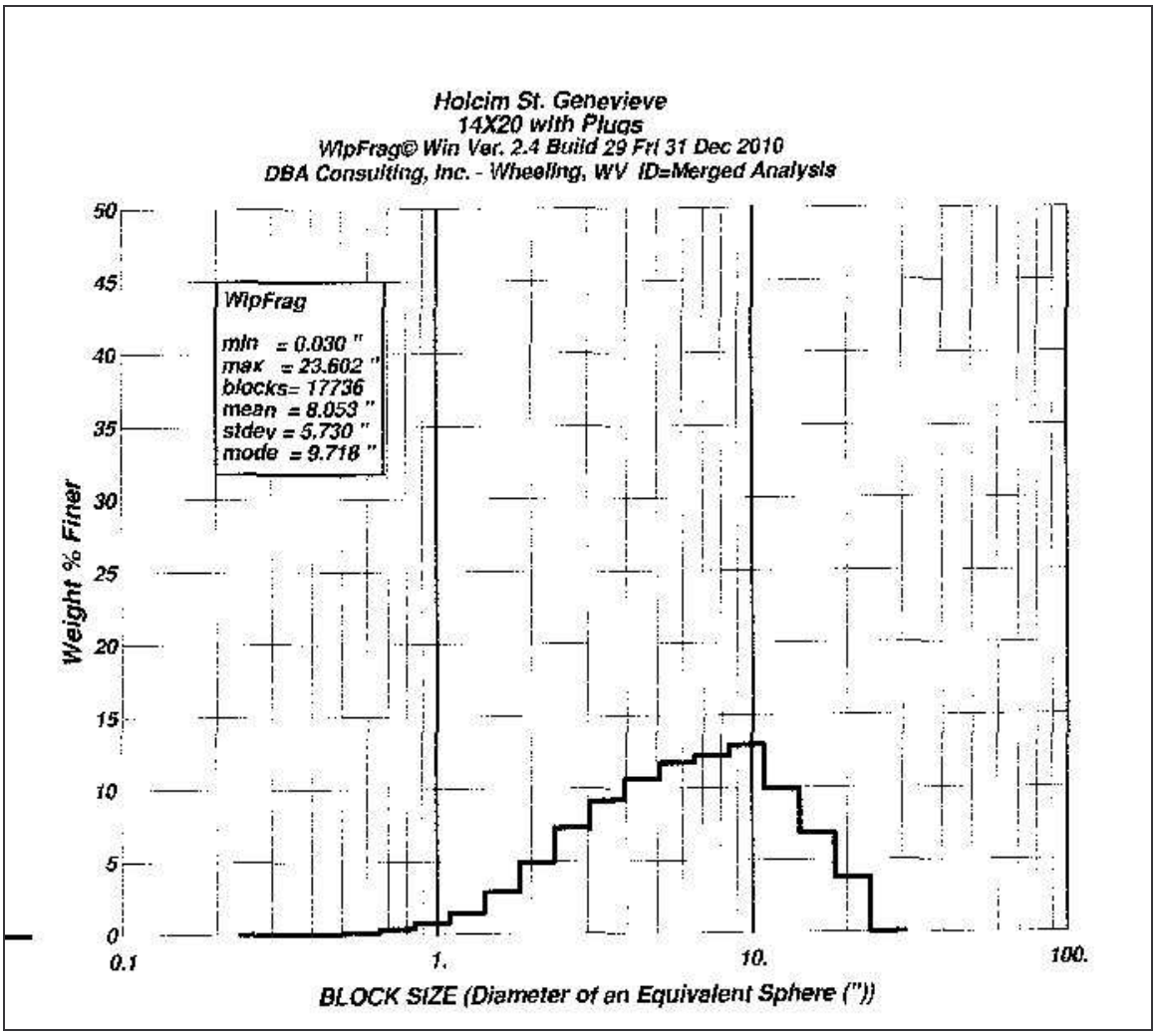
14X19 Distribution Curve (Pattern 2)



14X20 Distribution Curve (Pattern 3)



14X19 Histogram (Pattern 2)



14X20 Histogram (Pattern 3)

Baseline 14X18 pattern compared to the 14X19 expanded Pattern 2.

Pattern 2	D_{10}	D_{25}	D_{50}	D_{75}	D_{90}	Mean	N
14X18	**1.9201**	**3.2604**	**5.9955**	**10.1868**	**15.4330**	**8.373**	**1.29**
14X19	1.8385	3.0882	5.4706	9.2004	13.4986	7.499	1.25
Differential	+ 4.4%	+5.5%	+9.5%	+10.7%	+14.3%	+11.6%	-3.2%

Baseline 14X18 pattern compared to the 14X20 expanded Pattern 3.

Pattern 3	D_{10}	D_{25}	D_{50}	D_{75}	D_{90}	Mean	N
14X18	**1.9201**	**3.2604**	**5.9955**	**10.1868**	**15.4330**	**8.373**	**1.29**
14X20	1.6912	3.2376	5.9938	10.0670	14.4618	8.053	1.12
Differential	+ 13.5%	+0.7%	+0.02%	+1.1%	+6.7%	+3.9%	-15.1%

Summary

A review of the previous data shows that the expanded pattern size of 14X19 with the implementation of the Varistem plug does yield improved overall fragmentation than the current 14X18 pattern typically used at the St. Genevieve Quarry. The added fragmentation performance represents a reduction of 11.6 percent in the "Mean" size of the rock from 8.373 inches to 7.499 inches. The size distribution throughout the D_{10} – D_{90} sampling is also improved. This increased fragmentation benefit would permit the current 14X18 blast design to be increased to the 14X19 pattern thus eliminating 6% of the blast holes necessary to produce the same volume of rock with improved fragmentation.

The 14X20 expanded pattern fragmentation analyses exhibits very little difference in the fragmentation performance. It does conclude that the pattern expansion of 2 feet using the Varistem plugs will not change the overall fragmentation when compared to the current 14X18 pattern with no stemming plugs used. Therefore, if the current fragmentation is sufficient, the pattern could be expanded to a 14X20 with the implementation of Varistem plugs thus reducing the number of holes drilled by 10% to produce the same volume of rock.

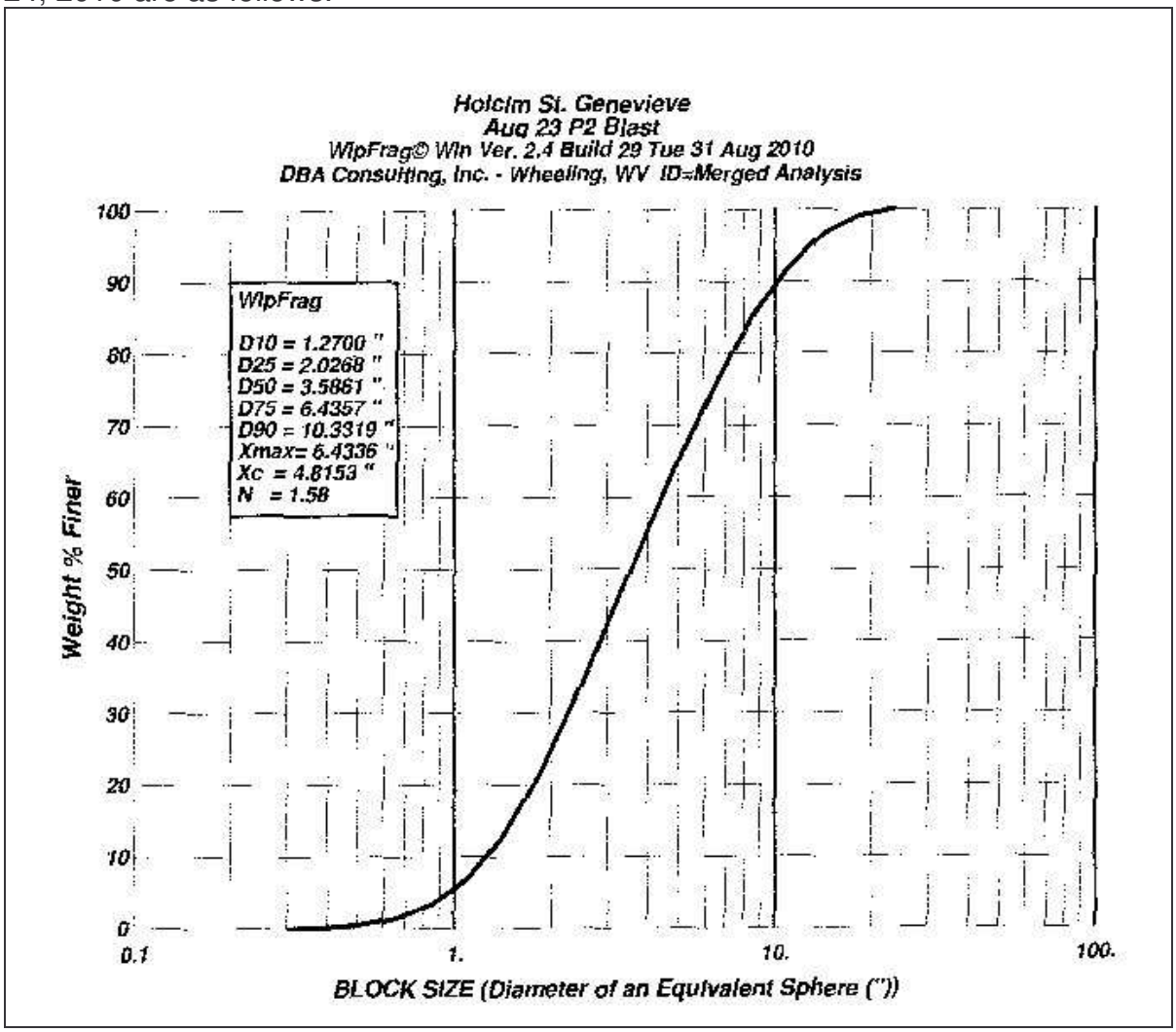
Acknowledgements

I wish to thank Mr. Miroslav Jaderko, Mr. Larry Scales, Mr. Michael Toelle and Mr. Micheal Nixon of the Holcim Cement Company for their willingness to participate in this study. Their cooperation throughout the days of blasting and data collection is very appreciated.

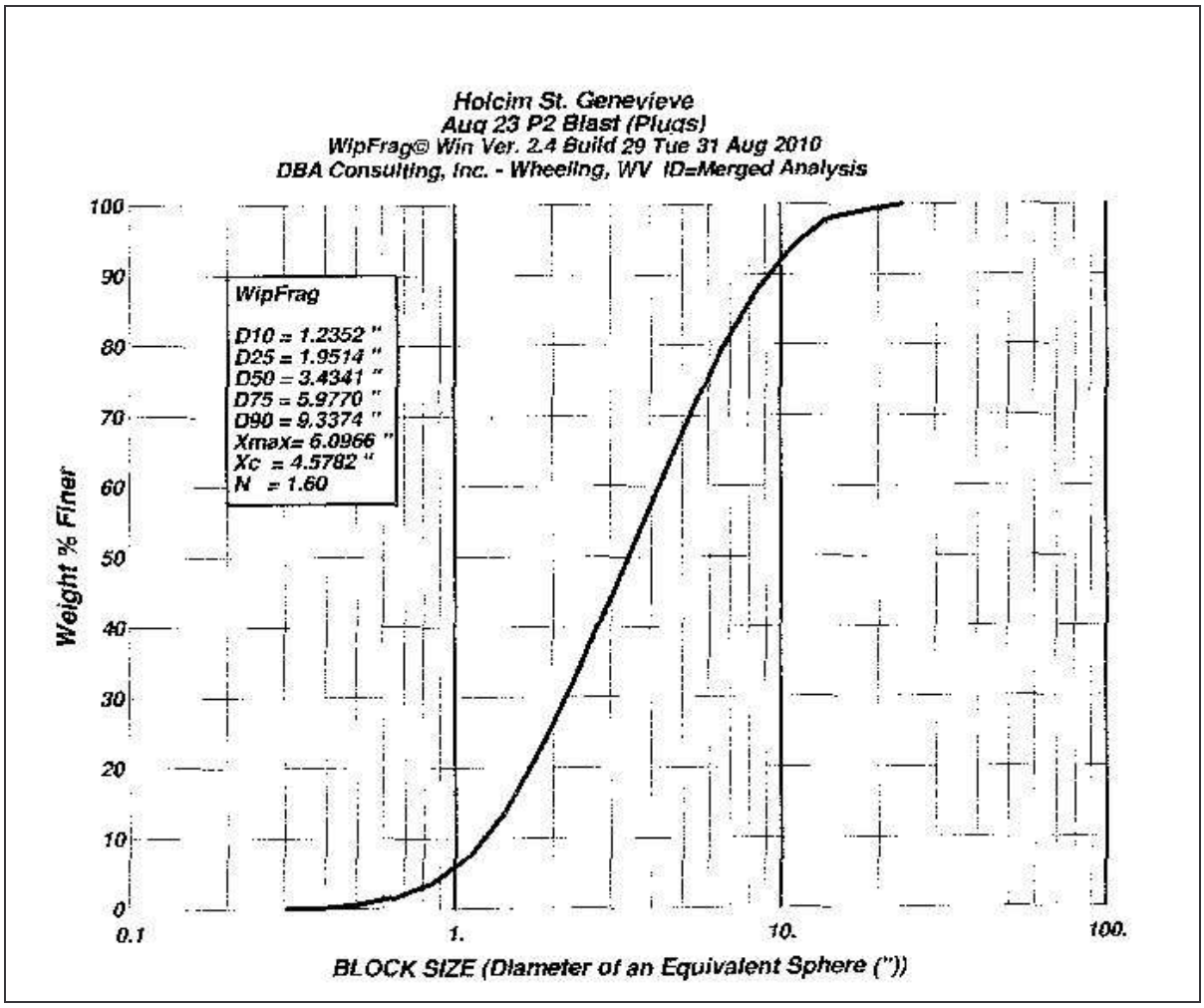
We also thank the DYNO Corporation based in Hermann, MO for providing excellent cooperation and field practices.

Supplement

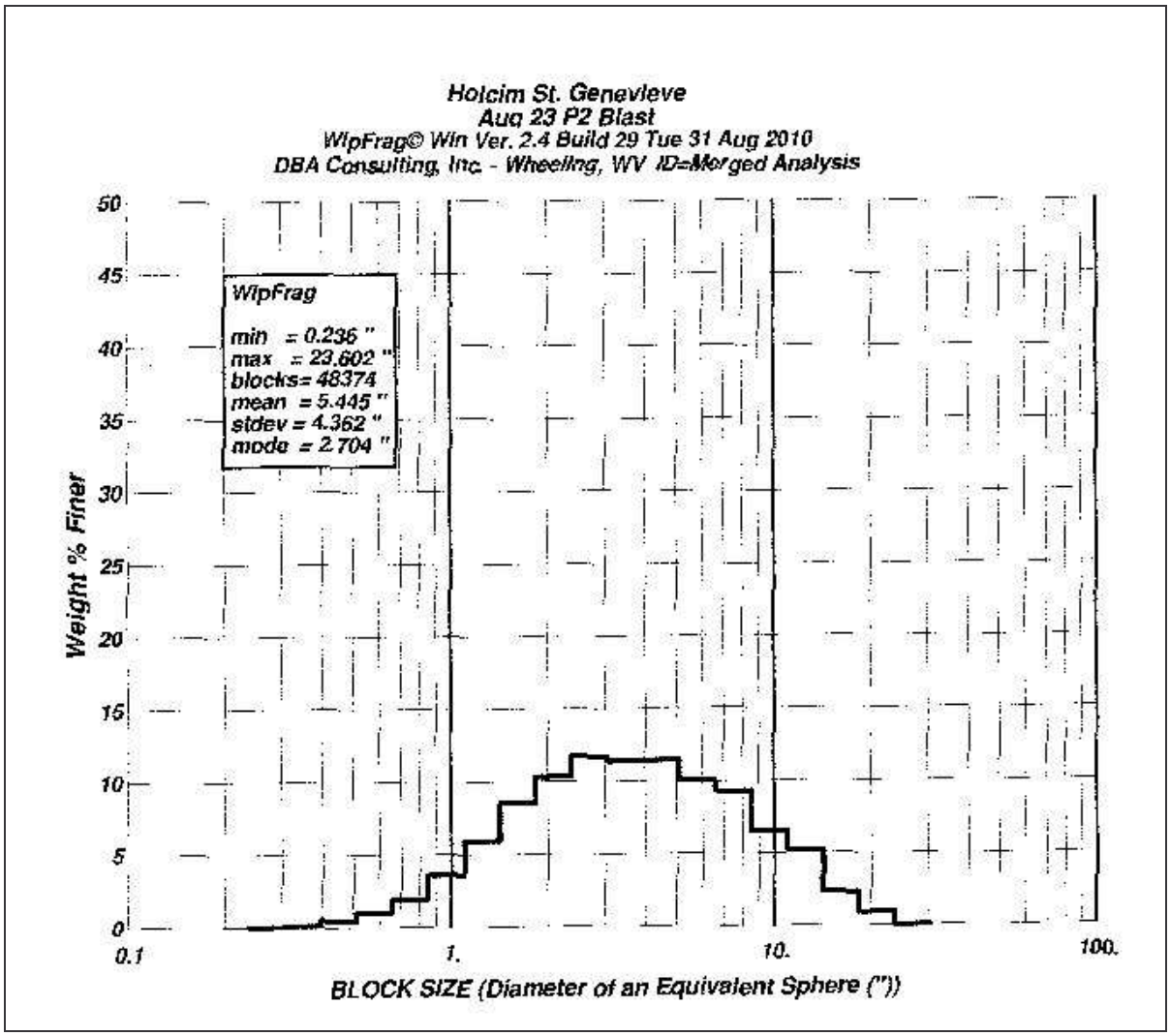
The pattern of the initial test blast on August 24, 2010 was incorrectly drilled to a 13'X15' pattern instead of a 14'X18" pattern. This resulted in a substantial increase in the ratio of explosives energy to volume of rock and will intuitively result in a much increased level of fragmentation. It was decided not to integrate the data collected with this blast into the data collected with the other test blast patterns. Even with the high powder factor, which typically in and of itself will induce increased rock fragmentation, the blast holes equipped with the Varistem plugs exhibited even higher levels of fragmentation. The primary purpose of this and the second test blast (Pattern 1) was to determine if the implementation of Varistem hole plugs would yield a sufficient fragmentation increase to substantiate further expanded pattern testing. Therefore, even though the pattern was incorrectly drilled, the fragmentation analysis of the August 24 blast does demonstrate the effectiveness of the hole plugs with a mean size reduction of 7.2%. The fragmentation analysis of the test blast #14 detonated on August 24, 2010 are as follows.



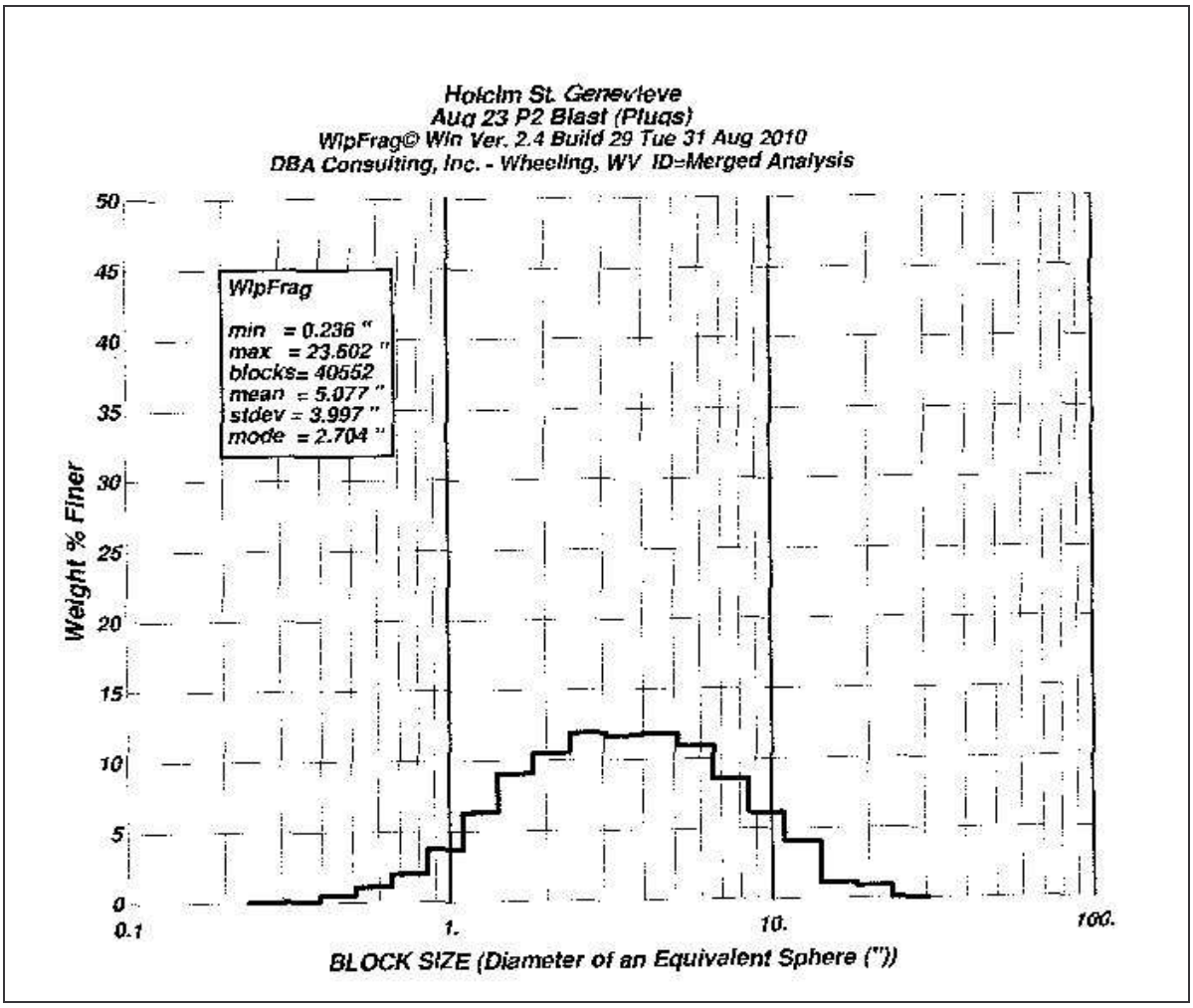
Distribution curve of fragmentation analysis with no plugs used in blast holes.



Distribution curve of fragmentation analysis with Varistem plugs used in blast holes.



Histogram curve of fragmentation analysis with no plugs used in blast holes.



Histogram curve of fragmentation analysis with Varistem plugs used in blast holes.

A review of the fragmentation data is as follows. A positive differential percentage denotes a higher level of fragmentation. The D_{10} through D_{90} values represent a percent passing size in inches. The “Mean” is an arithmetic mean of the fragment sizes in inches.

Shot 14	D_{10}	D_{25}	D_{50}	D_{75}	D_{90}	Mean	N
No Plugs	1.2700	2.0268	3.5861	6.4357	10.3319	5.445	1.58
Plugs	1.2352	1.9514	3.4341	5.9770	9.3374	5.077	1.60
Differential	+ 2.8%	+3.8%	+4.4%	+7.6%	+10.6%	+7.2%	+1%