FACTORS DRIVING CONTINUOUS BLASTING IMPROVEMENT AT THE LAFARGE RAVENA PLANT

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ABSTRACT

The Lafarge Ravena Cement Plant in Ravena, New York demonstrated continuous and extraordinary improvement in productivity during the past several years. The factors driving continuous improvement at the Lafarge Ravena Plant include:

1) Management techniques including regular scheduled and effective Blasting Optimization Team meetings.

2) A real time blasting database to guide blasting product and procedure decisions. Key decisions involved all levels of quarry and blasting supplier personnel and a close working relationship between production and blasting areas of expertise was demonstrated.

3) Blast optimization and optimization of quarry operating parameters such as blast location relative to crusher location, hours worked, etc.
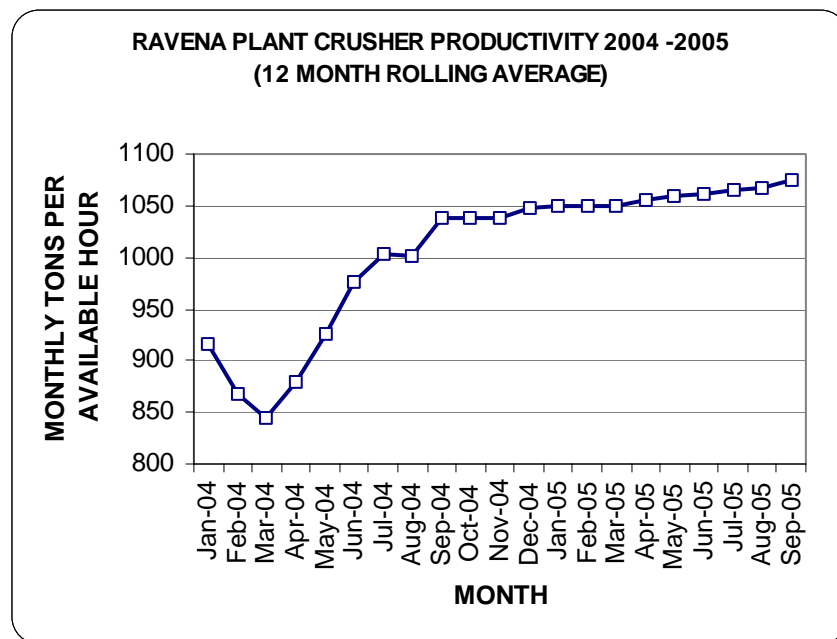
A statistical analysis has been conducted to quantify and understand the effects of blasting changes and other factors to determine the factors involved in productivity improvement.

The statistical methods developed for this analysis and the management techniques described in this report can be used in other locations to guide continuous productivity improvement and achieve operating efficiencies in a wide variety of quarry operations.

INTRODUCTION

The Lafarge Ravena Cement Plant is located in Ravena, New York and has been in operation since 1962. The quarry produces both aggregate and feed to the cement plant. Four million tons will be crushed and 3.7 million tons will be wasted in 2006 for a total of 7.7 million tons. Jim Batterton with Dyno Nobel was in charge of blasting operations for the entire period described in this study. Blasting is conducted using a 6 ½" diameter hole, Fragmax™, miniprills and a variety of initiation systems. The primary crusher is an Allis Chalmers 54 x 74 Gyratory with a 70-ton rock box. The quarry operates a fleet of two Cat 992G loaders and four Cat 777 haul trucks.

The Lafarge Ravena Cement Plant quarry demonstrated continuous and extraordinary improvement in productivity during the past several years as shown below. Two of the co-authors, Dave Bremer and Robert Ethier, were awarded Lafarge's President's Award for this achievement.

A statistical analysis has been conducted to quantify and understand the effects of blasting changes and other factors to determine the factors involved in productivity improvement. The statistical methods developed for this analysis and the management techniques described in this report can be used in other locations to guide continuous productivity improvement and achieve operating efficiencies in a wide variety of quarry operations.

The factors driving continuous improvement at the Lafarge Ravena Plant include:
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3) Blast optimization and optimization of quarry operating parameters.

BLAST OPTIMIZATION TEAM (BOT)

Regular periodic meetings are held with all involved quarry and blasting personnel to set goals, check on progress towards goals, and adjust key blasting and quarry operations parameters to achieve the goals.

Where possible key benchmarks and indicators are given numerical values. Decisions involved all levels of quarry and blasting supplier personnel and a close working relationship between production and blasting areas of expertise is demonstrated. The results are formalized in a report as shown below. Continual revisiting and confirmation of decisions is a requirement for success.

LAFARGE — **Blast Optimization Team 2002**

Team

Location:

Meeting Date:	3/6/02			Attendees:	

General Discussion:

| Criteria:			Work Subject	Date Completed	Responsible Person(s)	Comment(s) & Impact(s):
1		Safety	No accidents			
			No Flyrock			
			Signage, From TIP's			
			Contractor forms, Misfire procedure			
2		Environment	Complaints			
			Tracking			
			Noise , Vibration			
3		Productivity & Quality	Tonnes processed per operated hour			
			Tonnes blast			
			Tonnes crushed			
4		Cost	Explosives Cost per Tonne			ETI Blast database
			Drilling Cost per Tonne			
			Drilling & Blasting Cost per Tonne			
5		Training	ISEE, Practical Blasting Fundamentals Level 1			
			Tips, signoff			
6		Site Objectives	1.			
			2.			
			3.			
			4.			
7		Miscellaneous New Issues				

BLASTING DATABASE

Lafarge and Dyno Nobel have maintained an extensive blasting database, which is continually updated and contains information gathered from all Lafarge North America sites. The database was developed and maintained by Dyno Nobel's Dale Bodnarchuck and has been in existence

since the late 90s. Lafarge coordinated the adoption of a standard shot report for input to the database as shown below.

The standard shot report allows summation of information by region and company wide if desired. Standard reports, including key graphics and trends, are issued monthly and in many cases are the focus of the BOT meetings discussed earlier. Special reports are created from time to time as required. The shot report information can also be outputted in the form of spreadsheets that are used in the statistical studies that follow in this article. Blasting information can be sliced and diced in infinite ways to help the BOTs achieve their goals.

BLASTING AND QUARRY OPERATIONS OPTIMIZATION

The following charts illustrate the types of information that were extracted from the Lafarge Ravena production database and the Lafarge-Dyno Nobel blasting database. Below are several of the operating parameters must be taken into account when evaluating the effects of changes to blasting parameters. Crusher productivity is defined as tons per available hour.

The use of numbers generated in a database by blasts and productivity records to optimize is a daunting but rewarding exercise. A typical increase in productivity resulting from this type of analysis is usually in the range of   5% to 10% with an even greater savings reflected in costs.

There are many nonlinear blasting and production variables, seasonal relationships, site-specific modes of operation, and numerous changes in operational parameters that must be accounted for in any analysis. Nevertheless with enough data, useful information can be extracted. The results right or wrong are usually immediately evident and can form the basis for further work. The results when correct have a huge impact on production rates and overall costs. The methods can also be used to evaluate different types of explosive, initation systems, etc. A key thing to remember is to try to confirm hypotheses in more than one way if possible before making major changes.

Most quarries are seasonal and production rates as well as total production requirements are affected by weather and seasonal demand for stone, cement and other products. Over a period of years however, trends develop that can be used for future decisions in deciding blasting and production requirements. For example, below is the expected crushing production requirement for the Ravena operation using data from 2004, 2005, and 2006.
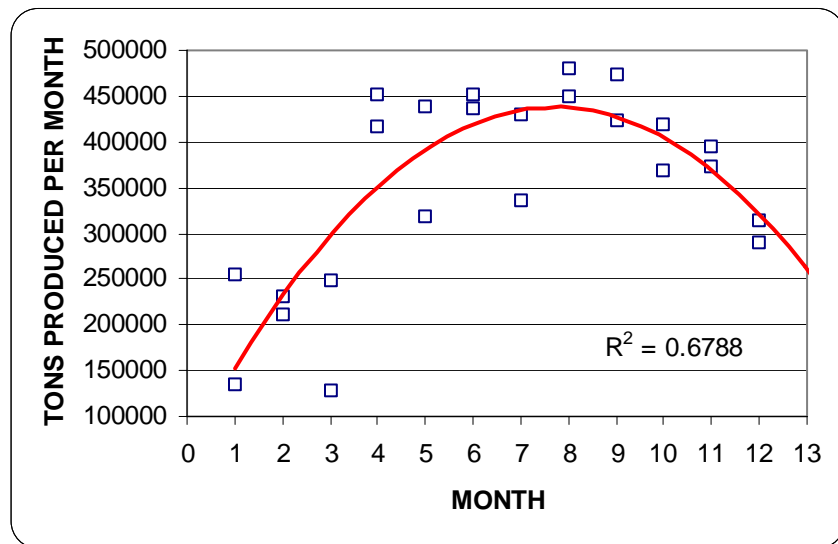

At Ravena, product is produced for two major purposes, aggregate (AGG) and cement (CM). Aggregate and cement are each blasted in different ways and crushing rates are different. Below is a summary of monthly crushing rates at Ravena depending upon the mix of aggregate or cement raw material crushed.
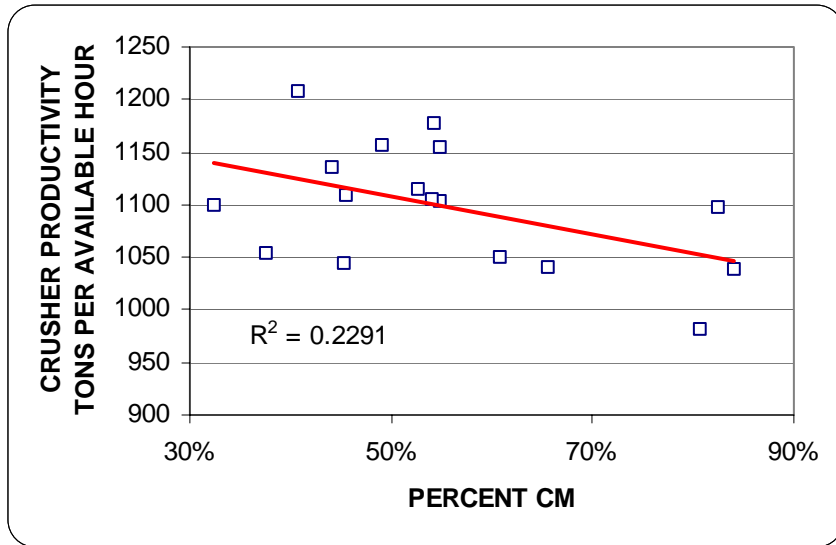
With the information above, the data was sorted to only look at the cement feed blasting and crushing rates as shown in the monthly summary below. The increasing trend is evident and indicates further improvements in March and April 2006.
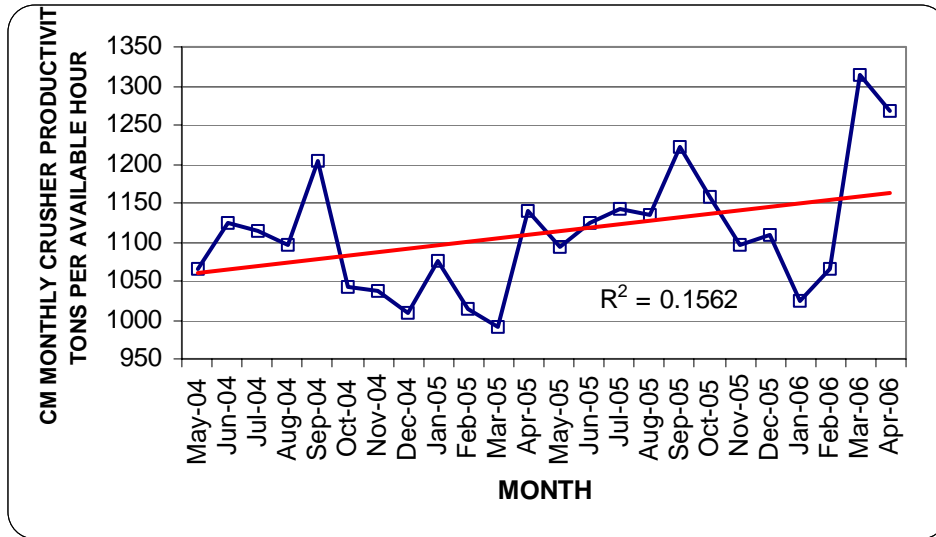
Another production variable that is key to the analysis is the change in crusher productivity as scheduled hours increase as shown below for cement feed.
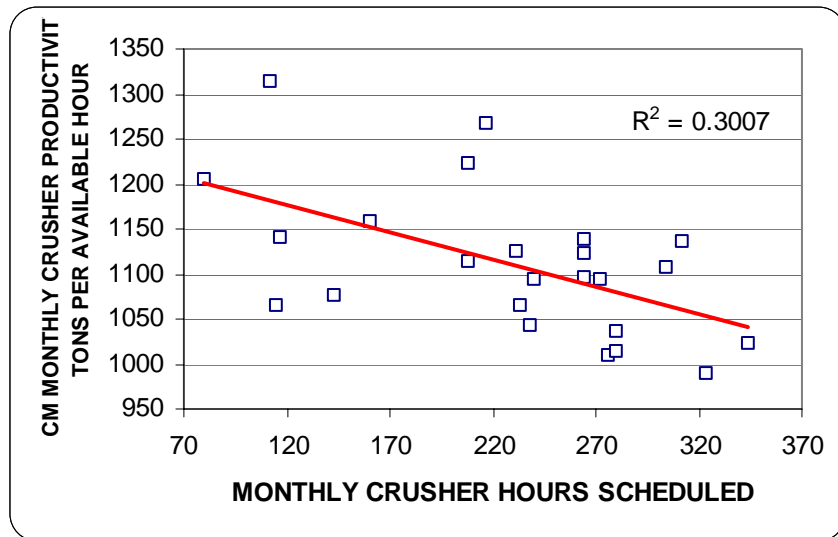
The following charts illustrate the types of information that can be extracted from the Ravena blasting database when combined with the Ravena production database. Again, the data is limited to cement feed. The first chart illustrates the typical nonlinear relationship between powder factor (tons/lb) and crusher productivity. There is an optimum at approximately 2.0 tons/lb. When powder factors are too high, oversize is created. The crusher chokes with fines when powder factors are too low. The high productivity of the two months in 2006 is evident at close to the optimum powder factor.
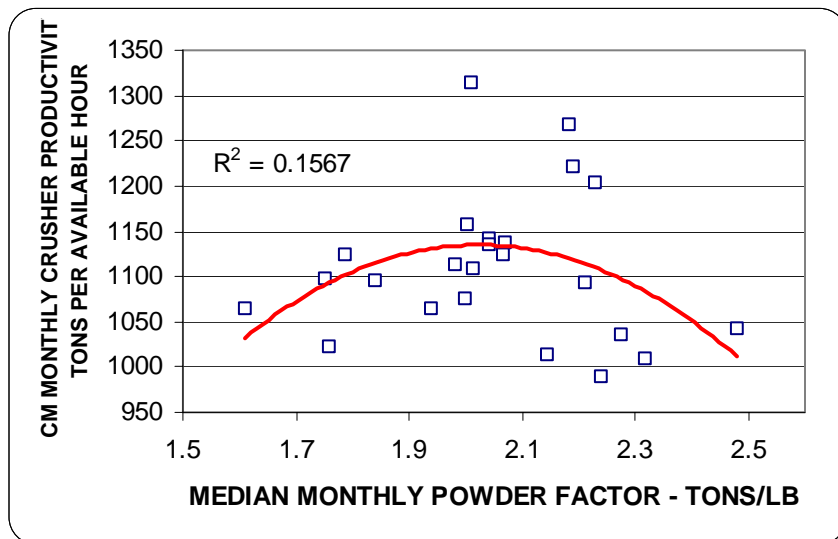

To confirm the relationship and optimum point between powder factor and tons per available hour found using monthly data, a graph of the daily relationship was made. While most quarries do not relate the blast to the crushing rate and many blasts can be processed on the same day, with enough data the relationship becomes evident either by using the blast data relative to the crushing rate from blast to blast or for a set period of time. Two factors help this analysis, the fact that powder factors usually are

adjusted within bounds slowly during the year and most quarries are trying to minimize the amount of inventory on the ground. A third method of timing loads through the crusher related to specific blasts can be used if the relationship is not evident in other ways. The chart below indicates an optimum in maximum productivity at approximately the same 2.0 tons/lb as indicated in the monthly data.
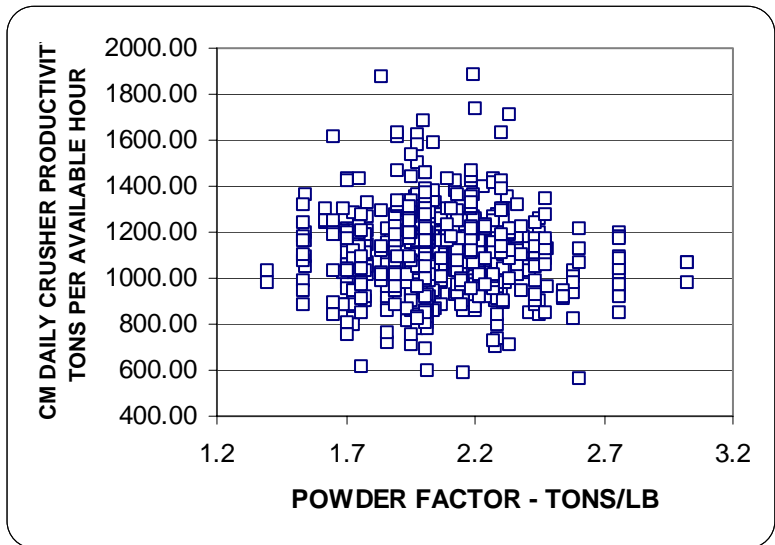
Other blasting variables can be looked at to see whether the optimum values are being selected. Note in the example below larger spacings are indicated for increased productivity. However decisions need to be made because larger spacings are related to higher vibration levels (relationship from blasting database also). In most cases other ways can be found such as limiting pounds per delay to adjust vibration levels to achieve optimum blasting parameters.
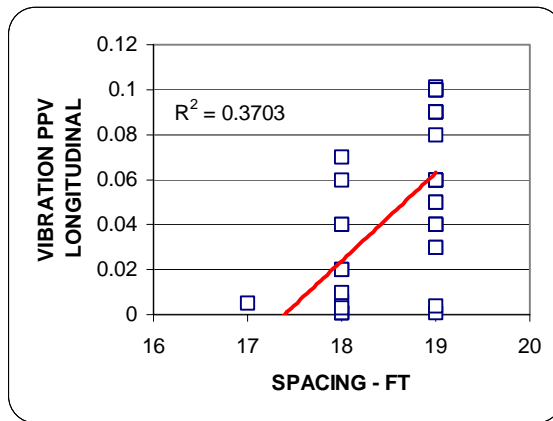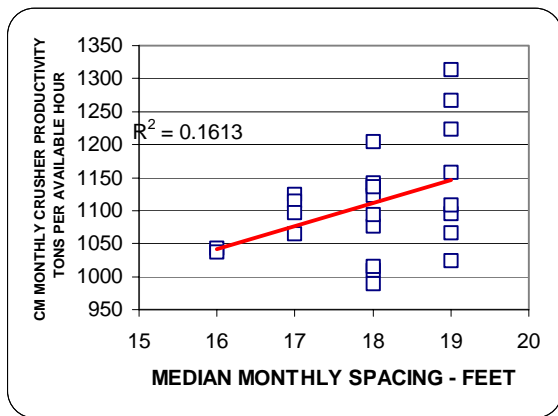
Finally, when all significant blasting and production variables have been identified, a multivariable, nonlinear regression can be computed as shown using Microsoft Excel. This method gives a comprehensive model of the operation and not just a single variable relationship in isolation. The equation facilitates the ability to drill down and isolate root cause and effect and determine the lowest cost solutions.

Regression Statistics			Coefficients	Standard Error
Multiple R	0.896869	**Intercept**	-1599.021745	1024.783
R Square	**0.804373**	**M**	59.47667731	14.57985
Adjusted R Square	0.700039	**M^2**	-4.606088792	1.119176
Standard Error	44.21848	**SCHD HR**	-0.382891043	0.136411
Observations	24	**PF**	2373.943233	1045.381
		PF^2	-564.26729	256.7929
		SPACING	58.61611032	16.66363
		BURDEN	-54.3105688	18.43084
		# ROWS	28.70309944	21.8568

The regression analysis above yields the following equation relating many of the significant blasting and production variables to the crusher productivity for cement feed (tons per available hour). The forecast and actual data are graphed below for comparison.

MONTHLY TPAH = -1599.02 + 59.47668 x MONTH –4.60609 x MONTH^2 -.38289 x SCHD HRS +2373.943 PF –564.267 PF^2+ 58.61611 x SPACING –54.3106 x BURDEN +28.7031 x # ROWS
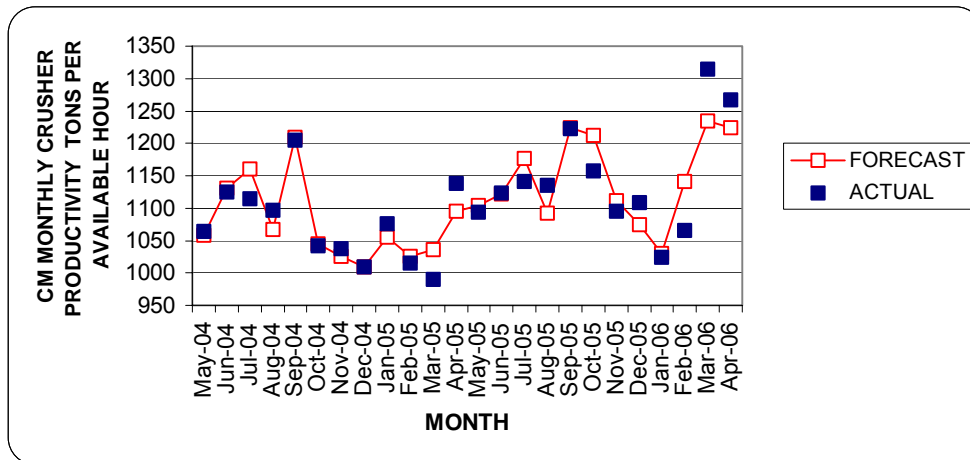
The equation explains 80.4% of the variation in monthly crushing rates. Other factors that could be considered include the number of trucks, number of loaders, shot size parameters (tons shot, number of holes, lbs explosive per blast, etc.), pattern area, initiator accuracy, blast timing, haul distance, crusher settings, etc.

Several cautions need to be taken into account when doing this type of analysis: 1) Many variables are cross correlated such as powder factor and pattern area and should normally not be used together in the equation, 2) Adding too many variables into the regression analysis can overspecifiy the equation and be inaccurate, and lastly 3) Working outside the range of data can lead to erroneous decisions.

In summary, the factors driving continuous improvement at the Lafarge Ravena Plant include:

1) Management techniques including regular scheduled and effective Blasting Optimization Team meetings.
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While the statistical data analysis can be very time consuming, the sometimes non-intuitive results can be exciting. Several hundred statistical analyses have been performed in North America resulting in productivity improvements of from 5% to 11%. The cost savings resulting from the productivity improvements is an even higher percentage making the exercise extremely rewarding. The techniques illustrated in this paper are expected to be refined and automated in the future to more fully integrate blasting and quarry operations in the future.

"When you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meager and unsatisfactory kind."
       LORD KELVIN

ACKNOWLEDGEMENTS

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