Blast optimisation at limestone quarry operations – good fragmentation, less fines

Benjamin Cebrian

Abstract

Rock blasting at quarries represents multiple challenges not easy to see at first sight. Aggregate industries face similar or superior prices for explosives while extracting a material that usually is of less value of metal mining operations. Therefore, learning to optimize a quarry operation can be a perfect training for a position in blasting at larger metal mining operations.

Medium to small quarry operations rarely can afford a blasting engineer unless incorporated on a big group that allows for technical services that includes blasting optimization. Therefore, quarry managers have few man-hour to do trial-and-error approaches to mine-to-mill optimization.

Apart from budget and management restrictions, quarry blasters and engineers must face a very delicate economical equilibrium between achieving maximum fragmentation at the blast while minimizing the fines portion. The definition of fines varies from industry to industry from few inches to less than an inch, but in all cases implies a loss of mineral reserves or obtaining of product of a size whose value is much less than at coarser sizes.

Limestone operations often add to all of the above with additional challenges because of geology, as caves and clay veins severely affect blast performance. Therefore, optimizing blasting operations at limestone quarries can be defined as a challenge that should be approached step by step on a rational basis.

In this paper, a practical case for optimizing blasting operations at a large quarry in southern Spain describes all the evolutions performed in the information, management and technical aspects involved in mine-to-mill optimization at a limestone operation with multiple benches and geologies.

Introduction

Manilva limestone quarry is located in Malaga, Spain. It produces up to 6 million tonnes of aggregate products for concrete manufacture, big to medium sizes for sea port construction, roads and home building.

Its large orebody and the depth of the open pit contain several geologies of limestone that has to be dealt with in order to rationalize drilling and blasting costs, maintain quality levels of materials produced and adapt planning to wet and dry seasons, when different benches are more suitable to work at because of their clay content.

Blast Consult S.L. has developed a 2 year program in which its activity is embedded with quarry staff for placing, designing, implementing design, load, connect, monitor, shoot and evaluate at least 90% of their blasts.

Optimizing a quarry

Since quarries make their profit by selling sizes and quality rock, it must be ensured we are looking at the right indicators to measure how to approach optimization. Sorting out by value, first we look for maximizing high quality, high added value products, and then, once that is kept constant, we look to minimize operational costs on a mine-to-mill approach.

Key performance indicators taken are stops at the crusher due to oversize every 100 hours, mill output, fines produced at the mill, drilling and blasting costs and secondary breackage costs.

First thing needed to optimize a blasting operation is to look to geology, as we have to adapt to those conditions imposed by nature, as if we are making a custom-fit suit to it. At the Manilva operation, three dry-condition blast designs were implemented after several blasts were tested all over the quarry.

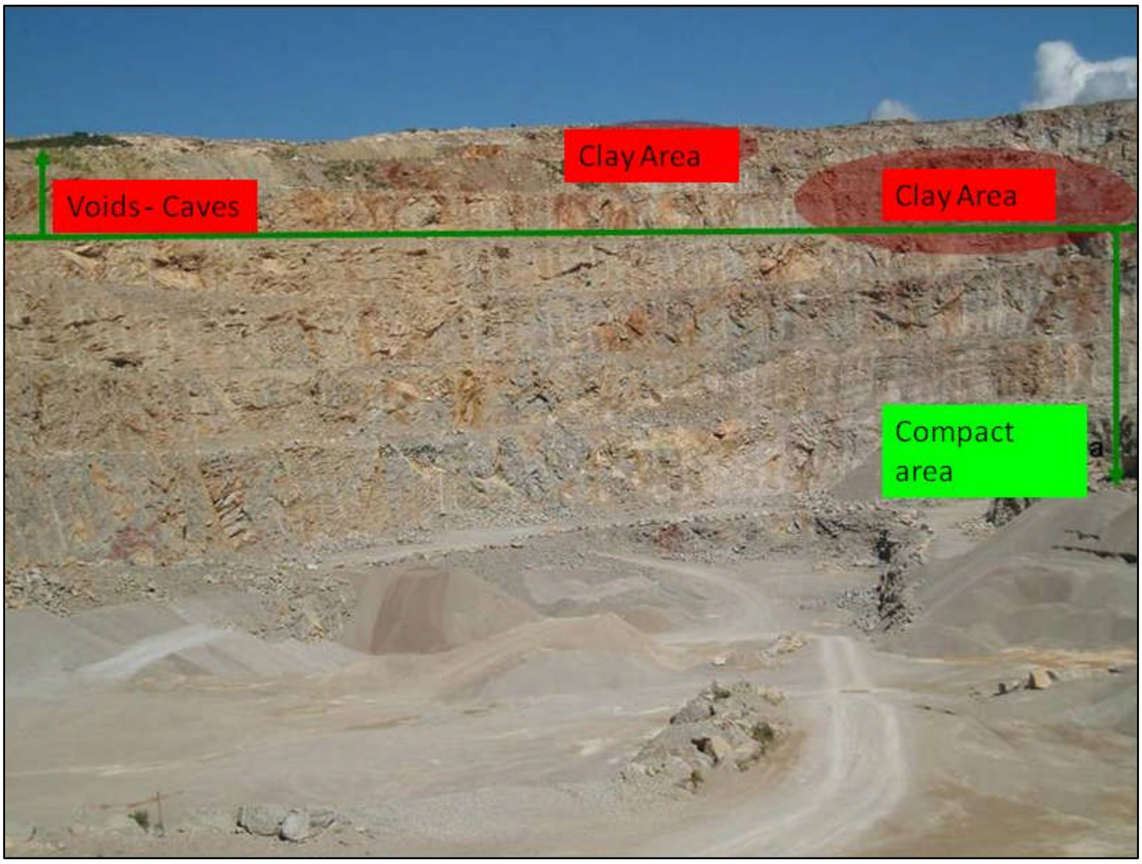


Figure 1: Geological areas at which different blast designs were applied: Bench8 – overburden blast design (OBB), benches 7 -5: Blast_A, benches 4-1: blast desing_B

Different blast designs implemented

Original blast design used throughout the entire quarry was:

- Hole diameter: 113 mm(4 1/3”)
- Burden x Spacing: 3.5 m x 4 m (11,5´x 13,3´)
- Stemming: 2 m (6.6´)
- Bottom charge: 11 kg (22 lb) of dynamite
- Column charge: ANFO
- Time between holes: 17 ms
- Time between rows: 42 ms

Initial auditing period was needed to ensure consistency on this blast design. Although the design was correct, the implementation needed assistance, since the following points needed an increased supervision:

- Hole length: up to 20% deviation from needed
- Burden: actual values up to 30% from design
- Burden-Spacing ratio: strong variability – inconsistency
- Stemming length highly variable

Once corrections were done to traditional blasting techniques, and supervision of those proved repeatable results, a first approach to optimization was done. After this, three blast designs were implemented on areas that resulted in good results at KPI values.

Overburden blast design

Overburden area was the hardest area to blast, as great amounts of both caves and clay interfered with the performance of blasts. Cutoffs were not uncommon in the past and big boulders were always present in this area.

Many holes were also usually lost before loading due to ground conditions, high backfill needs and new cracks as this bench was preconditioned because of previous blasts.

Figure 2: Overburden bench. Note the high content in clay, backfill and geology prone to be opened by adjacent blasts

Modifications made to this area in order to improve results were:

- Shorter time between holes and rows, down to 9 ms interhole and 17 ms interrow, with a 42 ms delay to the last row to ensure displacement
- Reduced bottom charge due horizontal bedding
- Laser profiling pre-drilling survey
- Stemming material: crushed rock
- Inter-stemming explosive deck to break top thick-rock layer

This was called Over Burden Blast design (OBB)

Clay and/or caves areas: Blast design A

Benches 7 to 5 presented several areas with high probability of caves/voids filled or not with clay. This was due two paleo-rivers that had existed on the overburden removed on top of those benches.

What had to be ensured is that these benches would produce a good degree of fragmentation so oversize would be kept to a minimum. Front end loaders have a poor selection capacity of materials, and therefore it is likely that the crusher could be stopped due to bridging of big sizes or just a size too big for the crusher entrance.

Burden value was kept the same (3.5 m – 11.6´) , but spacing was increased to 1.2 times this, since the soft nature of the rock allowed for an energy distribution good at this value.

Bottom charge: from 11 kg (22 lb), this charge was reduced to 5,5 kg (11 lb), as laser profiling revealed to be of great help on accurately locating the bottom of the holes.

Also, as in all cases, planning of the blast was done in order to create 2 free faced benches. This design improves muck displacement and also causes less damage to the resulting bench that has to be blasted afterwards.

In cases where drilling revealed clearly the existence of caves, detonating cord was added to ensure continuity of the charge, along with gas bags to stop the flow of ANFO out of the holes.

Blast design B for non-clay areas

In benches 4 to 1, no clay nor caves where historically detected. This is possibly due to the increase in depth of those benches, at which kastic dissolution of limestone was minimum or non existing.

Optimization of blasting at these benches was possible by opening the pattern, ensuring its consistency and by using laser 2D profiling before drilling. This reduction of explosives consumption was done without increase in oversize.

This blast design included:

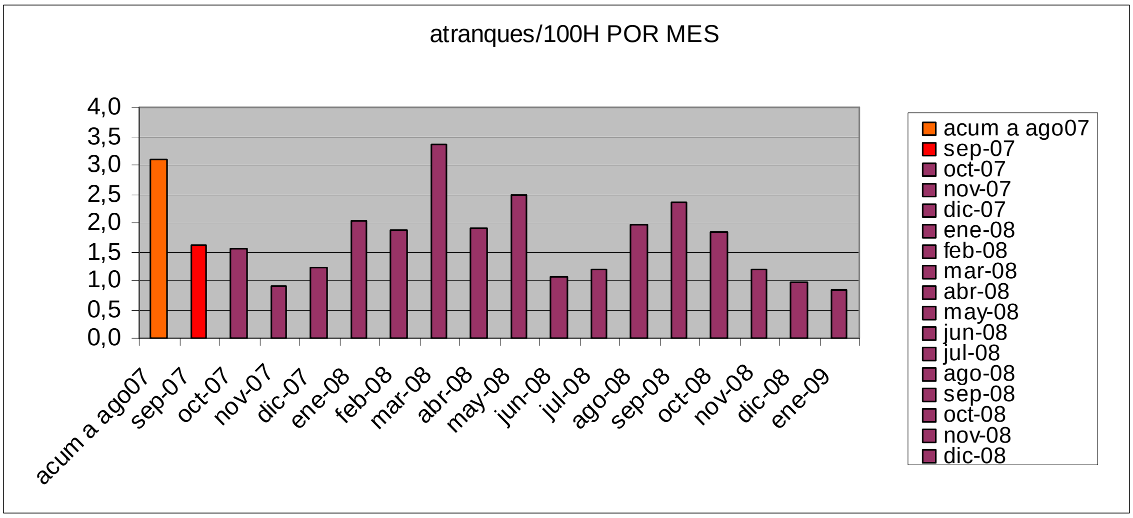
- Burden:3,75 m (12.5´)
- Spacing 4,5 m (15´)
- Stemming 2 m (crushed rock)
- Bottom charge: 5,5 kg of dynamite
- 2D profiling pre-drill

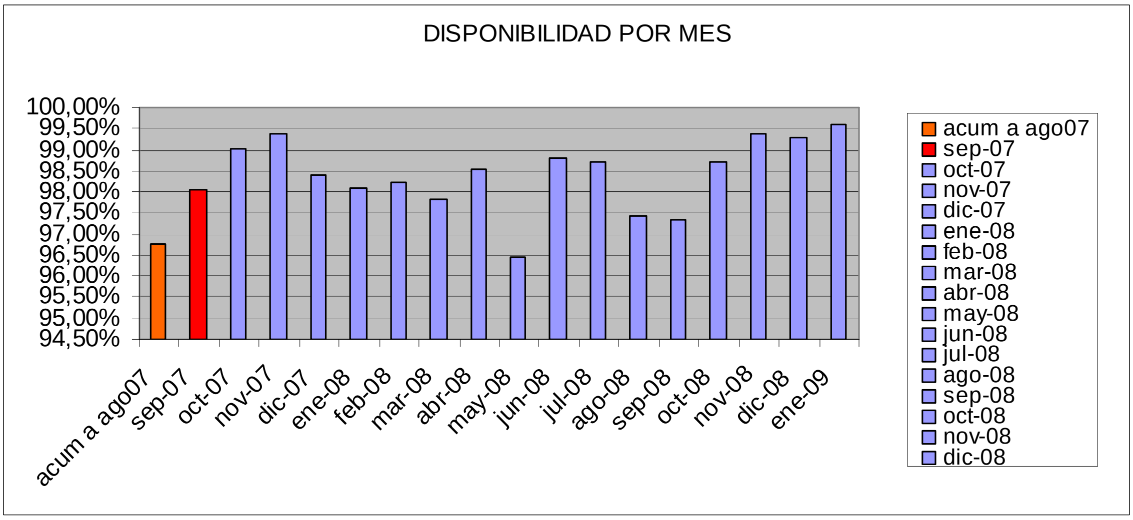
Economic results of blast designs OBB, BDA, BDB

An economical balance was recorded for the period 2007 (year of start of optimization) -2008, based on the opportunity cost of tonnes not produced during plugs at the mill, savings of explosives related to accumulated historical costs, hours of secondary breaking of oversize (hydraulic hammer) and accumulated historical drilling costs.

ECONOMICAL BALANCE	
ITEM	**2007- 2008**
Increase in mill disponibility	**114.880 €**
Savings in explosive	**132.315 €**
Secondary breakage	**24.050 €**
Blast supervision	**- 49.030 €**
Savings in drilling	**35.020 €**
TOTAL	**257.271 €**

Chart 1: Items included in the economical balance of different blast designs implemented at Manilva quarry





Figures 3 and 4: Follow up on figures plugs/100 h – mill availability

Monitoring and blast design tools

Basic tools for monitoring and design used were common sense, laser 2D profiler and a measuring tape. Apart from this, a blasting engineer was committed on a permanent basis until procedures were implemented and on a semi permanent basis for monitoring, supervision and, controlling of blasts and follow up on data.

Figures 5, 6 and 7: Laser 2D profiling before drilling for positioning

In a 2-3 row blasts, keeping control of the first row of holes is essential for the performance of the blast. A laser 2D profiler is a very useful tool to ensure an appropriate burden value before drilling and also for auditing an already drilled blast.

Supercharged blasts / Fines control

On lower benches, were a wider pattern was possible due to better geological conditions, a series of 4 high energy blasts were implemented in order to increase the fines portion of non-valuable material with a higher content of carbonates, which would allow selling for 6 times higher.

In this case, blast design was:

- Burden: 3,2 m (10,6´)
- Spacing: 3,8 m (12,6´)
- Time between holes: 9 ms
- Time between rows: 17 ms

This resulted in a highly fragmented rock pile, which resulted in higher loading-hauling-crushing rates. However, the rock mass increase in carbonates was not enough to provide for a higher quality rating, despite the increase in fines of 30% from original 24%.

Fines were controlled at this type of blast due:

- Higher powder factor
- Precise control of burden with laser 2D
- Short firing times (9ms and 17 ms)

ECONOMIC RESULTS of supercharged blast

The positive outcome of supercharged blast in aggregates could be a mine-to-mill approach in total costs overcoming increase in blasting costs.

Mill output increased up to 20% with this energetic design. However, the loss of 6% of tonnage that would sell for 6 euros/tonne instead of 1 euro/tonne did NOT compensate the increase in costs.

Acknowledgements

Javier Orive, Operation Manager at Manilva quarry (Italcementi group)

Bibliography

Floyd, J – 2007 “Efficient blasting techniques” Reno, Nevada