Reducing Vibration Level Using Simulation & Predictive Software with EDD (Ten Years of History in Two Lafarge Quarries)

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**ABSTRACT:** Many quarries in France are subject to vibration complaints. With Lafarge Company, six years ago, a program was set up to reduce vibration level around two cement quarries. This program began with the analysis of blasting configurations followed by involved blasting and vibration simulations using Qualishot software. The goal was to stop the telephonic complaints from inhabitants close to the quarry after each blast. After 6 years and more than 600 blast records per quarry, the results clearly showed how vibration levels were dramatically and consistently reduced during this period. The introduction of EDD within the last year opened new horizons and reduced vibration level by 50% from the previous period.

1 **INTRODUCTION**

In the history of the quarry business, there are very few cases where you have more than 10 years of track record of vibration levels. The case study presented here started 11 years ago, in a quarry where the management of the site was very sensitive to environmental problems link to blasting. They started to monitor blasting vibrations 24 hours a day, 7 days a week and tried to manage neighbors’ disturbance.

2 **WHERE THE ACTION TAKES PLACE**

The action takes place in a quarry of Lafarge Cement Group located in south of France, close to Nice. The quarry produces about 500 000 t of limestone per year split between two pits. The smallest pit (see picture 1) is surrounded by houses located at an average distance of 200 m from the blasting area. The pit is nearly circular, so that, where ever you blast, you have houses near the blast. With years, blasting areas have moved closer to certain houses and during certain stages of the quarry, the blasting took place close to 100 m from certain houses.

Since the beginning, the management of the quarry decided to set up continuous monitoring of vibration around the pit in order to know the vibration level and then manage blasting improvement in order to eliminate inhabitants’ claims about vibrations. They also decided to start a huge program of training of the blasting crew and a consulting program with Delta Caps to improve vibration control.
3 THE BLASTS

This is a typical quarry blasting process. Blasts contain one or two rows with 89 or 102 mm diameter holes. Bench height are 9, 15 and 20 m height. Loading of holes are done with packaged ANFO and emulsion. Initiation systems are electric or electronic and there are multiple decks in long holes (up to 4 decks per hole).

An average blast on a 20 m bench involved about 10 holes, one row and 500 kg of explosive per hole.

4 VIBRATION LEVEL HISTORY

4.1 Comment:

For confidential purposes, data communicated in this paper is given on a relative basis. The maximum of vibration level recorded 11 year ago in the quarry has been taken as the reference for this article and given the value of 100%. So all the vibration levels mentioned in this paper are expressed relatively to that level and expressed as a percentage. (The same method was applied to all the other parameters that are considered as confidential by the quarry.)

4.2 Consistency of the study

Over the 11 years a 1000 vibrations have been recorded, which makes this analysis very consistent.

4.3 Vibration level and Complaints

Going back 11 years ago, the management of the quarry decided to work on vibration level reduction because of the number of complaints recorded after each blast. Of course the objective was zero complaints. We can clearly see on picture 3 that the number of complaints decreased with a decrease of the average vibration level. Eleven years ago complaints were systematic and multiple (100%) after each blast and today there are less than 4% per year that represents 1 or two phone call per year.

Graph 4 : Vibration level trend over the last 11 years

The chart showing the decreasing of complaints versus vibration level is very interesting and clearly shows that below a certain level, complaints reach a level close to zero.

Graph 5 : complaints versus vibration level

In 1993, after various attempts to control these vibration level, Lafarge and Delta Caps started working together on that subject. The process applied to reach that zero level was very simple and started with these two first following objectives:

Defined the attenuation law of vibrations in order to design blasts with a correct charge per delay that will give a accurate predicted vibration level.

Target lower vibration levels and correlate them with complaints.
Very quickly we could see that as far we were progressing in decreasing the charge per delay and consequently the vibration levels, the number of complaints was also decreasing. We applied this process until 1996 very successfully. In 1997 the quarry expanded its exploitation in the direction of the houses and due to the short distances it was difficult to continue to decrease the charge per delay without changing the drilling equipment and the bench height. At this time we were using four decks per hole and the number of complaints was quite low but not at the zero level. We had to wait until the end of 1999, beginning of 2000 before we could introduce Electronic Delay Detonators to continue to decrease vibrations to drive the number of complaints close to zero. In that stage, the use of electronic detonators resulted in the further decrease in vibrations versus the previous situation without decreasing the charge per delay; in fact, we even increased it in 2002.

Starting from the initial level (base 100%) in 1992 vibration level has been reduced by 80% in 10 years and the number of complaints per year is now close to the objective of zero. (see graph 3)

We have to keep in mind that this level of vibration that give this "zero complaint level" is characteristic to the site and the people living around this site and we can not generalize.

As regard the frequency range no substantial changes have been noticed during the 11 years. The frequencies of the vibration records are in a range of 20Hz to 50Hz.

The second objective of this process was to minimize the scatter around the vibration level. When you look at the vibration level recorded at a location versus the vibration level predicted by the attenuation law, there is always a difference. This difference could be positive that give more vibration than expected or negative that is always good but not expected. The scope of this difference can be measure by the standard deviation of the records per year.

In 10 years the standard deviation has been reduced of 66%; happening gradually through the years. This allows accurate prediction of the vibration level and consequently the use of a higher charge per delay. The last 3 years, the introduction of the Electronic Detonators has shown a 5% reduction of the standard deviation. The consistency of the vibration level is now very good and the quarry manager is now very comfortable; gambling on vibration level has been definitively suppressed !!!
5 TOOLS AND TECHNOLOGY USED TO OBTAIN THESE RESULTS

The first tool, as mentioned above, is the charge per delay. It is well known this method can give very bad and inaccurate results if a minimum of care is not taken.

- Control of charge weight have to be accurate especially with bulk product.
- Distance between blast location and seismograph location has to be measured and not estimated.
- Seismograph direction and sealing has to be correct.
- Attenuation law has to be readjusted after each blast.

The second tool is the training of the blasting crew and the management on

- how important all these parameters are in order to manage this vibration level, and
- the impact of vibrations on people’s mind and structures.

The third tool is the Quality Management System applied to blasting. Delta Caps was among the first companies to be certified ISO 9001:2000 for blasting applications. This warrants that all the blasting process available to control vibration are applied as defined and gives the expected results with a continuous improvement process. We consider today that a large portion of the success of this vibration management through the years is a consequence of that.

The fourth tools are all the computer software used to predict vibrations and design the blast. Delta Caps used QUALISHOT software and its VIBRASEQ module (see graph 5) for vibration prediction bases on signature hole analysis (see graph 6) and more recently VISUALBLAST software with the use of Electronic Detonators.

The last tools but not the least important are the initiations systems. Progress was made by starting with conventional electric detonators, then by using them in conjunction with sequential timers, and nowadays the by the use of electronic detonators that provide flexibility and accuracy of timing, that allow to maintain vibration level as minimum of possible with a very good consistency and an increase of the charge per delay. This can be shown on graph 4 and 5 with the increase of use of electronic detonators since 1999.
CONCLUSION

Managing vibrations in order to reach a zero complaint is a reality that is demonstrated with this example. The key issue is principally Quality Management System apply to blasting operation and continuous improvement that means that every blast has to be consider as a special blast with a maximum of care taking into account the previous vibration history.

We can notice that this is achievable with conventional initiation system (i.e. electric detonators) and that more than the low vibration level the small standard deviation on the result is an interesting to notice.

The use of Electronic Detonators show clearly the potential of this technology that increase the consistency of results and allows either to decrease more the vibration level or in that case allows to increase the charge per delay keeping the vibration level at the same level.

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