EFEE

NEWSLETTER

Influence of stemming length and initiation sequence on rock movement and dilution during blast

New Technology to understand the link between cracking and vibration

Verification optimal millisecond timing delay of blasting in quarries with electronic detonators

and more...

NEWSLETTER

March 2020

We in EFEE hope you will enjoy the present EFEE-Newsletter. The next edition will be published in May 2020. Please feel free to contact the EFEE secretariat or write to newsletter@efee.eu in case:

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Doru Anghelache, Chairman of the Newsletter Committee and the Vice President of EFEE

and Teele Tuuna, Editor of EFEE Newsletter - newsletter@efee.eu

EFEE

EFEE SECRETARY GENERAL
ROGER HOLMBERG, JÄRNGRUVEVÄGEN 6
618 92 KOLMÅRDEN, SWEDEN
info@efee.eu
www.efee.eu

Dear EFEE members, the President´s voice

The beginning of the year has been full of dramatic Coronavirus news and development. The situation has evolved at great speed during the recent weeks – travel and other restrictions touch all of us in Europe. The future looks unclear. We at EFEE have also had to rearrange our meeting routines. A planned and booked board meeting in Milan had to be postponed till the end of the year and the February meeting had to be held as online conference calls. The April committee, board, council and AGM meetings in Istanbul are also in great risk to be moved to October. It is impossible to know how and how long the COVID-19 will finally affect our lives, but at the moment we need to play it safe. The risk will pass eventually, and we can continue business as normal. Until then it is our most important duty to keep ourselves, our families and our colleagues out of harm's way.

It has been a very unusual winter also up here in the north – we have hardly had a drop of snow during the whole winter at the level of Helsinki, Stockholm and Oslo. On the other hand, towns up at polar circle report record amounts of snow. These kinds of anomalies in the weather are not totally unprecedent, but extremely rare in historical perspective. We can clearly see that they are becoming more frequent due to effect of global warming. Users of explosives are perhaps now enjoying this snowless warm winter since it is much easier and safer to execute blasting works when steel is not fragile, hands and blast holes are not frozen, benches slippery and det lines lost in the snow. Despite some benefits to our business we are expected to do our part in turning this development around in the future. The carbon footprint of explosives and blasting is also becoming under focus, especially in mining where used amounts are big, but soon more so also in construction industry. Our clients are already demanding more information of our carbon footprint and soon, undoubtedly, also clear action and choices for less emissions. Is our industry prepared for these requirements? Will we soon drill rock with electric rigs? What can we do to reduce CO_2 emissions of explosives charges? Most CO_2 emission in relation to use of explosives comes from the manufacturing processes and especially production and use of ammonium nitrate. When are possible AN-free explosives at our disposal? Although we are now transporting huge amounts of explosives and raw materials from remote production plants to end users in Europe, typically thousands of kilometres with trucks, share of logistics is still not large for carbon footprint. Users of explosives can of course reduce the transportation distance by choosing the local supplier. Transportation can also be done more on sea and rails instead of roads and fossil free fuel can be used in transportation vehicles to further reduce emissions.

What else can be done to minimize the emissions in our industry? The old truth that environmental effects are smallest when all explosives detonate in an optimal way is still valid and goes also for emissions. Success in this not only brings lowest costs but usually also lowest emission, vibrations, secondary breaking, air over pressure and fly rock. How do we achieve this? Many factors must align but it all starts with successful planning of the blast including drilling, charging and initiation. Selection of the optimum shape of blast, burden and spacing, hole diameter, inclination and sub drilling are all essential. After that it is much up to a careful and professional execution of the plan. Accurate drilling according to the plan is the most important necessity for a successful result. This should also be measured if any doubt. Selection of explosives and initiation should match rock conditions. Only careful charging work will guarantee the detonation of all explosive charges.

Finally, the implementation of correct stemming helps to intermediate most energy from charges into rock instead of air. Only good professionals who truly understand the effect of their work and choices succeed in this work time after time. Therefore, we should increase the level of knowledge and training within our drilling and blasting engineers and teams. This is one important aim of EFEE and we have worked hard on our PECCS (Pan-European Competence Certificate for Shot- firers) project to enhance the level of training and expertise in Europe, not only for safety but also for environment. The first PECCS training course has taken place in Sweden. I am looking forward to co-operation with many educators of shotfirers in Europe in the coming years. We will contact you shortly!

Jari Honkanen, President of EFEE

Influence of stemming length and initiation sequence on rock movement and dilution during a blast

M.Lachamp[a], S.Grannas[b], R.Chavez[a]

a. EPC Groupe, 61 Rue Galilée, 75008 Paris, FRANCE
b. Mandalay Resources Corporation, 76 Richmond Street East, Suite 330 Toronto, CANADA

ABSTRACT: Björkdal is an open pit and underground gold mine located in northern Sweden. The study briefly presented in this paper has been carried out in the open pit part of the mine.
In this mine, the ore body is an assembly of vertical quartz veins, with a thickness included between a few centimeters and two meters.
This disposition in vertical veins makes the ore very located among vast zones of waste. In this context, movements linked to blasting have impact on selectivity. The goal of the study was to increase the knowledge on how the rock moves during the blast so we could implement it into the design parameters and improve the outcome, such as less dilution and rock movement. Here, we focused our interest on what kind of pre-blast and post-blast information could be measured and what kind of correlations could be assessed from such information. The measurement techniques deployed to carry out this study included drones for generating a 3D modelling of pre and post-blast areas; modelling from which we extracted swelling fields to assess to the muckpile shape. We also used the information from drilling reports to estimate, hole by hole, the top layer's fragmentation due to the previous blast. At this occasion, we also updated the Expertir software to directly import data from rigs and calculate the most efficient stemming for each hole in the blast pattern.
The rock movement during the blast was recorded by BMM® sensors placed on different locations and 3 different layers in the blasted area. We carried out some tests with different initial parameters in the blast design and, from all the records, highlighted correlations between stemming blown out, swelling and local rock fragmentation. We also found an interesting way to improve the rock movement by adapting the stemming, hole by hole, to the surface fragmentation due to the previous blast.
That's what we proposed us to show during our presentation: techniques of pre and post blast measurement, and our first results and ways of improvement concerning the reduction of dilution during blasting.

1. RECORDED DATA AND PROTOCOLS OF MEASUREMENTS

For each test blast, we aimed for measuring the following parameters:
-average rock swelling
-standard deviation of the rock swelling
-horizontal rock movement
-upper layer fragmentation induced by the previous blast
-rock fragmentation after the blast

Blasts parameters like hole pattern, charges used and initiation sequence were saved for each blast in the Expertir[1] software. More qualitative information as photos, videos of each blasts and excavating operators feedbacks were also recorded.

Figure 1. Quartz veins (in white) viewed from the top of a bench.

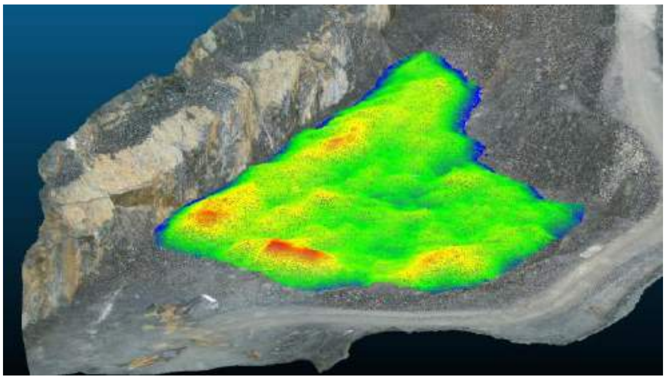

Figure 2. Swelling field displayed on the 3D model created before blasting. (Blast N°110b3003)

For measuring the rock swelling we used a drone carrying a camera. It allowed us to recreate a 3D model of the blasted area by photogrammetry. For each blast two models were created: one before the blast and one after the blast. Each model was geo-referenced. By comparison of both models in CloudCompare[2] software towards the vertical axis, we have been able to evaluate the swelling and the muckpile shape:

In Figure 2, the highest areas are displayed in red and the lowest ones in blue. The Gaussian distribution of elevations within the muckpile can also be displayed and gives us information on how even the swelling was (Figure 3):

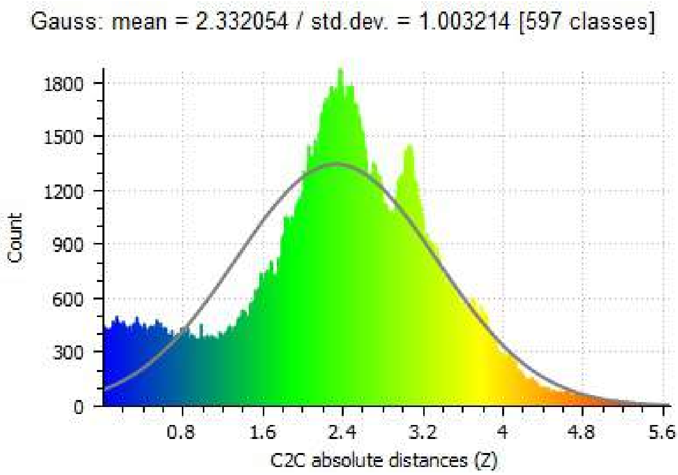

Figure 3. Repartition of elevations within the swelling field with its mean and standard deviation in meters. (Blast N°110b3003)

The horizontal movement was measured by BMM®[3] sensors. For economical reason, BMM® sensore were only used in blasts containing ore. The number of BMM® sensors used was different for each blast, depending mainly on the number of veins and their repartition. The sensors were dispatched at the rate of 3 sensors per monitoring hole as shown in the Figure 4:

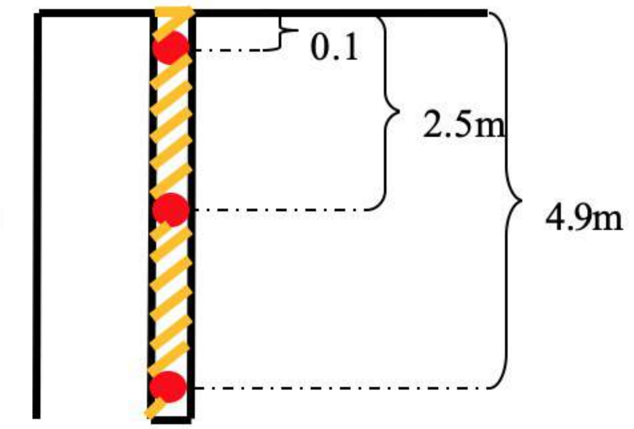

Figure 4. Loading pattern of a 5.5m deep monitoring hole.

From the movement recorded by BMM® sensors, the mine is able to create the polygons marking the ore's new position; and this for each layer. For the project, the mine also transmitted those polygons to EPC to display them in Expertir on the blast plan. By superposition of these polygons and the initiation sequence in Expertir, we have been able to correlate the horizontal movement with the sequence.

For measuring the rock fragmentation before the blast, we used the penetration rate provided by drilling rigs in IREDES4 files (Figure 5).

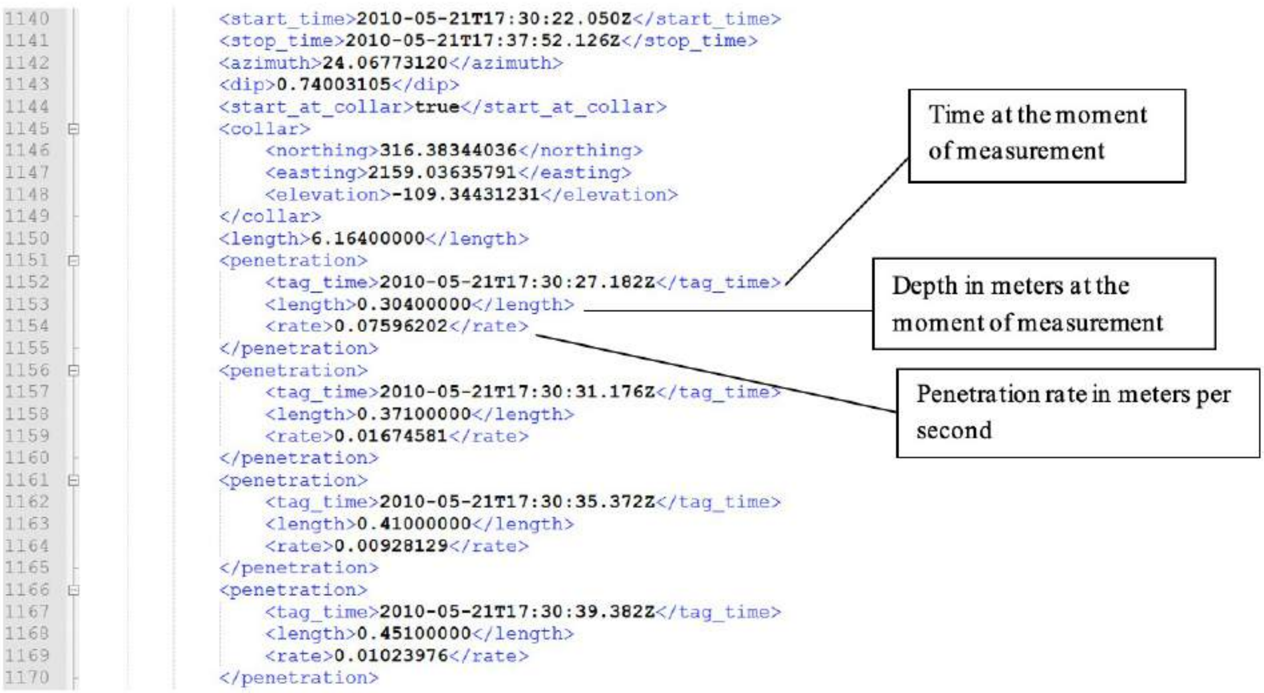


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Figure 5. Structure of IREDES file extracted from drilling rigs.

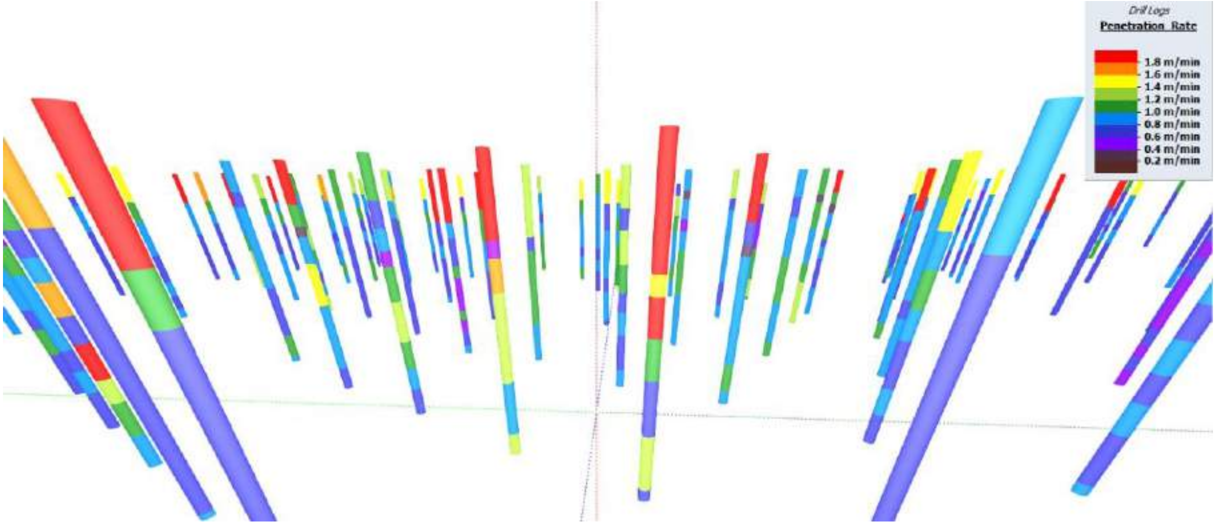


Figure 6. Display of penetration rate for each hole in Expertir.

Imported in Expertir for analysis, this penetration rate gave us an estimation of the depth of the rock fractured by the previous blast, and this for each hole (Figure 6):

As can be seen in Figure 6, the quality of the rock varies a lot from one hole to another.

The rock fragmentation after the blast was evaluated in a qualitative way from muckpile photos and excavating operators feedback.

2. FIELD TESTS CONDUCTED

This study is mainly focused on the influence of stemming and initiation sequence on the blast. Consequently we have acted on these parameters. The explosives used are the same in all the following blasts. In order to establish a reference basis of results to compare our tests with, we first monitored several blasts without changing any parameters. These blasts we will call in the following of this paper "standard blasts" (Figures 7, 8 and 9), are characterized by a delay of 0ms between holes of a same row, and a stemming of 2.5m. The delay between two rows is 42ms and will never change in the study. Then, we conducted one test with a 2.7m stemming and a standard sequence, three tests with a 9ms delay between holes of a same row and a standard stemming, and one test with a stemming adapted for each hole to the rock fragmentation measured by rigs.

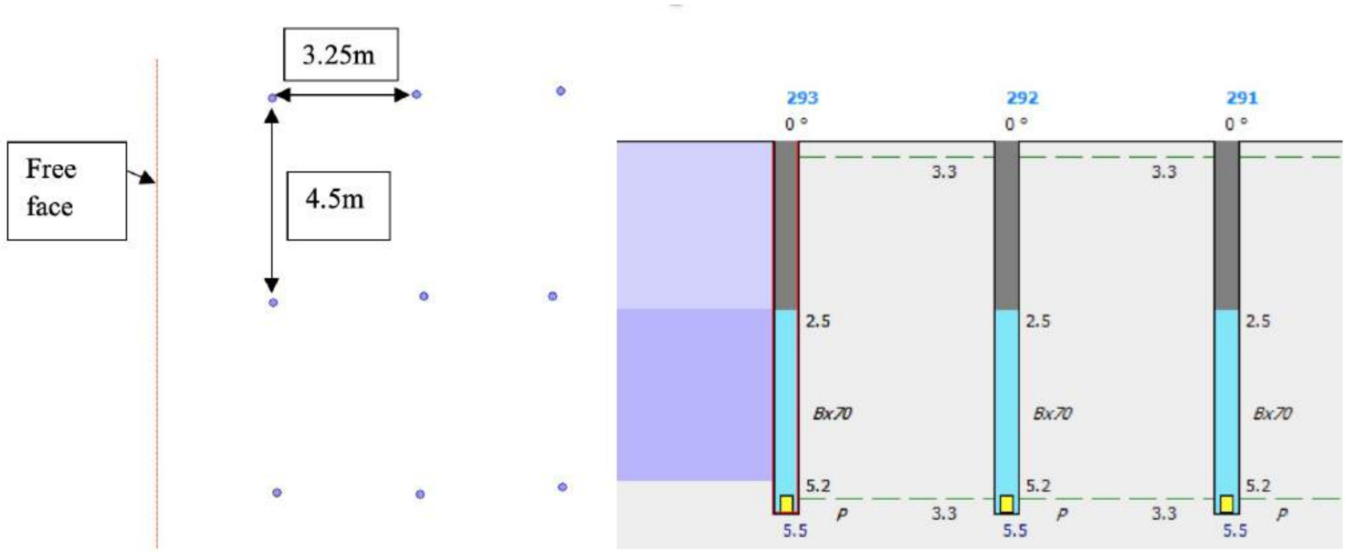


Figure 7. Hole pattern and loading plan for a standard blast.

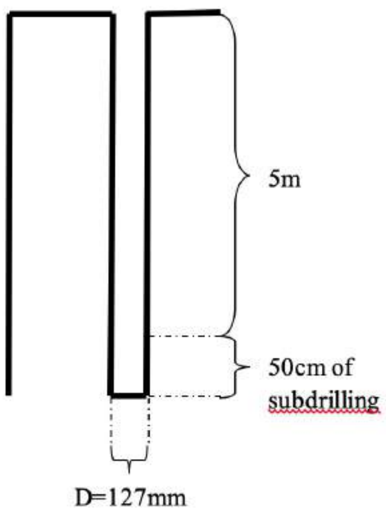


Figure 8. Drill pattern used for a standard blast.

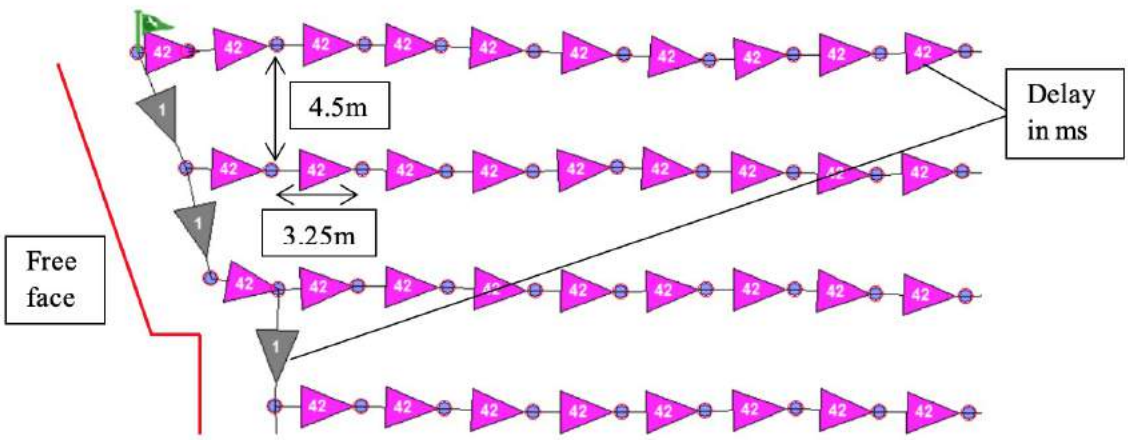


Figure 9. Sequence used in a standard blast (Nonel sequence).

A summary of all monitored blast is presented in the table 1 below:

Blast	InitialSettings
110b3001	0ms 2.5m Stemming
115b3001	0ms 2.5m Stemming
110g3011	0ms 2.5m Stemming
105g5007	0ms 2.5m Stemming
110b3002	0ms 2.5m Stemming
115b3002	0ms 2.5m Stemming
110b5011	0ms 2.5m Stemming
115g3011	0ms 2.7m Stemming
110b3003	9ms 2.5m Stemming
115b5010	9ms 2.5m Stemming
110b5012	9ms 2.5m Stemming
115b5009	9ms AdaptedStemming2.7/2.5/2.4m

Table 1. Summary table of recorded blasts with their initial settings.

3. RESULTS

3.1-Effect of initiation sequence on the direction of movement

As presented in Figure 10, the superposition of ore polygons and isochrone lines calculated in Expertir from the initiation sequence, shows that the movement is perpendicular to isochrones. We found the same result for all the monitored blasts independently of initials parameters used in blasts.

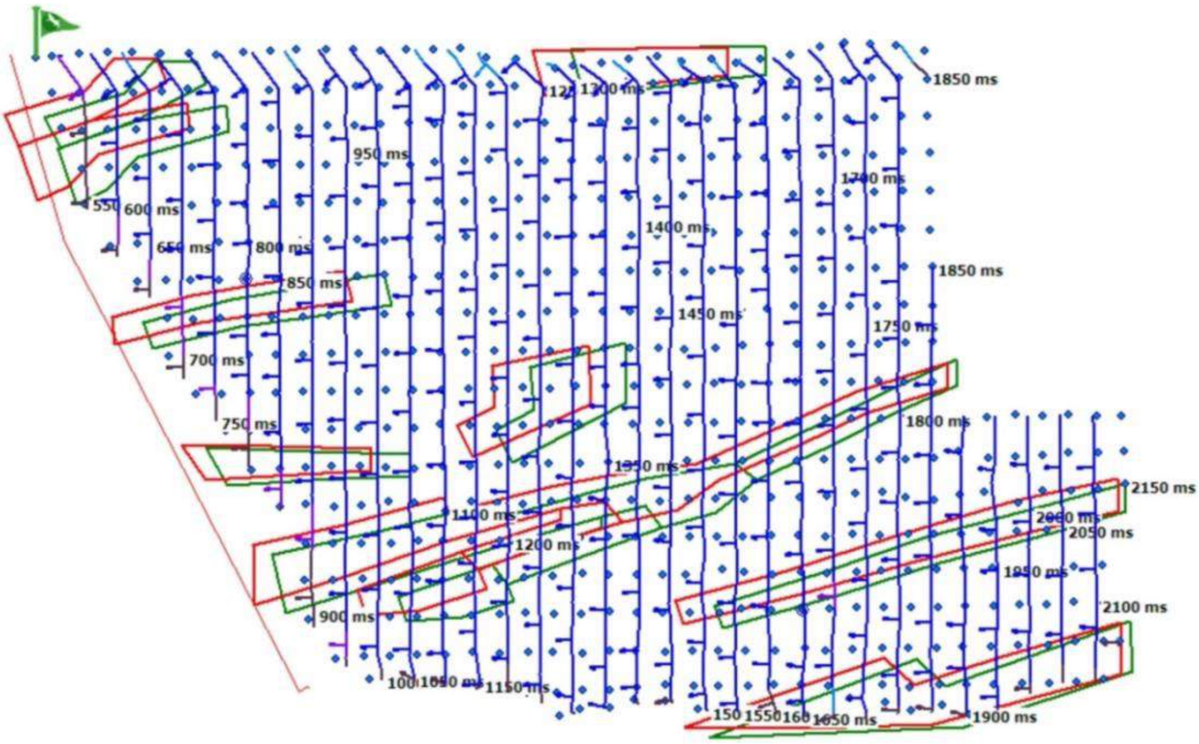


Figure 10. Correlation between ore movement (green: initial position, red: final position) and isochrones (in blue).

3.2-Effect of the 2.7m stemming

It's important to note that both blasts presented in the following table were shot one above the other. Blast 110g3011 is situated on the level -105m in the open pit; blast 115g3011 is situated on the level -110m. The number 3011 is the reference of their position. Consequently, we can make the approximation that the rock is the same for both blasts; the only parameter to have changed is the stemming height.

Even if there are no BMM® sensors in this blast, the video shows us a better movement. In this blast, there is much less fly rock. According to the excavating operator's feedback, the bottom and middle layers are easier to dig than in a standard blast. But the top layer contains a lot of big rocks which is bad for the dilution:

	Avg Swelling(cm)	Swelling StdDev(cm)
115g3011 (2.7m stemming)	207	67
110g3011 (2.5m = standard)	140	79

Table 2. Summary table of recorded swellings.

Figure 11. Coarse fragmentation at the top of the muckpile from blast 115g3011 with 2.7 m stemming.

The longer stemming leads here to two phenomena:

-First point, the better gas retention creates a higher swelling and a finer fragmentation for both middle and bottom layers even if there's less energy in the hole since the stemming is longer.
-Second point, this more important stemming means that there is less energy at the top of the column which leads to the coarser fragmentation on the top layer of the muckpile.

3.3-Effect of the 9ms delay

Except for the isochrones orientation, there isn't any noticeable quantitative differences of swelling and horizontal movement between blasts with 9ms delay and standard blasts recorded (Figures 12 and 13).

The feed-back from excavator operators reveals that it is easier to dig in muckpiles from a 9ms blast. The tiny delay of 9ms between the holes creates more open faces when a hole is going to explode. (cf. References, Ustrulid, Chapter 5.6) Consequently, there is more shock energy efficiently used for cracking the rock.

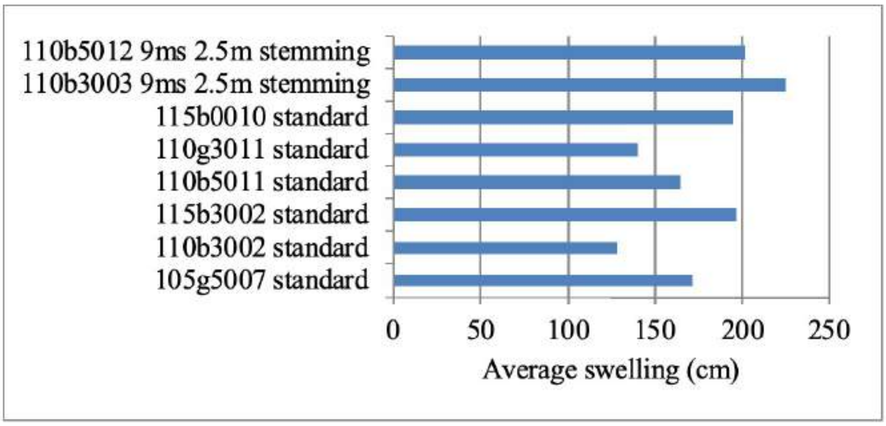


Figure 12. Average swelling recorded from swelling fields.

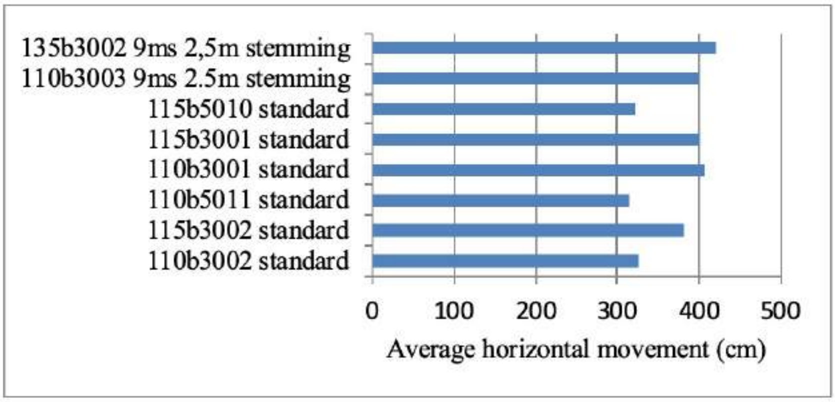


Figure 13. Average horizontal movement recorded with BMM® sensors.

This explains the better fragmentation obtained with this delay. (The fragmentation has only been evaluated qualitatively with feedbacks from excavating operators)

3.4-Effect of stemming blown out and cracks on the muckpile shape

Each blast is filmed. On blasting videos, we can see several stemming columns blow out. We can also observe areas with smaller swelling where a blow out happened. A photo taken of those areas also shows a coarser fragmentation in muckpile's first layer (Figures 14, 15):

Figure 14. Blast 110b5011: correlation between stemming blow outs and smaller swelling.

Figure 15. Blast 110b5011: coarse fragmentation at the blow out location.

Stemming columns blown out aren't the only explanation for areas with smaller swelling. As shown in the following figures, the existence of open cracks or fractures has an impact on the rock movement:

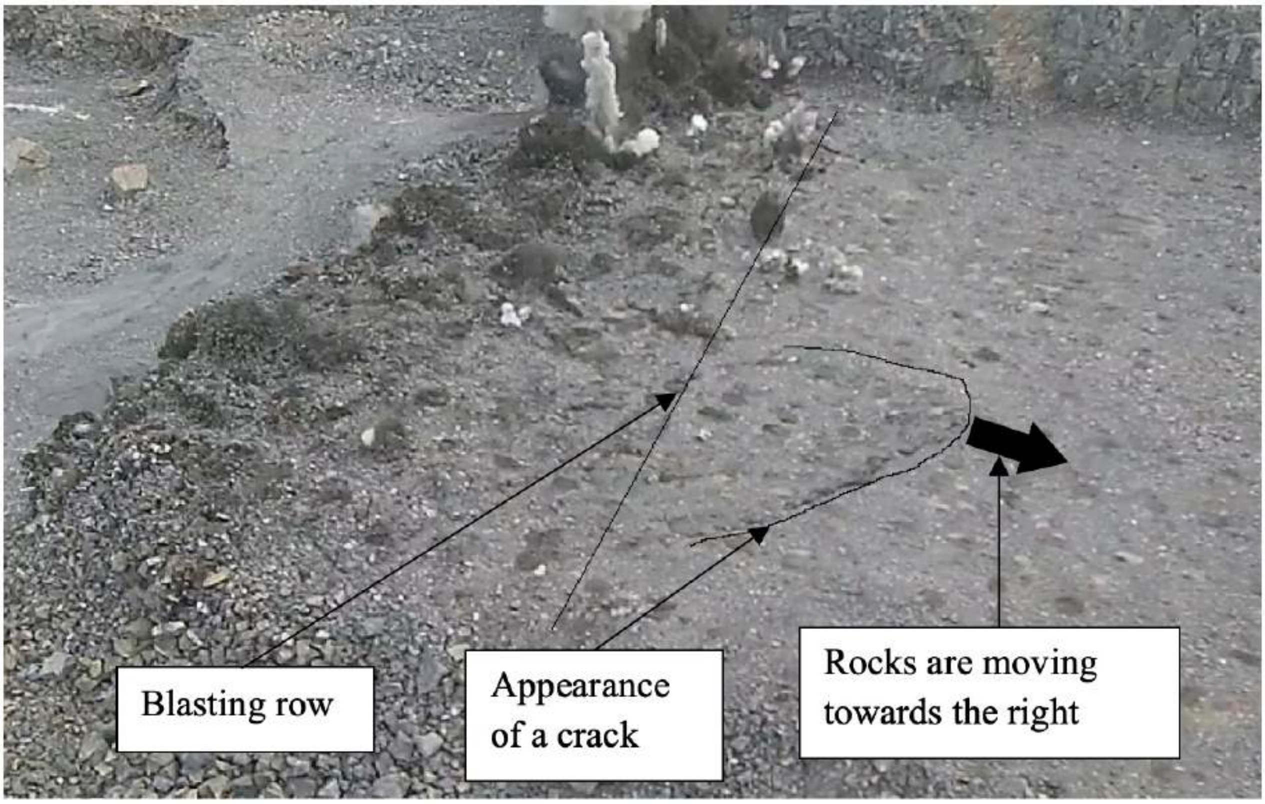
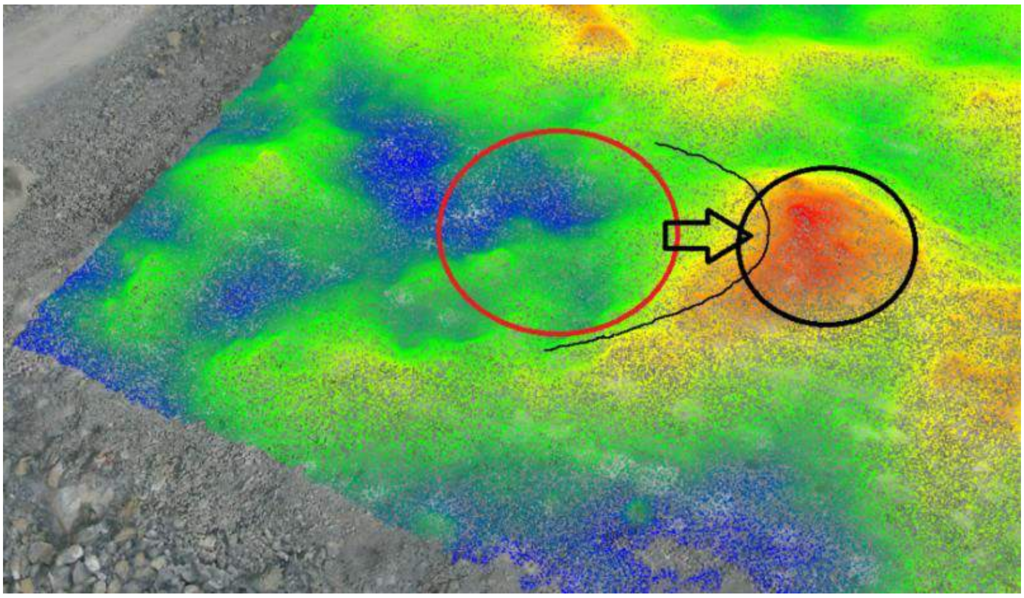


Figure 16. Blast 110b5012: effect on a crack in the rock mass seen on the video.



Location of
the crack
seen on video

Figure 17. Blast 110b5012: effect on a crack seen on the swelling field.

Unlike in a blow out area, there is no coarse fragmentation observed on the area with small swelling in this case.

We observe here two negative phenomena for the dilution:

-Blow outs because they create a coarse fragmentation and fly rocks projections.
-The variation in material movements from one point to another because they create a rock mixing.

Both phenomena are correlated with a smaller local swelling. Therefore, we will get a lower dilution from a muckpile with a smaller standard deviation of the swelling when average swelling is acceptable.

3.5-Effect of the varying stemming lengths on the movement

For this test, stemming values were increased from 2.5m to 3m according to the surface fracturing of the rock as measured by the drilling rigs. (cf. References, Ustrulid, Chapter 4.9)
We used the penetration rate information in Expertir to calculate an optimal stemming length for each hole (Figures 18, 19).

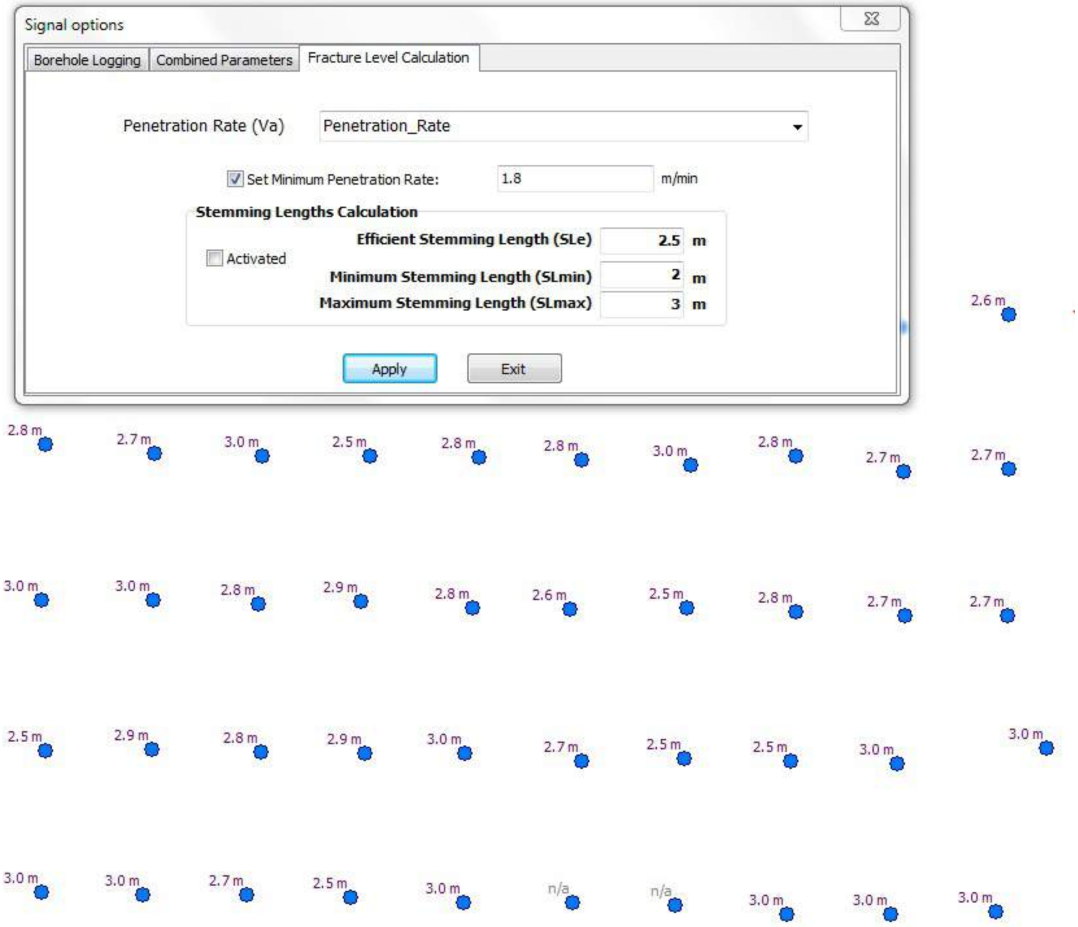


Figure 18. Different stemming lengths in the same blast, calculated by Expertir.

The optimal stemming length is calculated in the following way: as shown in figure 18, it is possible to set in Expertir an efficient stemming length (here it is 2.5m). The depth of rock fractured by the previous blast is then taken into account, if for example 30cm of fractured rock is measured by the rig, then 2.8m of total stemming will be displayed in Expertir. In order to avoid to put too much stemming in a hole, a maximum stemming length is set (here 3m).

We can see here a noticeable decrease in the horizontal movement of the blast with a differential stemming. There isn't any major difference concerning other measured parameters. The feedback from excavating operators told that the muckpile wasn't harder to dig than usual.

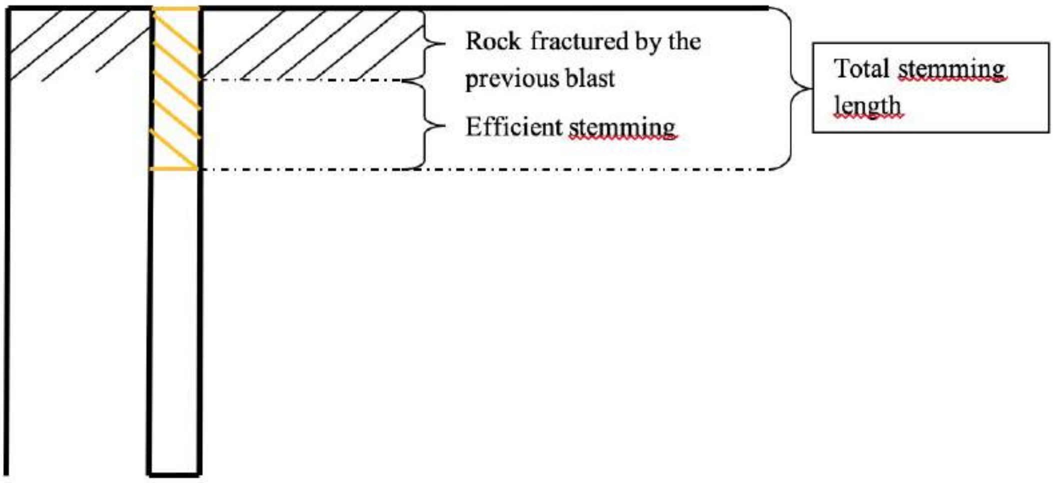


Figure 19. Definition of efficient and optimal stemming lengths.

The results for the horizontal movement measured with BMM® sensors are presented in the following figure:

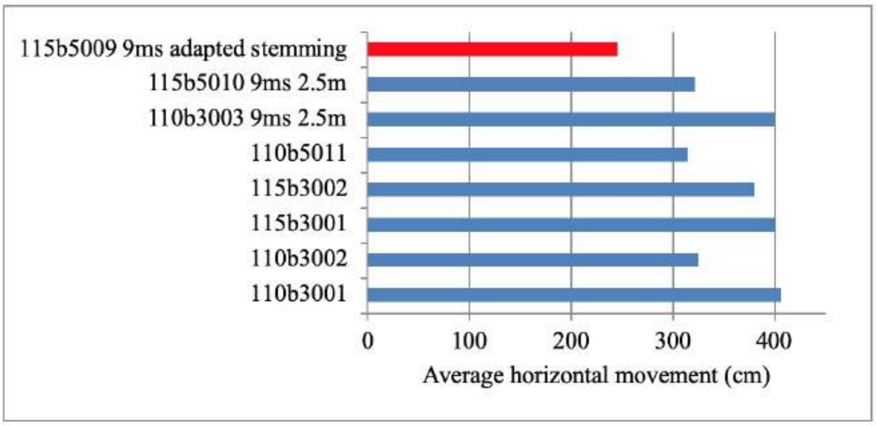


Figure 20. Horizontal movement comparison for different initials parameters.

4. DISCUSSION ON DILUTION AND CONCLUSION

We have seen that a stemming blow out was correlated with a smaller local swelling and a coarser fragmentation. Coarser fragmentation in the muckpile leads to more dilution, the flyrock projected by the blow outs also leads to more dilution. Furthermore, if the muckpile swelling is not even, there's a larger chance to have some rocks moving from the highest parts of the muckpile to the lower parts, which also leads to more dilution. Consequently, it is important to limit as much as possible stemming blow outs. When we used varying stemming lenths, we also observed an overall smaller horizontal movement, which is also a good point for reducing the dilution. In mines characterized by a heterogeneous fragmentation of the top layer, using a varying stemming length can be a good way to achieve the goal of reducing stemming blow outs and dilution.

The mapping of swelling fields appeared to be a very effective way for evaluating quantitatively the shape of a muckpile. An ideal blast should lead to a homogeneous and vertical swelling: the vertical standard deviation of a muckpile should ideally tend to 0. The swelling should be important enough for allowing an easy digging: this condition is measurable by the mean of the swelling for the whole muckpile. Both the mean and standard deviation values for a muckpile are easily measurable from the swelling field.

Finally, it is important to keep a critical eye on the job done here: the correlation between stemming blow outs, small swelling and coarse fragmentation has been observed in many cases and can be believed to be valid. However it is not the case for the smaller horizontal movement observed on the blast with varying stemming. Even if the movement reduction was clear compared to all other monitored blasts; it is important to confirm the result we got there by testing the varying stemming on at least one more blast since blasting involves a lot of unexpected and more or less random effects.

REFERENCES

Hustrulid, W, 1999, *Blasting Principles for Open Pit Mining,* Volume 1, *General Design Concepts,* A.A. Balkema, Rotterdam, 382p.
Chapter 4.9, *Measure-while-drilling system,* p. 101-106
Chapter 5.6, *Some sequencing principles*, p. 144-149

BACK TO TOP

New technology to understand the link between cracking and vibrations

T. BERNARD
Thierry Bernard Technologie, Nice, France

ABSTRACT
Mining, near buildings or housing, has always been the subject of complicated debates when it comes to the origin of cracks in buildings. Residents believe they are created by mine blasts, whereas for operators, the seismic levels are not sufficient to create or enlarge cracks. However, where is the truth? When trying to reply to this question, not from a theoretical standpoint but from a practical point of view, we have developed a technology enabling us to associate building vibrations and the development of their cracking, directly and in real time. Thus, it becomes possible to reply simply and objectively to the question of the link between cause and effect for vibrations and cracking. There are plenty of examples to support this.

1. Scope

It was in the 1980s that USBM published one of the first regulations to protect constructions from the effects of vibrations caused by mine blasts. Several countries have made their own regulations or recommendations since then with vibration limits that are often lower. However, on many sites, operators choose vibration limits that are lower than those of the existing standards, in order to limit the number of complaints received. The real question is how can we know what level of vibration is susceptible to create or worsen an existing crack in a construction. Within the scope of an environmental monitoring programme, we have developed a technology enabling us to associate building vibrations and the development of their cracking, in order to learn if there is a relationship between the evolution of damage to existing constructions and the seismic levels of vibrations created by mine blasts

2. Data Acquisition

In order to carry out these studies, some mines asked our partners and us to fully equipped houses that were thought to be representative of the chief types of existing disorders, i.e.: cracks in structural parts (foundations, load-bearing walls) and cracks in non-structural parts (indoor wall-covering). The buildings were equipped with four types of instruments to measure the static opening of cracks, the dynamic opening of cracks, seismic tremors and temperature.

The principle, to discover whether there is a link between the seismic levels and cracks or their evolution in buildings, is to be able to associate a seismic level measured in a building with the evolution of an existing crack. The most traditional method is to install an extensometer on the crack and note the opening of the crack one or more times a day. Therefore, we obtain the evolution of the opening of the crack as the days go by. This is a static measurement because we are interested in the opening of the crack at precise moments of the day.

At the same time, a seismograph measures the seismic solicitations of the building and, in particular, we monitor those relating to mine blasts.
There then ensues the tricky job of analyzing these two data sets to see if there is a relationship between them. The chief difficulty is that when we record the seismic signal of a mine blast, it never coincides with one of the crack opening static measurements but is always in between two measurements.
Hence, if the second (the next) static measurement of the opening of the crack is higher than the first, we tend to accuse the seismic level, thus the mine blast.

When the second measurement is lower, no conclusion can be drawn.

The system (figure 1) that we implemented 2 years ago, aims to simplify the interpretation of the data by synchronizing all the seismic, extensometer and temperature sensors on the same acquisition unit. The synchronization signifies that when a measurement is made, it is carried out simultaneously on all the sensors. The opening of a crack can thus be directly associated with a seismic level or a temperature.

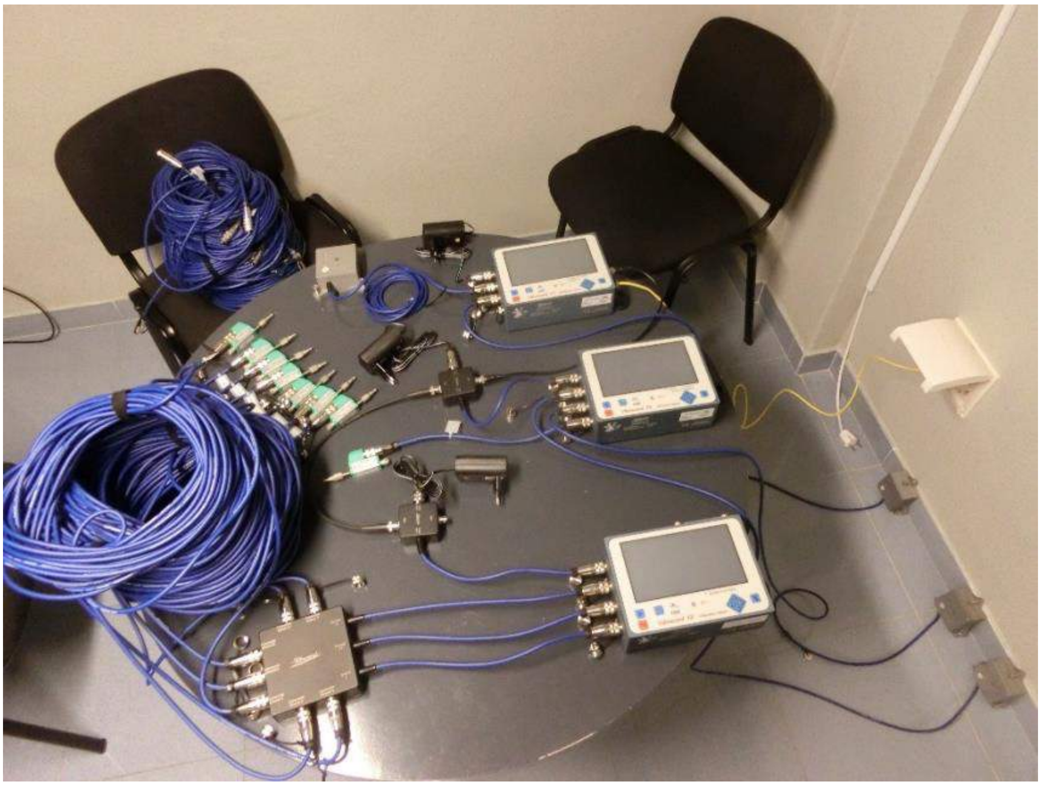


Figure 1 : Example of a system with geophones and accelerometers

Hence two types of measurements are available:

Continuous so-called static measurements, over a series of given intervals, where the maximum value of each sensor is retained for that interval. The standard interval is set to 32 s and can be decreased to as little as 1s according to needs. This method is often referred to as a "histogram" due to its presentation. It enables the evolution of a value to be monitored throughout time in an overall manner.

So-called "dynamic" measurements, where the system makes a simultaneous measurement of all the sensors (seismic, extensometers and temperature) with a sampling frequency of 2000 Hz. One of the seismic sensors is chosen as the reference sensor and this sensor triggers the recording of all the others when a vibration threshold is exceeded. This method is used to discover how cracks behave dynamically, i.e. when a seismic solicitation "shakes" the building.

Figure 2 : Example of an in-situ system with geophones and accelerometers

3. The static opening of cracks

The photograph below (Figure 3) shows an "extensometric" type sensor which measures the gap or the opening of the crack.

The graph below (Figure 4a) illustrates the movements of various extensometers in a wall according to a short period of time (3 months)

Figure 3 : Extensometer

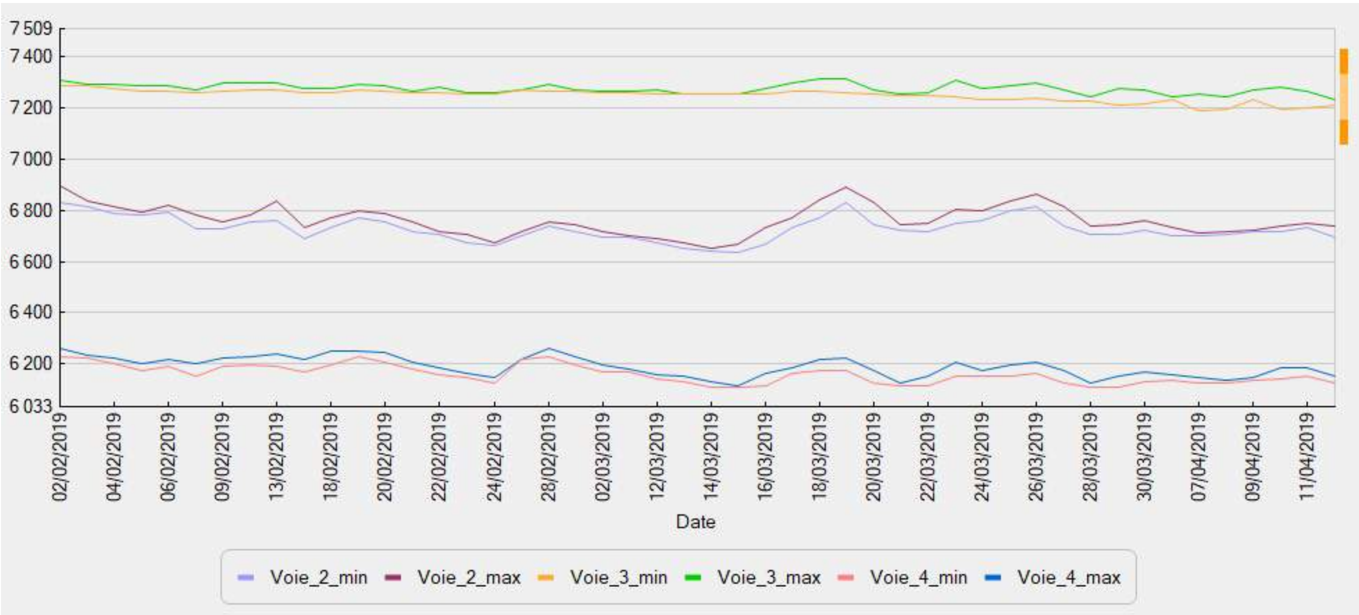


Figure 4a: Example of the evolution of the opening of a crack

The graph below (Figure 4b) illustrates the movements of an extensometer in a wall according to a long period of time (18 months)

4. The static measurement of Temperature

Each extensometer is equipped with a temperature sensor that measures the ambient temperature when the opening of the crack is measured. The graph (Figure 5) below illustrates the variation of the temperature measured near an extensometer.

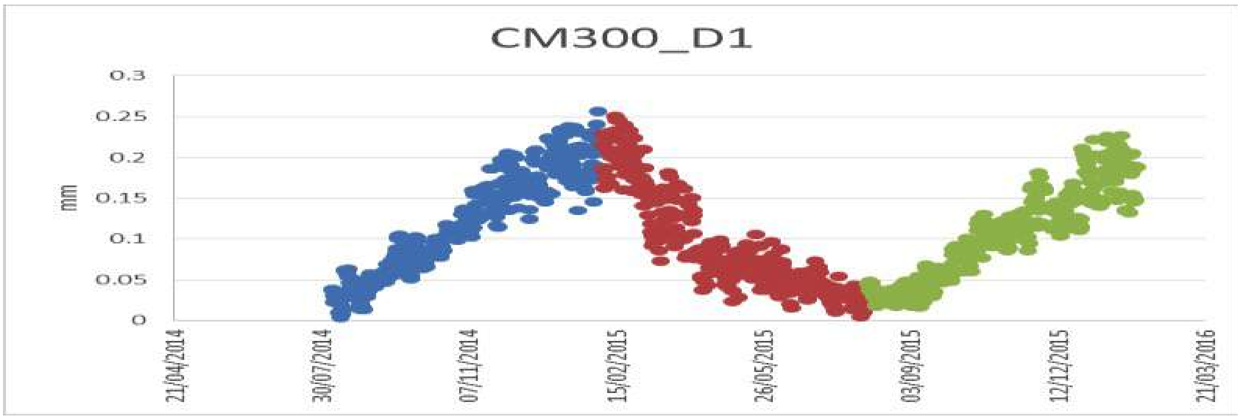


Figure 5b: Example of the evolution of the opening of a crack

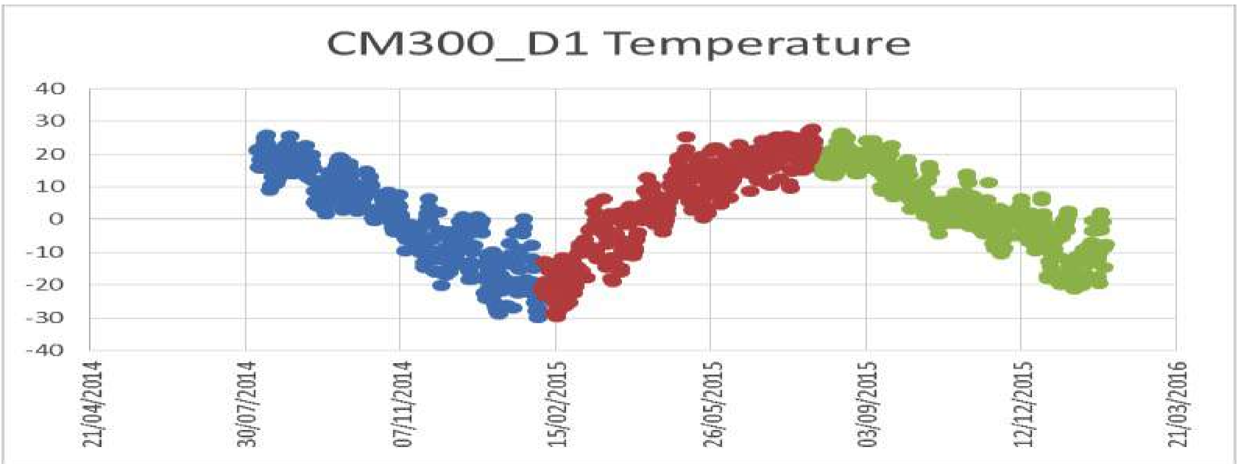


Figure 6 : Evolution of the temperature near a crack

5. The dynamic measurement of the opening of cracks

The dynamic data represent the evolution of the opening of the crack in a short lapse of time (32 seconds in this case). The measurement is taken 2000 times a second with an extensometer and is triggered by the recording of seismic sensors (Figure 7), which in turn is triggered by the vibrations of the mine blasts. The graph below (Figure 6) illustrates a dynamic measurement of the opening of a crack throughout time.

It should be noted that the opening of the crack vibrates with the rhythm of the vibrations in the ground (See Figure 7) and that after the blast, the opening returns to its original value.

Various scenarios are visible in the analysis of the dynamic data of the extensometers. The first one is an oscillating movement of the crack around its average value with no visible evolution. This is the case for the recording below (Figure 8). The vibration from the mine blast simply vibrates the crack and its average opening (red line) is not modified throughout time. The vibrations of this mine blast have no influence on the crack.

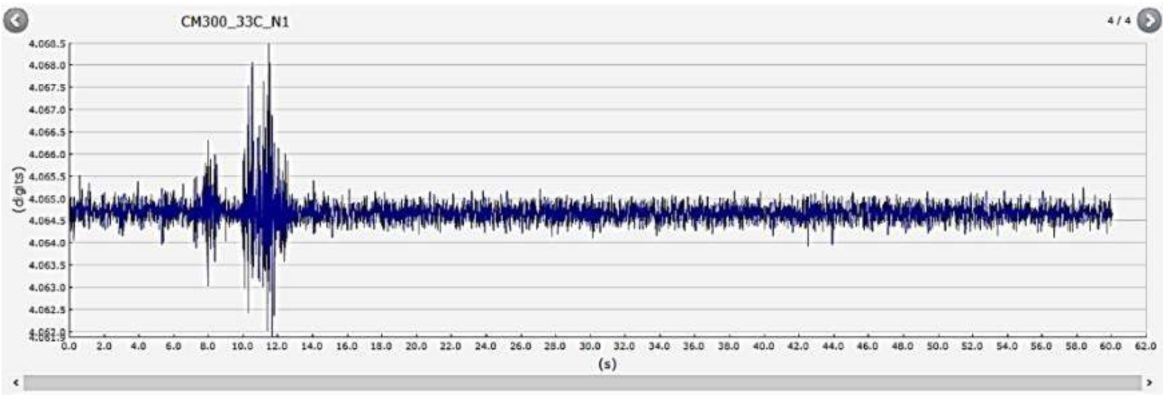


Figure 7 : Example of the dynamic evolution of a crack with no effect

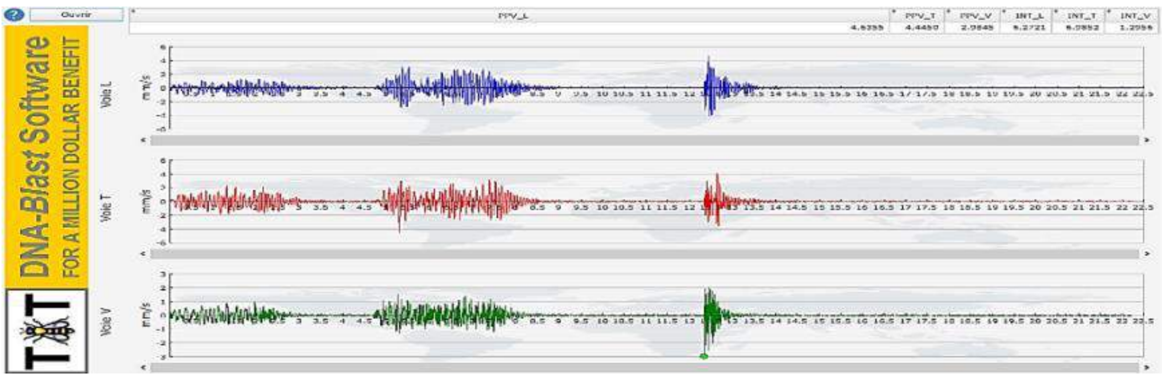


Figure 8 : Recording of vibrations associated with the measurements of an extensometer

Various scenarios are visible in the analysis of the dynamic data of the extensometers. The first one is an oscillating movement of the crack around its average value with no visible evolution. This is the case for the recording below (Figure 8). The vibration from the mine blast simply vibrates the crack and its average opening (red line) is not modified throughout time. The vibrations of this mine blast have no influence on the crack.

The second is in oscillating movement of the cracks with a visible evolution. In some cases (Figure 9) during the blast vibration, the average opening of the crack changes value. It can be noted that the jump, although clearly visible on the graph, represents a variation of 5 microns (thousandth of a millimetre) (195 microin).

In addition, the opening will disappear throughout time (decreasing slope in dotted red in Figure 10) to return to its original value (in a few minutes) that can be found in the static values.

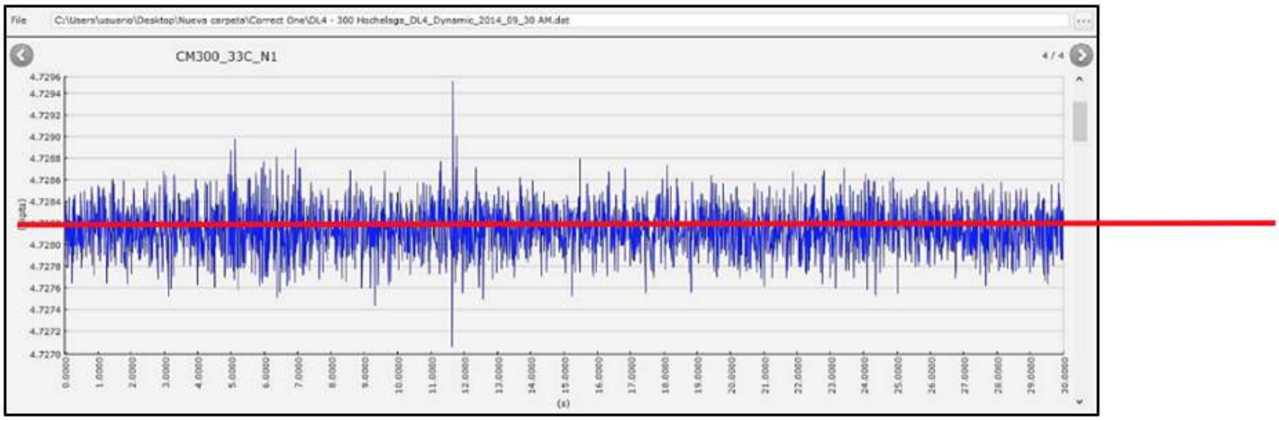


Figure 9 : Vibration of a crack with no evolution

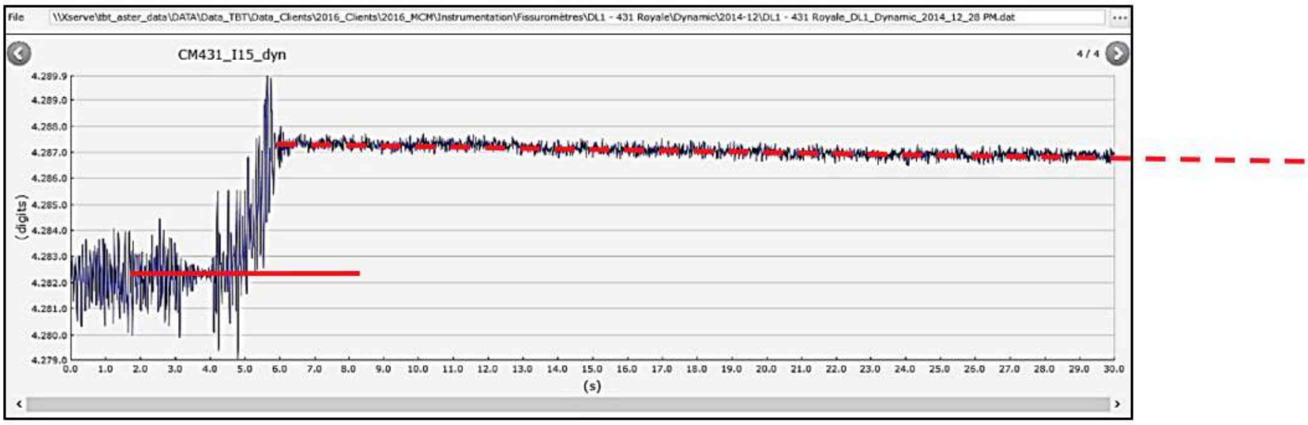


Figure 10 : Vibration example of a crack with a simple evolution

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In the example below (Figure 11), we can see several successive evolutions of the average value of the opening; the jumps are due to several blasts occurring one after another. In the same way as in Figure 7, the evolution of the opening of the crack is 6 microns (234 microinch), which is insignificant.

It can also be noted that in some cases, cracks close during the solicitation (Figure 12) of the mine blast and also return to their original position after a few minutes. This behaviour depends on the orientation of the blast compared with the cracks. For all the data analysed, the maximum dynamic evolutions measured are all below 8 microns (312 microinch), except one value in hundredths of a millimetre (0.039 in).

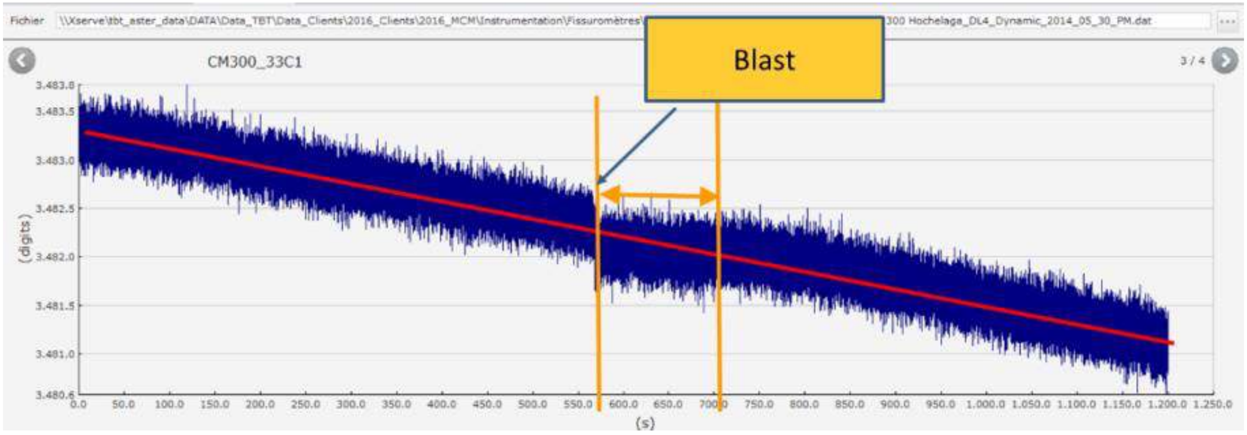

Figure 11 : Vibration example of a crack with a return to original value

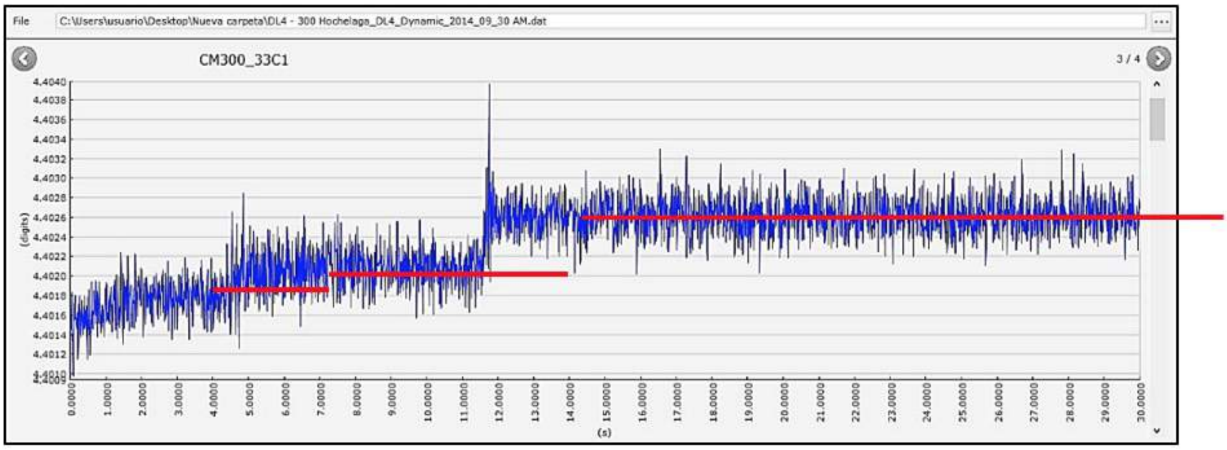

Figure 12 : Example of the vibration of a crack with multiple opening evolutions

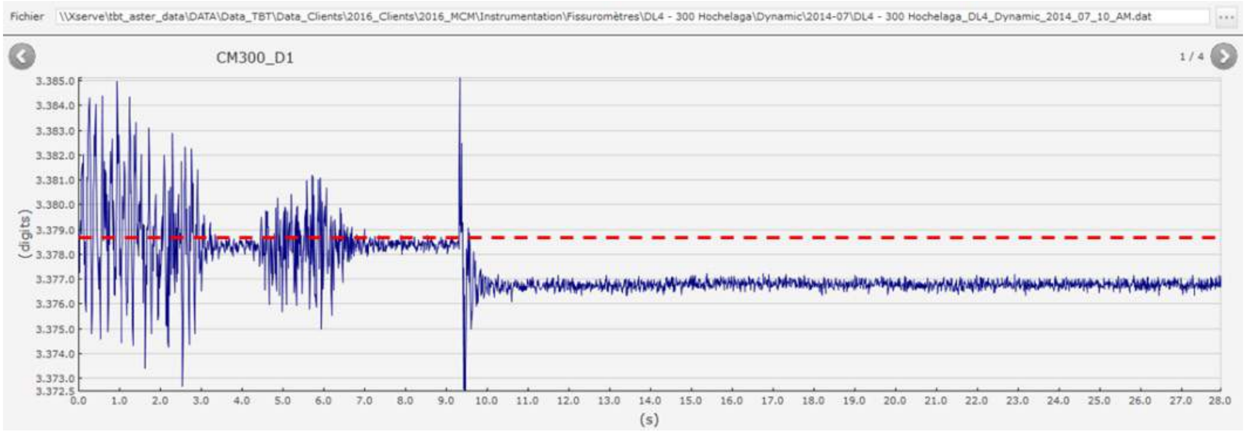

Figure 13: Example of the vibration of a crack with a closing evolution

6. The correlations

The search for a correlation consists of displaying the value of a parameter according to the other to see if there is a correlation between the two. The system supplies synchronized values of the various parameters, so the correlations are direct and not interpreted.

The example above (Figure 13) illustrates the correlation between the opening of a crack and the ambient temperature nearby. On the "Value of the extensometer/temperature" graph, we can see that the points are lined up, which signifies that there is a linear correlation between the two parameters. Therefore, the opening of the crack is directly proportional to the temperature.

The search for a link between the dynamic movement of the crack during a mine blast, and the static opening of the crack, that was different to the opening resulting from the temperature. The first stage consisted of analysing all the dynamic measurements and measuring the main characteristic, i.e. the deviation of the opening measured between before the mine blast and after the mine blast. The dynamic data from an extensometer were automatically analysed by specially developed software.

For each extensometer, by tracing a graph whose horizontal axis represents the level of vibration (PPV) and whose vertical axis represents the dynamic opening of the crack in mm (or in), we obtain a graph of the following type (Figure 14), where each point represents a level of vibration associated (synchronized) with a crack opening.

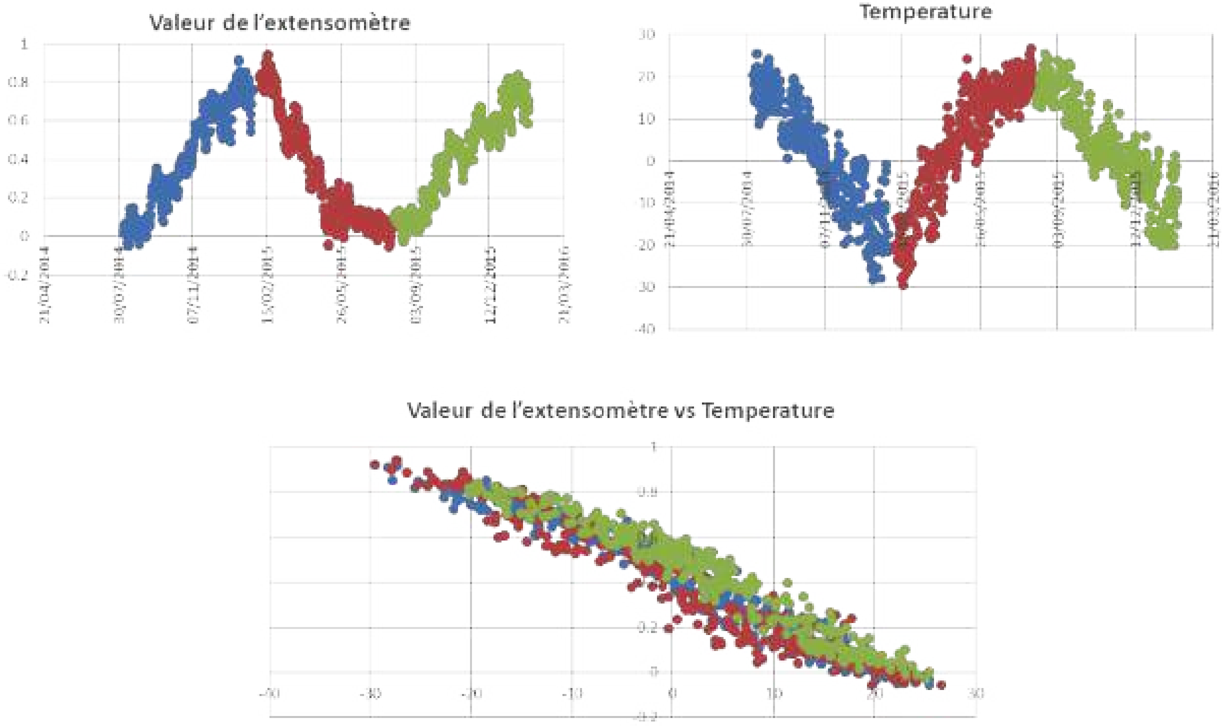

Figure 14 : Example of the correlation Value of the extensometer/Temperature

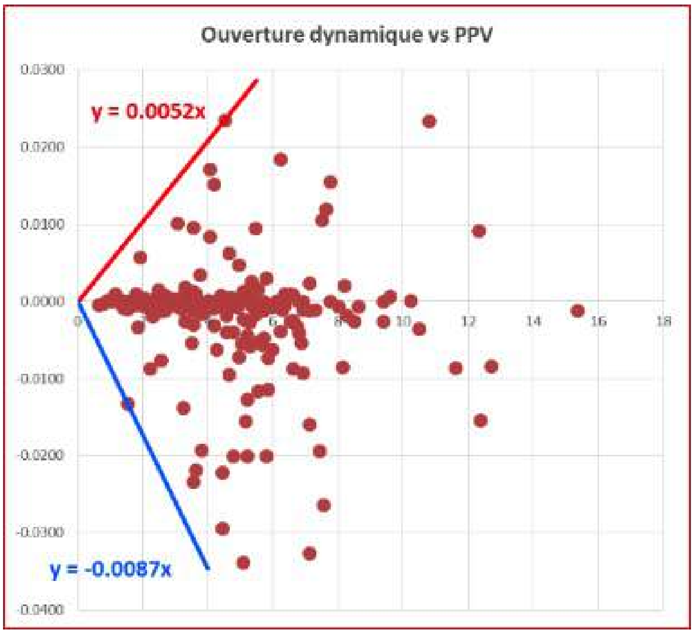

Figure 15 : Example of the dynamic opening correlation (Y axis)/PPV (X axis)

In this graph we can clearly see that all the points are situated in a cone following the dynamic opening correlation of the crack according to the level of vibration. The maximum dynamic opening increases with the level of vibration. The straight red line represents the straight envelope (positive values) and is the expression of the correlation: maximum dynamic opening of the crack in relation to the PPV. The straight blue line represents the straight envelope (negative values) expressing the correlation: maximum dynamic closure of the crack in relation to the PPV.

Example of information we can obtain from these measurements.

By making the hypothesis that such correlation (dynamic opening of the crack/level of vibration) continues to be linear for higher vibration levels, it is possible for each crack to extrapolate the level of vibration (Figure 21) that would lead to a dynamic opening of 0.2 millimetres (0.008 in) that represents an average value frequently quoted in reports as being a significant visible evolution threshold of a crack. As a result, we obtain a rough probabilistic PPV of 90 mm/s (3.54 in/s), which in some cases, might make some cracks evolve by opening 0.2 millimetres (0.008 in), a value which is significant when the solicitations are repeated. This value is taken as the hypothesis of a threshold that can dynamically change the crack beyond the elastic field, permanently.

It should be noted that this reasoning is valid both for the opening and closing of the crack.

WARNING: these values have no link with the level of vibration that might create a new crack in healthy material. To do so, we would need to attain the tensile breaking point, which for concrete, whose average compressive strength is 25 Mpa (3625 psi), and which has a density of 2.4, is approximately 2 500 mm/s (98 in/s).

7. Conclusion

The system that is developed, including synchronized geophones, extensometers and temperature sensors enables us to carry out measurements on the movement of cracks when seismic solicitations are created by mine blasts.

These simultaneous measurements provide answers to the question: Are mine blasts an aggravating factor in the opening of existing cracks?

Based on a relatively comprehensive equipment system for the surveillance of existing cracks, it has been possible to obtain the following findings: The main evolution of the opening of cracks is linked to variations in temperature. The linear behaviour, the proportionality between the static opening of a crack and temperature, is clearly identified with opening variations of a few tenths of millimetres.

The analysis of the dynamic opening of cracks (seismic solicitations) shows that cracks evolve with extremely low ranges (from a few microns to a hundredth of a millimetre) for vibration levels below 25 mm/s (1in/s). The opening is within the elastic field and the cracks return to their original opening a few minutes after the blasts.

An extrapolation of this dynamic opening enables us to provide a rough probabilistic estimate of 90 mm/s (3.54 in/s), which in some cases, might make some cracks evolve by opening or closing 0.2 millimetres (0.008 in), a value which is significant when the solicitations are repeated.

According to the direction of the mine blasts with regard to the houses, the cracks can react by closing during the seismic solicitation.

VERIFICATION OPTIMAL MILLISECOND TIMING DELAY OF BLASTING IN QUARRIES WITH ELECTRONIC DETONATORS

1 Prof. RNDr. Blažej Pandula, CSc. – Institute of Geosciencies BERG Faculty Technical University of Košice, Slovakia and SSTVP, Slovakia , blazej.pandula@tuke.sk
2 doc. Mgr. Julián Kondela, PhD. – Institute of Geosciencies BERG Faculty Technical University of Košice, Slovakia and SSTVP, Slovakia,
3 Ing. Ivan Buchla – Carmeuse Slovakia and SSTVP, Slovakia,
4 Ing. Ján Baulovič – B blast s.r.o., Slovakia and SSTVP, Slovakia
5 Ing. Marta Prekopová, PhD. – Institute of Geosciencies BERG Faculty Technical University of Košice, Slovakia,

ABSTRACT: Blasting induced vibration is one of the fundamental problems in the quarries and intense vibration can cause critical damage to environment nearby the quarries. Blasting operations generate seismic waves with different maximum particle velocity and wide spectrum of frequencies. This process depends on the properties of the rocks, properties of charges and technology of blasting. It is very important to study how to control vibration induced by blasting in the mitigation of negative effects of blasting in quarries. Maximum values of the particle velocity are depended on great number of different factors. Using the electronic detonators, an optimal millisecond interval has been sought to reduce the intensity of vibrations due to interference of seismic waves. Experiments confirmed the theoretical assumptions that the greatest reduction in vibration intensity occurs when seismic waves are in the opposite phase. The results of the experiments were confirmed in practice during the operation of the blasting works in various quarries in the Slovak Republic.

1. INTRODUCTION

Blasting technology has dominantly developed from the invention of dynamite by Alfred Nobel in 1867 and from this time blasting operations have become a more effective and efficient method of blasting. On the other hand blasting brings about a lot of problems due to noise and vibrations. First of all vibrations generated by blasting can damage the nearby buildings and evoke a sense of discomfort for inhabitants. The reduction or the regulation of the vibration impact means a problem for most of quarries. Bench blastings are generally known as an effective way of vibration reduction. Applying this method the particular charges in the boreholes are blasted one after another with a certain time delay. There is a mutual interference in the seismic waves activated during the blasting operations and the Peak Particle Velocity (PPV) can be reduced by means of appropriate timing. In spite of theoretical simplicity it is mostly much more difficult to forecast PPV in an adequate precise way because of failing in timing delay between particular charges and nonhomogeneous rock medium.

Different studies have been worked out on vibration regulation and moreover the following well-known practical methods were applied (Persson et.al., 1994, Langefors and Kihlström, 1978), whose recommendations are as follows:

1) Application of time delay between the boreholes;
2) Reduction of borehole numbers in the same time delay;
3) Application of multi-row blastings and appropriate time delay between rows;
4) Application of charge distribution and appropriate timing between charges ;
5) Division of quarry wall into more benches and as a consequence it leads to charge capacity reduction for one borehole.

According to the above mentioned facts it can be assumed that the application of time delay is advantageous for local vibration reduction because the verified time scheme of blasting operations has to be applied. Although this method was proposed by Langefors (Langefors and Kihlström, 1978), we have found out that the accuracy of this method is not always sufficient. The accuracy of detonation timing by means of conventional pyrotechnical detonators presented a problem which was solved by introduction of electronic detonators. The application of electronic detonators enabled the vibration reduction.

The development of highly precise digital electronic detonators enabled a very precise timing of blasting operations. The vibrations can be reduced by applying the principle of superposition of waves in the phase or in the opposite phase (Leššo, 2018). The key factor leading to the vibration reduction is the appropriate timing delay. The optimum timing delay was firstly described in the literature (Duwall and Fogelson, 1962), which was applied for the millisecond timing delay of blastings in quarries.

At blasting operations it is assumed that the method of timing delay calculation is derived from the propagation velocity of seismic waves and their frequency.

Furthermore the calculation of the timing delay takes into consideration the effect of disturbance by means of the superposition of seismic waves. Two seismic waves can achieve the maximum disturbance of vibration when the timing delay is the half-period of waves propagation. In the literature (Ogawa, 1994, Dojčár and Pandula, 1998) the timing delay is stated according to the experience of many projects. Langefors proposed the interval of millisecond timing delay as follows $\Delta t = T/2$ (T is the period of vibration waves), which enables the mutual interference of the most of vibrations under the condition of the constant vibration cycle and the same vibration types. Wada found out that if the model of linear superposition is applied for the regulate vibration the best result can be achieved if the timing delay error is less than 1–3 ms (at all, 1994).

The times of delay are assessed both according to the effect of rock medium disintegration and the effect of waves ´superposition. The structural characteristics of the rock medium, in which the blasting operations are carried out, can be identified by means of the measurement of propagation velocity of seismic waves in situ (Pandula and Kondela, 2010).

At millisecond timing of blasting operations there can be observed the simultaneous wave propagation from different sources. If there is a phase difference of two waves in a certain point 2 or another paired multiple, it leads to an interferential amplification. If the phase difference is an unpaired multiple, there comes to an interferential attenuation. The different cases of interference are very complicated because the interfering waves can differ from each other in wave length, amplitude, phase and direction of wave propagation. The simpliest presence of interference is the one of two wave propagations with the same wave length, spreading through the rock medium with the same phase velocity and the same direction. This is the case of blasting operations. The final interference amplitude of two equivalent wave propagations is the highest in the place of seismic waves collision with the same phase and on the contrary the lowest is in the place of seismic waves collision with the opposite phase. Therefore it is necessary to draft the millisecond timing of blasting operations on dependence of structural characteristics of rock medium, which is characterized by the velocity and frequency of seismic waves (Tatsuya and all., 2000).

In this paper there are presented the single-row millisecond blastings in boreholes in which the boreholes were initiated one after another from the boundary with predefined timing delay. We assume that the possibility of reproduction of single-row blasting is quite effective , in other words, the seismic waves propagation from each point of blasting proves the same procedure. At the same time each blasted borehole contains the same charge. The borehole length, the borehole distribution and the borehole size were the same as this principle is commonly applied in blasting operations and moreover it corresponds with current draft method of blasting operations. (Kou and Rustan, 1992).

2. EXPERIMENTAL MEASUREMENTS IN THE QUARRY TREBEJOV

2.1. BRIEF DESCIPTION OF THE GEOLOGICAL OBJECTS NEARBY THE QUARRY TREBEJOV

In the quarry Trebejov in the East from the village Trebejov there can be found the Ramsau dolomites. The dolomites are from light gray to gray only rarely they are dark gray. The thickness of the dolomite rock beds in the quarry Trebejov vary from 10 to 100 cm. Sometimes they appear such as massives. As they are rheologically really hard rocks they create in the terraine morphologically dominant shapes. There can be found mainly microcrystallic sometimes thicker crystallic dolomites with a low content of fossils first of all lamellibranchia, dasycladacean – presumably diplopora. Residuals of crinoids can be observed only rarely in the dolomites.

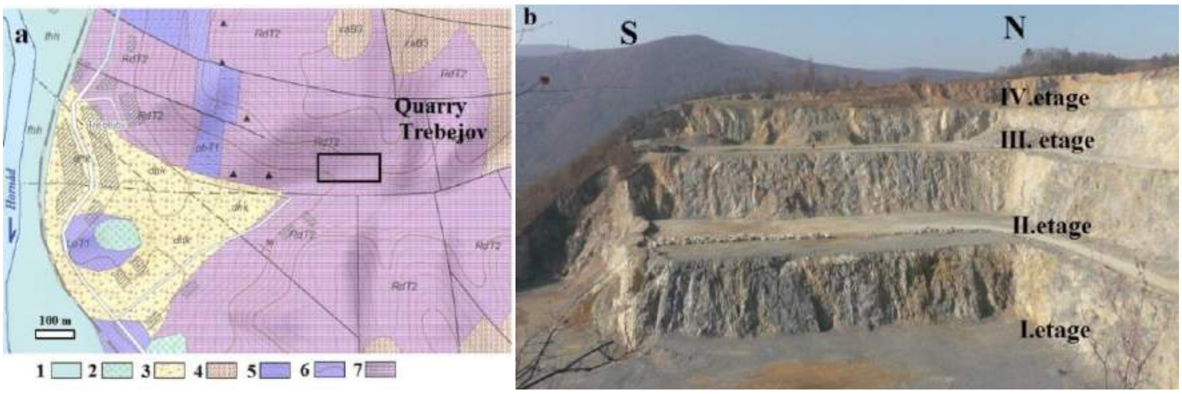

Figure 1. Geological map of the surroundings of the quarry Trebejov(a) and the view in Quarry(b). Quaternary: 1 – clay, gravel, sand (Holocene), 2 – sandy gravel, gravel (Pleistocene), 3 – deluvium (unstructured) mainly loam stony,Neogene: 4 – klčovské formation varhaňovské gravel: polymict, weathered, without pebbles of carbonates (upper Baden-lower Sarmatian), Mesozoic: 5 – variegated clayey shales, clay sandy shales, with interbeds of quartzite (lower Trias), 6 – lúžňanské formation– quartzite, quartzite sandstone, locally with the interbed shales (lower Trias), 7 – Ramsau dolomites (ladin).

In many places of the quarry the dolomites are karsificated along the tectonical structures or they create breccia. From the microstructural point of view there are present dolomicrites, but sometimes sparite can be found in the ortochemical component.

2.2. MEASUREMENT METHODOLOGY AND APPLIED INSTRUMENT AT BENCH BLASTING MEASUREMENT

For the measurement and graphical record of the seismic effects of blasts the following digital seismic instruments were applied at the particular measuring standpoints.:

- vibrograph UVS 1504 seismorecorder by the firm ABEM - S1,
- vibrograph ABEM Vibraloc and seismorecorder by the Swedish firm ABEM - S2 and S3,
- vibrograph VibraZEB VM-7D+ and seismorecorders by the firm Vibra - S4,
- vibrograph Mini - SuperGraph

  and seismorecorders by the firm Nomis – S11,
- vibrograph Minimate Pro6 and seismorecorders by the firm Instantel - S12,
- vibrograph Svantek and seismorecorders by the firm Svantek - S12,
- seismograph Terraloc Mk8 by the firm ABEM - profile T1-T4.

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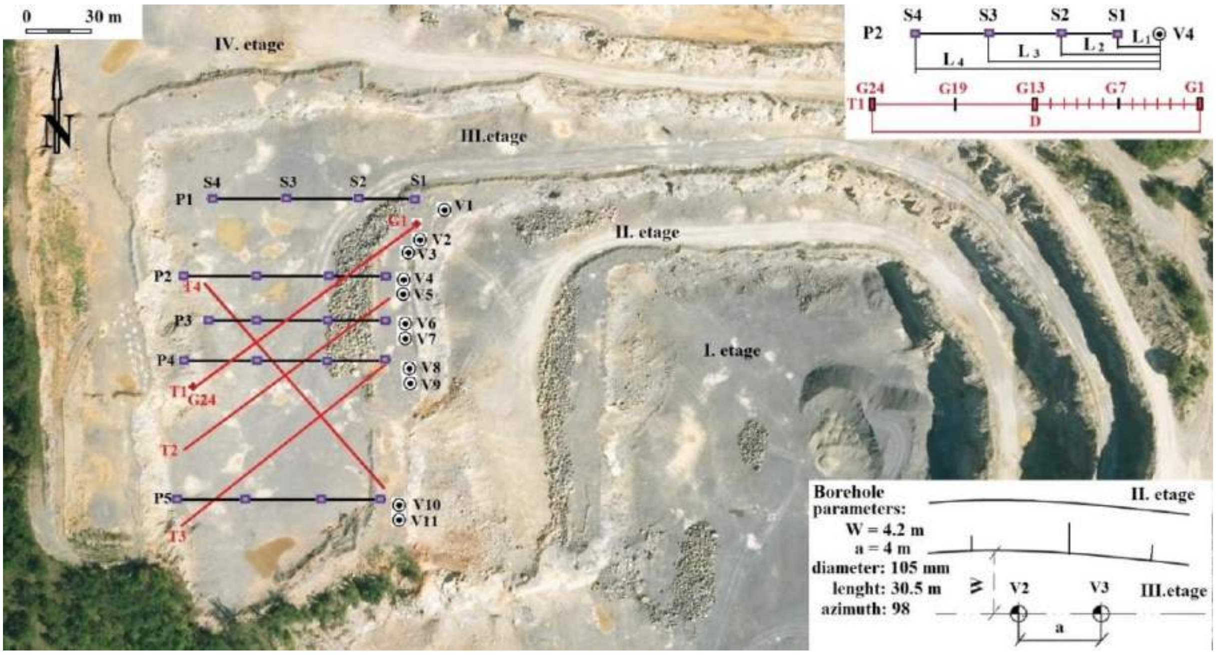

Figure 2. Position of experimental blasts No. 693 (V1), No. 694 (V2,V3), No. 695 (V4,V5), No. 696 (V6,V7), No. 697 (V8,V9) and No. 698 (V10, V11) in the quarry Trebejov in relation to the measuring profiles P and T. L_1=32,5 m L_2=40 m, L_3=60 m, L_4=80 m. Distance between G1 and G13 = 48 m, between G1 a G24 =96 m.

bore-hole	blast No.	blast coordinates			Distance from the blast to the measuring standpoint S12 (m)	
		x	y	Z	oblique	horizontal
V 1	693	-264218.93	-1226642.99	348.96	-	644
V 2	694	-264226.31	-1226658.40	348.83	-	636
V 4	695	-264228.14	-1226675.40	348.94		634
V 6	696	-264229.68	-1226692.32	348.96		632
V 8	697	-264233.44	-1226708.96	348.95		629
V 10	698	-264239.07	-1226785.96	348.05		631

Table 1. Data on position of the bench blasts and distance of measuring standpoints (family house) from the blasts (Figure 2)

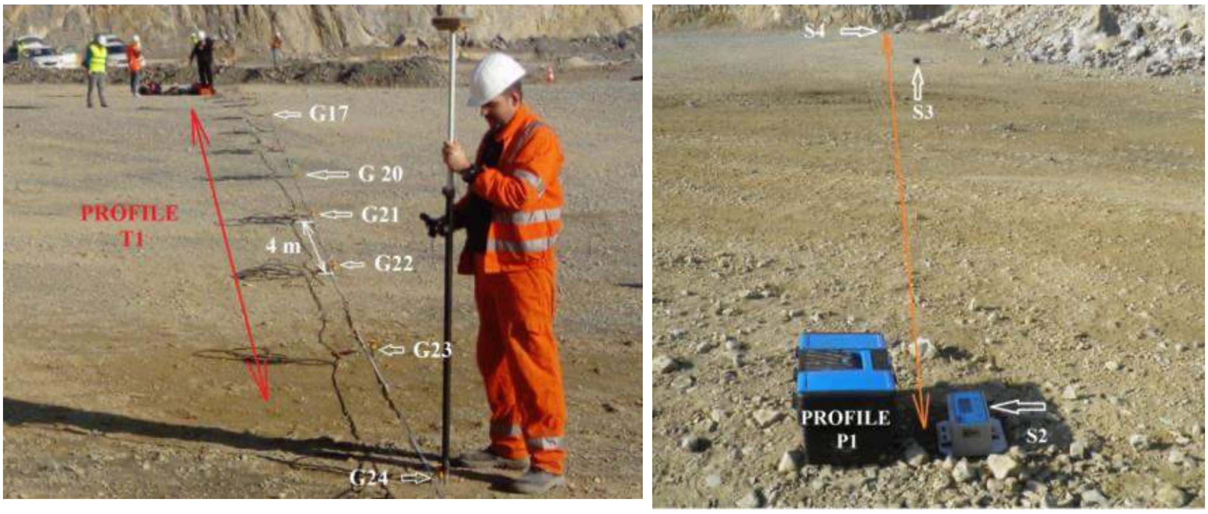

Figure 3. Measurement of seismic profile position T1 at the III. Etage with the seismic apparatus Terraloc Mk 8 during the measurement of propagation velocity of seismic waves at No. 693 and 694 in the quarry Trebejov. Position of the vibrograph Vibraloc ABEM at the measuring profile P1, standpoint S2 at the distance 26,5 m from the borehole mouth V1 measuring the vibration velocity during the experimental blasts No. 693 and 694 in the quarry Trebejov.

Figure 4. The monitored building object No. 91 in the village Trebejov and the measuring standpoint S11 and S12 at the entrance to the building object No. 91, wih the position of three-component vibrograph Mini-SuperGraph and Minimate Pro 6 in the village Trebejov.

For the measurement of the seismic effects on the measuring standpoint S11 the digital four-channel vibrograph Mini - SuperGraph and the seismorecorders by the firm Nomis were used. (Figure 4). The measuring standpoint S12 was placed in the interior of the building object No. 91 and at the entrance of the cellarage of the examined object – dwelling house No. 91. At the measuring standpoint S12 there were placed the vibrographs in the middle of the hall at the wall and Minimate Pro 6 in the entrance. The vibrographs provide a digital and graphic record on all three vibration velocity components of the environment,horizontal, longitudinal– $\mathbf{v_x}$, horizontal lateral– $\mathbf{v_y}$, vertikal– $\mathbf{v_z}$.. The vibrographs UVS 1504, Minimate Pro 6, Mini-SuperGraph and ABEM Vibraloc have an AD converter with automatic 14 bit dynamic extent which corresponds to 0,05 ÷ 250 $mm.s^{-1}$. For these measurements the electrodynamic geophones were applied with frequency extent 1 ÷ 1000 Hz and responsiveness 20 $mV/mm.s^{-1}$. Furthermore the three-component geophone by the firm Instantel with frequency extent 2 ÷ 1000 Hz and responsiveness 10 $mV/mm.s^{-1}$. was applied. The geophones were set on a special support with sharp steel spikes which assured continual contact with the foot. The vibrographs operate autonomously, they carry out tests of channels automatically without any intervention and influence of the operator recording the measured and registered characteristics of the vibration. Simultaneously with measurement of the vibration velocity and their attenuation at the profiles P there were measured the propagation velocity of the seismic waves applying the seismic apparatus Terrraloc Mk8 (Figure 3).

3. VIBRATION SOURCES

The sources of the seismic effects were the experimental blasts No. 693 – 698 at the dolomite layer of the quarry Trebejov situated ca 0.5 km in the East from the village Trebejov. The borehole size was 105 mm, slope 65°, depth 30.7 m and borehole distribution 4.0 m. The charge capacity in one borehole was 180 up to 190 kg of explosives Andex and 5 kg of explosives Poladyn 31 Eco (Table 3). The total charge capacity was 2042 kg. The blasts were carried out by means of electronic timed detonators UNITRONIC 600 (Figure 5). The experimental blast No. 693 was carried out at time 0 in one borehole V1. The experimental blast No. 694 was carried out in two boreholes V2 and V3 with millisecond timing 0 and 1 ms. The experimental blast No. 695 was carried out in the boreholes V4 and V5 with millisecond timing 0 and 5 ms. The experimental blast No. 696 was carried out in two boreholes V6 and V7 with millisecond timing 0 and 10 ms. The experimental timing No. 697 was carried out in two boreholes V8 and V9 with millisecond timing 0 and 15 ms.

The experimantal blast No. 698 was carried out in the boreholes V10 and V11 with millisecond timing 0 and 20 ms (Table 3). Before charging the inclinometer the measurement of the boreholes V1 up to V11 was accomplished. (Figure 5). The placement of blasts in the quarry Trebejov is illustrated in Figure 2.

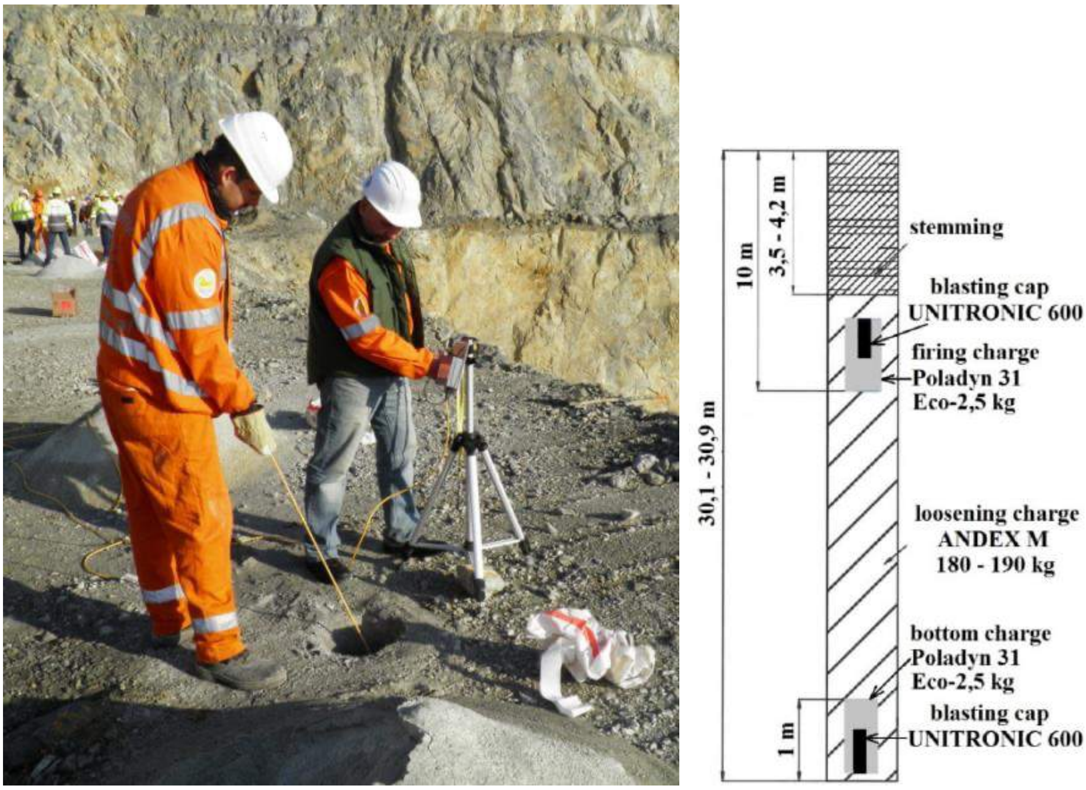

Figure 5. Charging, incklinometer measuring of boreholes and construction of charges No. 693 - 698 at the III. etage of the quarry Trebejov.

Blast no.	Bore hole	ANDEX M kg	Poladyn 31 Eco kg	Charge kg	milisecond timing		milisecond delay
					bottom charge	firing charge	
693	V1	180	5	185	0	50	0
694	V2	180	5	370	0	50	1
	V3	180	5		1	51	
695	V4	180	5	370	0	50	5
	V5	180	5		5	55	
696	V6	175	10	370	0	50	10
	V7	180	5		10	60	
697	V8	180	10	377,5	0	50	15
	V9	180	7,5		15	60	
698	V10	180	5	370	0	50	20
	V11	180	5		20	70	

Table 3. Data on applied explosives and millisecond timing at the experimental blasts No. 693 - 698

4. MEASURED VALUES

In advance to the measurements the apparatuses placed at the measuring standpoints were calibrated and their responsiveness was checked. At the measuring standpoints the graphical course was recorded of the individual components of seismic vibration at experimental blasts No. 693 – 698. The individual graphical records last four seconds. Fig. 6. The vibrographs were positioned at the measuring standpoints enabling assessment of impact generated by the technical seismivity on the surveyed objects. During this measurement we placed the measuring equipment UVS 1504, in the quarry Trebejov at the measuring standpoint S1 in nearby distance from the boreholes of experimental blasts.

At the standpoints S2 and S3 the seismic apparatus Vibraloc was placed. At the measuring standpoint S4 there was situated the measuring apparatus VibraZEB VM-7D+. This way there were created the measuring profiles from P1 to P5 near to the experimental blasts No. 693, 694, 695, 696, 697 and 698, which enabled to achieve the values of vibration velocity. (Tables 4 and 5) in order to assess in a very precise way the principle of the seismic waves attenuation law from the blasts to the receptors, the surveyed object in the village Trebejov. The measured values at the different measuring standpoints are demonstrated in the Table 4.

For the measurement of vibration velocity and frequency of seismic waves from the blasts the 24 channel seismic apparatus Terraloc Mk8 was applied . The recorded seismic entry from the experimental blast No. 693 is illustrated in Figure 7.

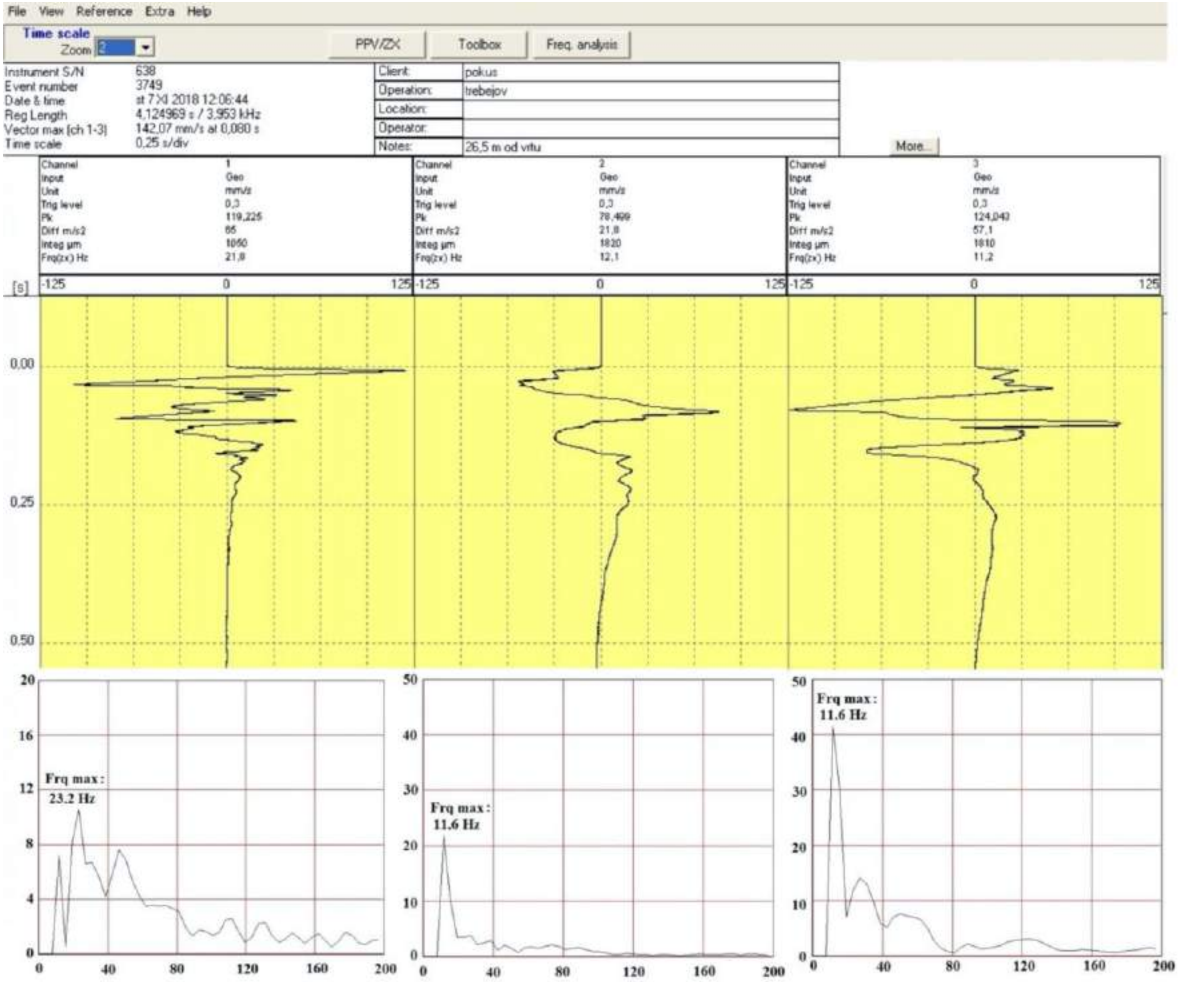

Figure 6. Grafical record and frequency analysis of particular vibration components according to the measurements at the standpoint S2 (26,5 m from the blast) in the quarry Trebejov – seismic apparatus ABEM Vibraloc at the experimental blast No. 693 at the profile P1. The first channel-z, the second channel-x, the third channel-y at the standpoint No. 693.

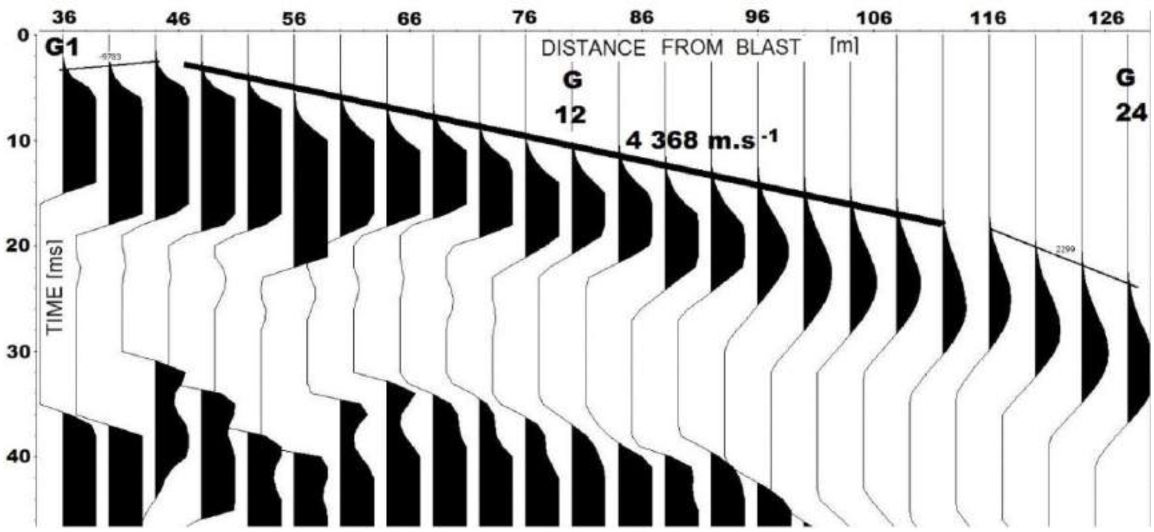

Figure 7. Seismic record accomplished with measuring apparatus Terraloc Mk8 of the profile T1 at the measuring standpoint No. 693 with identified propagation velocity of seismic wave 4368 m.s-1, frequency 24 Hz in the rock medium of the dolomites in the quarry Trebejov

5. MEASURED SEISMIC EFFECTS OF THE BENCH BLASTS AND THEIR ANALYSIS

Due to the analysis of frequencies of seismic waves propagation at the profiles measured with the apparatus Terraloc Mk 8 it can be stated that the frequencies at the individual profiles are different having the value mostly lower than 30 Hz (Tab. 4). These frequencies correspond to the extent of rock medium violation which were exposed to seismic waves generated by experimental blasts No. 693 – 698.

According to the theory on seismic waves propagation and attenuation the biggest attenuation can be achieved at millisecond timing only if the waves generated by further blast are in the opposite phase. Due to the calculations made by Leššo, at the frequency 35 Hz of the seismic waves it can be achieved applying the millisecond timing 14 ms (Leššo, I., 2018). In case of seismic waves propagation 4300 $m.s^{-1}$ measured with the seismic apparatus Terraloc Mk8 this maximum attenuation can be achieved in distance 60 m from the blast. At the seismic waves frequency 30 Hz it can be achieved by millisecond timing 17 ms. This attenuation can be achieved in the distance 70 m from the blast. In case of seismic waves frequency 25 Hz it can be achieved by millisecond timing 20 ms.

Table 4. Measured values of the frequency of seismic waves propagation at the profiles from T1 to T4

blast No. 693	Profile T-1			
Distance [m]	**30**	**40**	**60**	**80**
Frequency[Hz]	22,7	24,5	23,8	20,4
No. 694	Profile T-1			
Distance [m]	**30**	**40**	**60**	**80**
Frequency[Hz]	36,5	27	22,7	20,4
No. 695	Profile T-2			
Distance [m]	**30**	**40**	**60**	**80**
Frequency[Hz]	29	21	23,5	21,3
No. 696	Profile T-2			
Distance [m]	**30**	**40**	**60**	**80**
Frequency[Hz]	26	22	20,2	21,3
No. 697	Profile T-3			
Distance [m]	**30**	**40**	**60**	**80**
Frequency[Hz]	23,5	22	23,5	15,7
No. 698	Profile T-4			
Distance [m]	**30**	**40**	**60**	**80**
Frequency[Hz]	29	24,7	17,9	13,5

Blast No.	Profile	standpoint	V_x mm.s^{-1}	V_y mm.s^{-1}	V_z mm.s^{-1}	F_x Hz	F_y Hz	F_z Hz	L m
693.	-	village Trebejov 1	0,81	1,15	0,81	15	6,5	23,2	644
694.	-	village Trebejov 1	1,46	1,55	1,26	13,8	7,5	0,87	636
695.	-	village Trebejov 1	1,59	1,13	0,87	9,8	6,6	23,2	634
696.	-	village Trebejov 1	1,23	1,63	0,81	9,1	10,2	10,2	632
697.	-	village Trebejov 1	1,2	1,62	0,82	8,1	9,4	10,6	629
698.	-	village Trebejov 1	0,98	1,58	0,58	6,7	7,5	10,2	631
693.	-	village Trebejov 2	0,87	1,02	0,67	5,1	6,6	11,7	654
694.	-	village Trebejov 2	1,48	1,33	1,0	5,1	5,9	12,5	646
695.	-	village Trebejov 2	1,49	0,99	0,66	5,1	7,3	12,5	644
696.	-	village Trebejov 2	1,11	1,07	0,75	5,1	7,3	12,5	642
697.	-	village Trebejov 2	0,85	1,13	0,75	5,1	7,3	12,5	639
698.	-	village Trebejov 2	0,76	1,08	0,53	5,1	6,6	5,9	641
693.	P1	Quarry Trebejov S1	121	105	111	1,1	14	0,3	32,5
693.	P1	Quarry Trebejov S2	78,5	124	119	12	11	23	40
693.	P1	Quarry Trebejov S3	45,9	43,4	64,8	15	22	38	60
693.	P1	Quarry Trebejov S4	16,48	22,13	29,34	10	20	21	80
694.	P1	Quarry Trebejov S1	111	102	101	0,3	14	9,6	32,8
694.	P1	Quarry Trebejov S2	99,3	119,1	192	17	6,1	23	40.2
694.	P1	Quarry Trebejov S3	63,1	71,1	59,4	10	25	9,8	60.2
694.	P1	Quarry Trebejov S4	39,2	38,58	48,26	13	22	21	80.1
695.	P2	Quarry Trebejov S1	111	111	102	6,2	24	0,3	32.5
695.	P2	Quarry Trebejov S2	87,5	99,7	156	11	19	18	40
695.	P2	Quarry Trebejov S3	55,4	17,3	81,6	15	1,2	32	60
695.	P2	Quarry Trebejov S4	61,01	20,76	59,84	10	2	25	80
696.	P3	Quarry Trebejov S1	111	110	108	0,3	7,8	0,3	32.5
696.	P3	Quarry Trebejov S2	122	36,7	82,7	14	8,6	14	40
696.	P3	Quarry Trebejov S3	28,1	24,1	43,7	7,6	22	23	60
696.	P3	Quarry Trebejov S4	32.95	17.55	25.34	9	20	20	70.7
697.	P4	Quarry Trebejov S1	111	112	84	0,7	17	10	32.5
697.	P4	Quarry Trebejov S2	78.3	45.6	110	9,6	4,2	11	40
697.	P4	Quarry Trebejov S3	33.2	24.5	25.7	10	17	22	60
697.	P4	Quarry Trebejov S4	32.63	24.20	29.63	9	14	20	80
698.	P5	Quarry Trebejov S1	119	109	110	1.1	7.2	0.3	32.5

698 .	P5	Quarry Trebejov S2	89.5	63.3	99.1	8.9	8.7	31	40
698 .	P5	Quarry Trebejov S3	48.4	49.6	30.0	29	22	19	60
698 .	P5	Quarry Trebejov S4	17.19	8.7	30.35	19	19	32	78

Table 5. Measured values of peak [v] and frequency particle velocity experimental [f] at the blasts No. 693 - 698

This maximum attenuation can be achieved in the distance 86 m from the blast. At the seismic waves frequency 20 Hz it can be achieved by millisecond timing 25 ms. This maximum attenuation can be achieved in the distance of 107 m from the blast. At the seismic waves frequency 15 Hz it can be achieved by millisecond timing - 33 milliseconds. This maximum attenuation can be achieved in the distance of 142 m from the blast. Due to the frequencies of seismic waves measured at the seismic profiles it can be stated that the average frequency of seismic waves at the profiles is 22 Hz. The optimum millisecond timing corresponding to this frequency is 23 ms and the distance in which this maximum attenuation can be achieved is in this case 99 m from the blast.

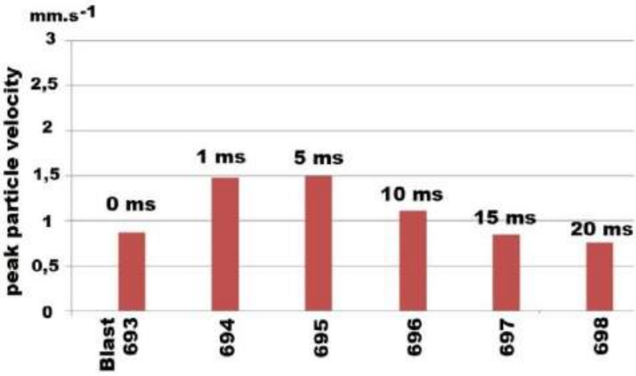

Figure 8. Grafical presentation of measured maximum values of peak particle velocity x at the standpoint S12 (buiding object No. 91 in the village Trebejov) at millisecond timing.

In Figure 8 there are demonstrated the maximum values of peak particle velocity at the standpoint S12 (building object No. 91 in the village Trebejov) at the experimental blasts No. 693, 694, 695, 696, 697 and 698. It can be observed in the graphical presentation that the highest attenuation of the seismic waves generated by blasting operations in the quarry Trebejov and the lowest values of the peak particle velocity at the building object No. 91 were achieved by applying millisecond timing 15 ms and 20 ms. The highest values of vibration velocity were measured at millisecond timing 5 ms. In case of timing 20 ms (blast No. 698) there was achieved a lower value of peak particle velocity than at blast No. 693, at which one borehole was blasted.

6. CONCLUSION

The results of the seismic effects measurements at the experimental blasts No. 693 – 698 on 7 November 2018, carried out in the quarry Trebejov, proved that the highest attenuation of seismic waves generated by technical seismicity in the quarry Trebejov was achieved at millisecond timing 15 milliseconds and 20 milliseconds. The lowest values of peak particle velocity 0.53 $mm.s^{-1}$ at the surveyed object were recorded at millisecond timing 20 milliseconds at experimental blast No. 698.

The accurate millisecondtiming was enabled due to electronic detonators Unitronic 600.

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EXPLOSIA

46th annual ISEE Conference on Explosives and Blasting Technique in Denver, USA

Roger Holmberg

The 2020 ISEE Conference was held at the Hyatt Regency hotel at the Conference Centre area in downtown Denver. Some 125 Exhibitors were participating and took up the whole exhibit hall and its foyer. More than 1500 people were registered and attended the conference.

At the 46th ISEE conference in Denver members of the EFEE Environmental Committee Johan Finsteen Gjødvad and Mathias Jern presented a paper "Vibration Monitoring Standards to the use of Explosives in Different Countries".

Johan Finsteen Gjødvad and Mathias Jern

On Sunday January 26th there was a Regulatory Panel Discussion where many aspects on existing regulations were presented and discussed. FAA-Federal Aviation Administration regulation on drones, ATF regulations, Pipeline blasting regulations and European blasting regulations-various Vibration Standards.

Johan Finsteen Gjødvad excellently reviewed the work the EFEE Environmental Committee has performed and the answers they had received from all their questions regarding vibration standards they had received from various countries.

On Monday 27th Mathias Jern presented his and Johan Finsteen Gjødvad´s work with similar focus on the found differences, similarities, traditions and possibilities in the different standards and use of these around the world.

At the meeting the updated EFEE/ISEE Support Agreement was signed by the new incoming ISEE President Alastair Torrance, ISEE Executive Director J. Winston Forde and EFEE Secretary General Roger Holmberg.

New ISEE President Alastair Torrance and Roger Holmberg

It was announced that the 47th ISEE Conference will be held in Orlando, FL, USA in February 7-10, 2021 and we are looking forward to this event.

Furthermore: Johan Finsteen Gjødvad was elected as a new member of the ISEE Board of Directors for one year.

Johan will focus on the cooperation between the two associations ISEE and EFEE and co-chair the ISEE standard committee as well as the international committee.

The International Blasting Technology Conference in Slovakia

Teele Tuuna

Slovakia has a very long history of mining. There has been mining from opals to aggregate, gold, silver, copper and of course the world´s largest magnesite deposits. Due to the large scale of mining activities, Slovakia is also considered as one of the fastest developing country in Europe. And so it is proven also on the International Blasting Technology Conference which is held in springtime, annually in the Tatra high mountains. The focus on the conference presentations is actually very wide, starting with blasting at mineral extraction, tunnels, demolition and other purposes; new products for blasting and drilling; vibration measurements; safety, health protection, accidents, environment and many more.

Examples of Slovakian mining then and now.

This year, the conference is taking place for the 32nd time. It has visitors and presentations from many different countries, Slovenia, Czech, Romania, Austria, Poland, Azerbaijan, Germany and many other. Quests can enjoy interesting new information and also the scenery of beautiful Tatra mountains.

First of all, a moment of recognition for the most remarkable members of the industry in Slovakia

The usual place of the conference in the middle of Tatra Mountais.

Slovakia, besides mining is also a country of castles and beautiful landscape

It is also a tradition to introduce the country to foreign visitors. All the caves, high mountain views, castles and of course wonderful food in cities and country side ar in the rich schedule. Slovakia is filled with surprises.

The conference is an excellent opportunity to share experiences but also to renew contacts and possibly create new business opportunities. It usually takes place in May A great way to start the season.

New EFEE members

We would like to welcome the following member who have recently joined EFEE

Associate Member

FEEM, Federation of European Explosives Manufacturers, Bruxelles, Belgium

Individual Members

Alexander von Oertzen, BAM, Germany

Upcoming International Events

EUROCK 2020
June, 15-19, 2020
Trondheim, Norway
http://www.eurock2020.com/hjem.cfm

HILLHEAD 2020
June, 23-25, 2020
https://www.hillhead.com

WORLD TUNNEL CONGRESS 2020
11-17 September, 2020
Kuala Lumpur, Malaysia
www.seacetus2017.com/4/443/welcome-to-malaysia/

15TH INTERNATIONAL CONFERENCE ON
DRILLING AND BLASTING TECHNOLOGY–2020
September 16th-18th, 2020
Velence, Hungary
www.mare.info.hu

MINExpo INTERNATIONAL 2020
September 28-30, 2020
Las Vegas, Nevada, USA
https://www.minexpo.com/

EUROCK 2020
June, 15-19, 2020
Trondheim, Norway
http://www.eurock2020.com/hjem.cfm

HILLHEAD 2020
June, 23-25, 2020
https://www.hillhead.com

SAFEX International Congress #20
May 21-26, 2021
Salzburg, Austria
https://iexpe.org/safex-congress-bulletin-call-papers/

15TH INTERNATIONAL CONFERENCE ON
DRILLING AND BLASTING TECHNOLOGY–2020
September 16th-18th, 2020
Velence, Hungary
www.mare.info.hu

SME Annual Conference
February 28-March 3, 2021
Denver, CO, USA
www.smeannualconference.com

ISEE 47th Annual Conference on
Explosives and Blasting Technique
February 7-10, 2021
Orlando Florida, USA
https://www.isee.org

Upcoming National Events

Blasting technique and pyrotechnics 2020

September 23 – 25, 2020

Place: Hotel Valeč, Czech Republic

Official language: Czech (foreign presentations in English)

Website/Contact info regarding the conference: www.sttp.cz

EFEE is looking for a MARKETING ASSISTANT

The European Federation of Explosives Engineers is having great success in our work and are looking for a marketing assistant to move a former voluntary position to being professional.

The primary objectives of the Federation are:

a) Promotion of standardisation and harmonisation of explosives training in Europe.
b) Promotion of explosives technology in all fields related to this technology.
c) Promotion of a Pan European Certificate of Competence for Shot-firers regarding the blasting work with explosives ultimately, to promote a European Shot-firing Certificate.
d) Promotion of safety, health, environment and security in the field of explosives technology.
e) The fostering of the image of the profession as well as good relations and co-operation with related associations.
f) Collaboration on the development of laws and regula9ons within the EFEE field of activities.

You can read more about EFEE on www.efee.eu

Your main tasks will be:

- Marketing of advertisement space in our Newsletter
- Marketing for EFEE membership
- Maintenance and control of EFEEs SoMe platforms

It is expected that the new Marketing Assistant should be self-motivated, innovative and able to form the position in cooperation with the EFEE chairman of the Marketing and Membership committee, the General Secretary and the EFEE president. The Marketing Assistant should furthermore have an adequate written and verbal English and an enthusiasm for sales work. Knowledge of other languages will also be noticed. Equally it is an advantage to have existing knowledge of the explosives business.

Initially the position is posted as a part time position for between 20 to 30 h a month. Which will increase as the role develops.

Enquiries and applications with a CV and salary request should be sent to the Secretary general at info@efee.eu. Deadline is the 8th of May 2020.