4th BALKAN MINING CONGRESS

18th - 20th October 2011
Ljubljana, Slovenia

General sponsor

PAPER'S BOOK

4th BALKAN MINING CONGRESS

18th - 20th October 2011
Ljubljana, Slovenia

CIP - Kataložni zapis o publikaciji
Narodna in univerzitetna knjižnica, Ljubljana

622(082)

BALKAN Mining Congress (4 ; 2011 ; Ljubljana)
Paper's book / 4th Balkan Mining Congress, 18th-20th October 2011, Ljubljana, Slovenia ; [editors Milan Medved, Milivoj Vulić]. - Velenje : Coal Mine, 2011

ISBN 978-961-269-534-7
1. Medved, Milan, 1960-
258079488

PROCEEDINGS

4th BALKAN MINING CONGRESS 2011, LJUBLJANA, SLOVENIA

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Publisher:

Velenje Coal Mine

For Publisher:

Doc. Dr. Milan MEDVED

Technical design:

Damjan KONOVŠEK, Ivo Hans AVBERŠEK

Printed by:

Velenje Coal Mine

Copies:

250

Web: www.balkanmine.si
E-mail: info@balkanmine.si

Publishing is approved by University of Ljubljana, Faculty of Natural Sciences and Engineering, Department of Geotechnology and Mining, Ljubljana, Slovenia.
All papers are designed and reviewed.

Predgovor

Četrti balkanski rudarski kongres je uspešno nadaljevanje tradicije rudarskih kongresov, ki so se začeli pred šestimi leti v Varni v Bolgariji. Drugi kongres je potekal leta 2007 v Srbiji, v Beogradu, tretji pa pred dvema letoma v Izmirju v Turčiji.

Prav je, da se ob tej priložnosti spomnimo naših kolegov, ki so že pred desetletjem začeli razmišljati o načinu povezovanja balkanskih rudarskih strokovnjakov oziroma področja celotne Jugovzhodne Evrope. To so bili dr. Tzolo Voutov, prof. dr. Vekoslav Ivanov, prof. dr. Slobodan Vujić in prof. dr. Peter Daskalov. Na njihovo pobudo je bila leta 2004 v Sofiji konstituiran BALKANMINE, ki je povezal deset držav članic. Letos se bo tej zvezi pridružila enajsta članica, to je republika Slovaška.

Četrti mednarodni rudarski kongres Balkanmine je letos organiziran v Sloveniji, v Ljubljani. Zahtevno organizacijo je prevzel dr. Milan Medved, direktor Premogovnika Velenje, ki je tudi generalni pokrovitelj omenjenega dogodka. Ob tej priložnosti balkanski koordinacijski komite izreka iskreno zahvalo pokrovitelju in posebej predsedniku organizacijskega odbora, doc. dr. Milanu Medvedu, ki je znal spodbuditi sodelavce, da so uspešno pripravili ta veliki projekt.

Zahvalo za sodelovanje izrekamo tudi Inženirski zbornici Slovenije, Naravoslovnotehniški fakulteti Univerze v Ljubljani, Oddelku za geotehnologijo in rudarstvo, Slovenskemu rudarskemu društvu inženirjev in tehnikov ter Društvu inženirjev in tehnikov Premogovnika Velenje.

Lahko rečemo, da knjižna zbirka rudarskih zbornikov, z letošnjim vred, s svojo ureditvijo in slikovitostjo omogoča tudi širšemu krogu strokovne javnosti zanesljivo odkrivanje in spoznavanje področja, ki je zelo pomembno za utiranje poti skozi novi čas.

Verjamemo, da se bo na četrtem rudarskem kongresu Balkanmine spletlo mnogo poslovnih vezi in kvalitetnih izmenjav izkušenj. Prepričani smo tudi, da je rudarstvo v tem delu Evrope lahko pomembna sila pri iskanju izhoda iz krize in da bo peti balkanski rudarski kongres potekal v bolj prijaznem času za znanstveno-raziskovalno delo.

V imenu balkanskega koordinacijskega komiteja želim veliko ustvarjalne energije pri podajanju in poslušanju referatov ter prijetno počutje vsem udeležencem.

Srečno!

mag. Marjan HUDEJ
Predsednik koordinacijskega komiteja Balkanmine

BLASTING EFFECTS IN RELATION WITH COSTS AND TYPE OF EXPLOSIVES

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ABSTRACT

Blasting is the basic operation in open pit mines in obtaining hard rock masses and has an important influence on the costs in the obtaining useful mineral raw material.

The costs vary widely depending on the capacity of the open pit operation, the organisation, the machinery used as well as the professional support. The major goal of every professional man deployed in the process of blasting is to bring costs down to a minimum or to set and define parameters. The paper offers analyses of several blasting series in terms of normative materials used and successful blasting.

KEYWORDS

Quaring, Blasting costs, Explosives, Series, Design, Values

1 INTRODUCTION

Drilling, particularly blasting, as production processes require a good choice of equipment and method of blasting including the means of crushing of rock mass. The equipment used in drilling and crushing must be brought into accord with the physical-mechanical characteristics of the working environment.

The right determination of drilling-blasting parameters is of importance for the process of exploitation or the adequate granulation of the mined out material. It also has an effect on all other phases of exploitation. Achieving of the right granulation depends on the right choice of the above mentioned parameters.

The importance of the adequately selected drilling-blasting parameters can be seen from the fact that in some pits the technological process amounts to 40% of total costs, of which blasting costs alone amount to more than 80%. Blasting efficiency has a great influence on the productivity and the price of cost per unit product.

The calculation or dimensioning of parameters for drilling and blasting are the first step in setting the technique of drilling and blasting which later, in local conditions, can be modified and yield the best possible results.

2 CHARACTERISTICS OF THE BANJANI OPEN PIT MINE

The Banjani limestone deposit is situated on the south slopes of the Skopska Crna Gora, some 800 meters east of the village of Banjani. The mine is 11 km far from Skopje.

The lens-like ore body is 1200 m long and variable in depth between 100 and 400 meters. The depth has not been determined, but probably amounts to several meters. It extends towards NNW - SSE towards NE with an angle of dip of 50° 70° .

Marbelised limestone is a useful mineral raw material. It is white to yellowish in colour with coarse-grained crystalline structure and stratified texture.

The marbelised limestone of Banjani is massive with coarse-grained structure and irregular fracture surface with sharp rims. It is characterised by a large system of cracks and joints of various extensions, mainly of NNE - SSW strikes.

The main physico-mechanical characteristics of the limestone are.

Table 1: Physico-mechanical characteristics of the rock

Specific gravity	$\gamma_z = 2.2 - 2.65 [t/m^3]$
Specific mass	$\gamma_s = 2.73 [t/m^3]$
Embankment mass	$m_n = 1.6 [t/m^3]$
Porosity	0,01
Angle of internal friction	Ø = 32 – 66 °
Koefficient of Strength	3
Resistance to pressure	$\sigma = 115 - 182 [MPa]$

2.1 Drilling-blasting parameters

The basic drilling-blasting parameters that have a great effect on the blasting costs are given below. They may vary depending on the design of the blasting series, the type of explosive, the location of blasting series etc.

Table 2: Drilling-blasting parameters

Parameters	Drilling diameter (mm)	Depth of borehole (m)	Burden, W (m)	Distance between borehole s(m)	Length of stemmin g (m)	Length of inter stemmin g, (m)	Drilling angle (^{0})	Amount of explosive kg/boreh	Theoretical interval of delay, ms
Values	105	20 - 22	3,5 - 4,0	3,5 - 4,0	3,0 - 4,0	0,5 - 1,0	75 – 85	140-150	17

Tip of explosive which is in use is diferent and depends of blasting series. The tip of explosives are: Amonit, AN-FO and Elotol. Initiating means which used in this series are: Deton. fuse C-12, Cap N^0 8, NONEL - sistem, Busters PP400. The amount of explosives per meter in hole is 6,5 - 8,5 kg/m$^!$, and per one hole is 140 - 150 kg depends of tipe of explosive.

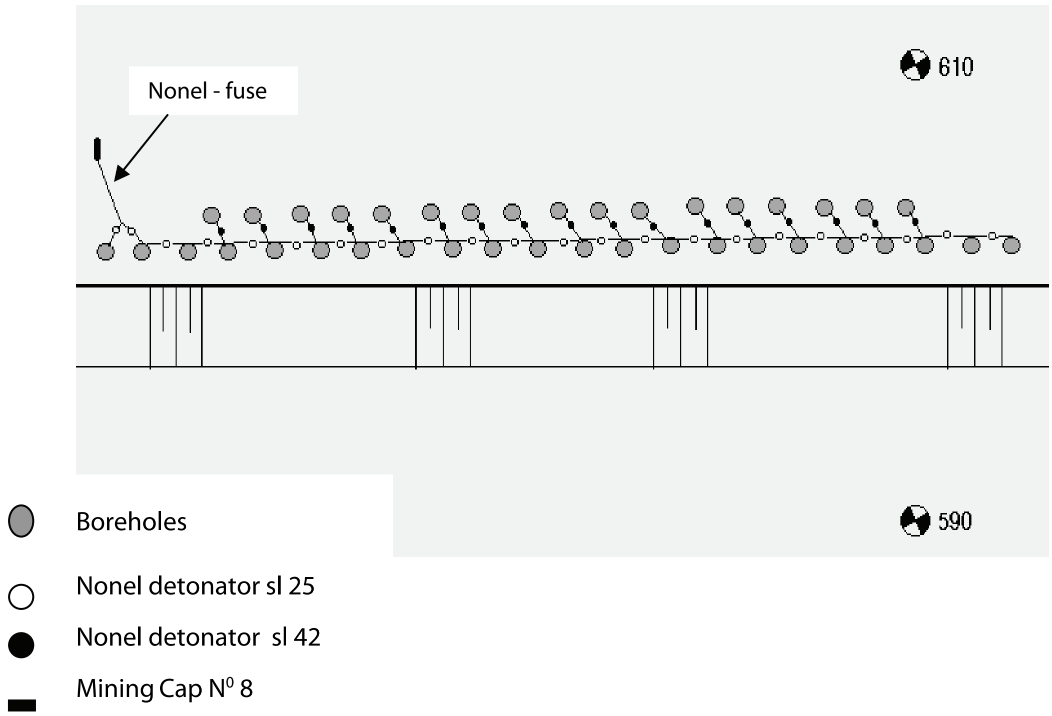

Figure 1: Schematic presentation of characteristic blasting series

3 BLASTING COSTS

Normative materials are consumption material per unit product of mined out mass, which is an indicator of their direct influence on production costs, and the overall operation.

Since almost all normative materials for drilling and blasting are imported, it is necessary to possess larger finances for their purchase.

Blasting costs are higher than drilling costs. However, the amount of costs may vary and may be higher or lower. This can be done by the application of various types of explosives, means of initiation, the method of blasting, its schemes etc. The diameter of drilling is 105 mm with angle of drilling of 85^o.

3.1 Costs per blasting series

- **Blasting series n°. 1**

Blasting of cut E-590	Type of explosive: AMONITE	
Parameters of blasting series	Measure unit	Value
Drilling geometry **(a x b)**	m	3,8 x 3,8
Burden (W)	m	3,8
Bench height	m	8
Number of boreholes	number	57
Mass obtained	t	
Per borehole	t	317,7
Total	t	18107
Buster + Nonel per borehole	usa $	6,0
Explosive per borehole	usa $	46,8
Nonel per series	usa $	342,6
Explosive per series	usa $	2670
TOTAL	usa $	3012,6
Specific consump. of explosive	kg/t	0,177
Costs per tonne mined out mass	usa $ / t	**0,167**

- **Blasting series n°. 2**

Blasting of cut E-590	Type of explosive: AMONITE	
Parameters of blasting series	Measure unit	Value
Drilling geometry **(a x b)**	m	3,8 x 3,8
Burden (W)	m	3,8
Bench height	m	16 - 24
Number of boreholes	N°	15
Mass obtained per borehole	t	771
Total blasting mass	t	11566
Buster + Nonel (U500)	usa $	10,76
Explosive	usa $	77,67
Nonel per series (SI 25, SI 17)	usa $	161,4
Explosive per series	usa $	1165
TOTAL	usa $	1326
Specific consumption of explosive	kg/t	0,175
Costs per tonne mined out mass	usa $ / t	**0,115**

- **Blasting series n°.3 and n°. 4**

E-610/590	Type of explosive : Elotol, AMONIT, AN-FO		
Parameters of blasting series	Measure unit	**Value** Blast series 3	Blas series 4
Drilling geometry **(a x b)**	m	3,8 x 3,8	3,8 x 3,8
Burden (W)	m	3,8	3,8
Bench height	m	21	20
Number of boreholes	N°	52	20
Mass obtained per borehole	t	803	710

Total	t	41786 14204
Buster + Nonel/borehole	usa $	11 10,7
Explosive/borehole	usa $	77,1 65,5
Nonel (total)	usa $	577 214,4
Explosive (total)	usa $	4008,9 1310
TOTAL	usa $	4586 1524
Specific consumption of explosive	kg/t	0,167 0,135
Costs per tonne mined out mass	usa $ / ton	**0,109** **0,107**

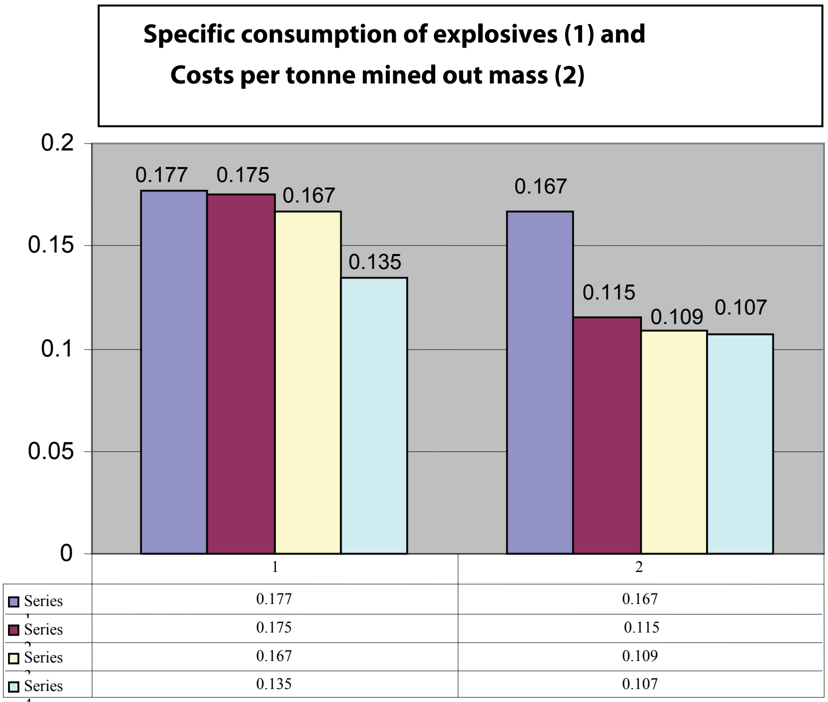

Figure 2: Grafical presentation of 4 (four) blasting series for Specific consumption of explosives and Costs per tonne mined out mass

4 CONCLUSION

The analyses carried out on several blasting series in the Banjani open pit mine indicated that the combination of several types of explosives in the borehole may significantly lower costs of explosives. The use of NONEL system for initiation leads to security in blasting, lower costs and better seismic effects. In blasting series of a larger number of blasting holes blasting costs are lower, and with used the tipe of Amonit and An- Fo, in same basthole, the cost are lowest, for this quarry, although the same types of explosives and manner of initiation are applied.

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EVALUATION OF THE NEED FOR ELECTRONIC DETONATOR SYSTEMS FOR BLASTING OPERATIONS IN SLOVENIAN MINING INDUSTRY

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ABSTRACT

Production of technical stone is an important economic branch in Slovenia. In 2009, we had 95 dolomite quarries, 27 limestone and 6 silicates quarries, according to the Ministry of Economic Affairs. Together they produced nearly 15 million tons of aggregates. The production in quarries is mostly performed with drilling and blasting method and only a minor part with other methods like mechanical mining method.
Despite the growing availability of Electronic Detonator systems, strong technical justification, and the obvious potential to integrate with resource management systems, there is a surprisingly slow acceptance of their value.
Usage of electronic initial systems in Slovene mining industry may have many advantages. It enables an accurate ignition delay and custom programming of the delay. Moreover, the frequency can be influenced, which is very important for reduction of negative impacts of mining and for better rock movement control. Consequently, the result is better material fragmentation, production is increased and usage of explosives is reduced. The possibility of checking detonators is also practicable within this system. The improvement of the parameters described above is possible with computer modelling programs.
There are many reasons for the slow take up of these systems, but worldwide experience has been positive, with upgrade of the whole mining process. Despite many debates around the usability of various systems, the important thing is rock breaking result.
In Slovenia, almost all quarries are located near the settlements and villages, therefore it is very important to have maximal control over all factors involved.
Our plan for the future is a practical usage of electronic detonators in Slovenia and for that reason we have done the comparison between classical and new blasting techniques.

KEYWORDS

Electronic Detonator, Electronic Initiation System, Technical stone

1 INTRODUCTION

The mining and explosive industries rapidly embracing new technologies, in order to improve overall performance, efficiency and cost-effectiveness in various types of blasting and also to mitigate its adverse effects. Most recently, technology that is developed to improve techno-economics and reduction of most of adverse effects in usage of explosive and blasting is »Precise and Accurate Delay Timing - Digital or Electronic Detonator« system. [3] Broadly speaking, accurate and flexible timing allows blasters to make small hole-to-hole and row-to-row changes to account for drilling inaccuracies. Adjusting the blast design to actual conditions can improve safety and fragmentation, which can cut costs by optimizing the loading and hauling cycle, increasing crusher throughput, and reducing the amount of oversize handling and secondary breaking. In addition, precise and variable delay timing manipulations have enhanced high wall stability and bench crest preservation, resulting in safer mines operations and also for reduction of blast induced ground vibration. These improvements allow for more accurate placement of boreholes for succeeding blasts.
Thus, the precision in delay timing has advantages such as:

- Better ground vibration control,
- Better control of rock movement and muck profile,
- Better fragmentation,
- Enhancement in productivity by optimizing utilization of explosive energy.

Mining activities remain a time and cost-intensive business therefore, accurate planning, cost efficiency have been the important factor in excavation operations. In a move to improve overall cost-efficiency in large mining and construction operations operators are adopting the use of Electronic Detonation blasting technology. The accuracy and flexibility of the programmable detonator have provided the mining industry with options, previously not available to improve timing designs for increased benefit in the areas of ground control and better fragmentation. The industry's whole approach to blast timing design can now be focused on greater safety, increased productivity and blast performance, rather than being restricted by the limited interval selections and inaccuracies the conventional pyrotechnics timing systems offer. The growing popularity of high-accuracy electronic detonators means the potential for an expansion of a quarry blasting program's capabilities and improved safety as well.

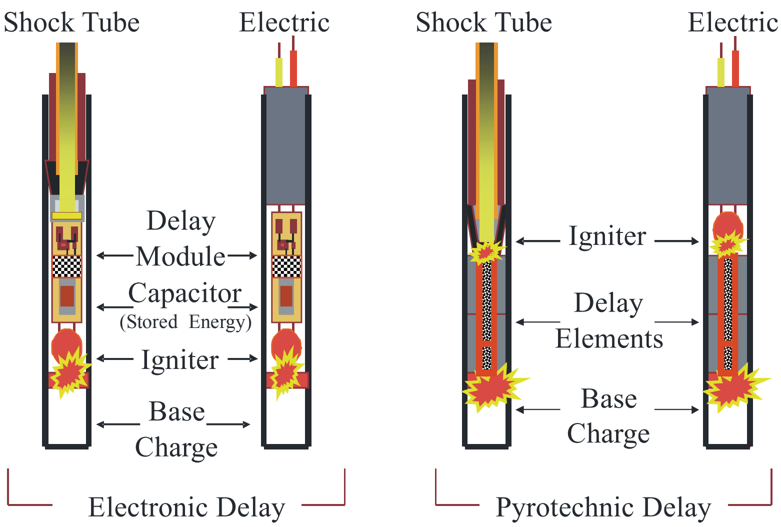

Figure 1: Pyrotechnic and Electronic delay initiation system [9]

2 UNDERSTANDING ELECTRONIC DELAY INITIATION SYSTEM

In order to understand the Electronic delay initiation system, we compare Pyrotechnic and Electronic delay initiation system. There are several types of electronic systems being tested and used in the mining industry, all of which utilize some type of stored energy device to provide energy for their timing and firing circuits. All Electronic Detonators have a system Fundamental Construction Differences [3]. Here are some fundamental construction differences:

- Basic differences in Electronic Delay with Pyrotechnic system of delay is in location of Igniter/Fuse head, In Electronic Detonator Igniter/ Fuse head is located below delay (timing) module,
- In Pyrotechnic system (Shock Tube and Electronic Detonator) Igniter/ Fuse head is located ahead of Delay elements.

One of the basic differences in electronic delay with pyrotechnic system of delay lies in the location of Igniter. In electronic detonator the Igniter is located below the delay (timing) module, whereas both shock tube and electric detonator (Figure 1) utilizes the igniter ahead of delay element (shock tube function as igniter in the shock tube device). Other basic difference in design of electronic detonator is the use of some type of stored electrical energy device, typically capacitor, is used in the delay module.

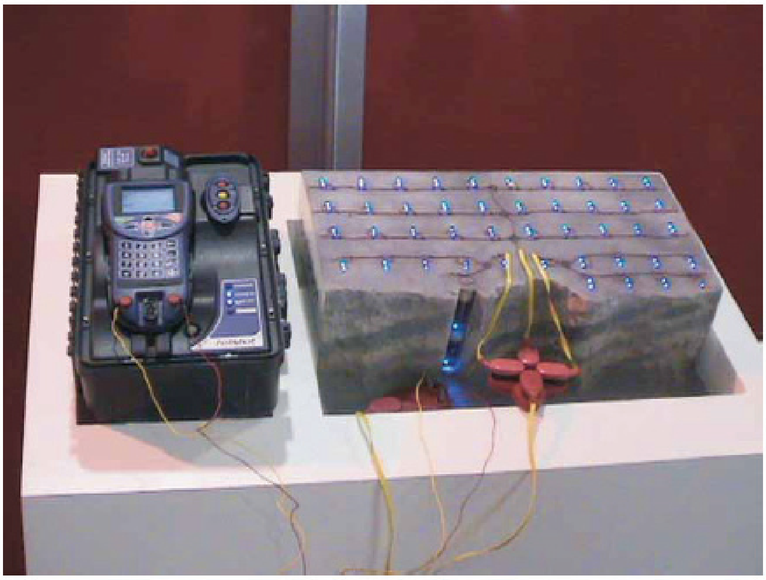

Figure 2: Electronic blasting system

The construction and design of electronic detonator varies from manufacturer to manufacturer. In case of electronic detonator which utilizes standard shock tube lead as the input signal, it transforms into electrical pulse through the use of a small explosive charge (booster) coupled to a highly efficient piezo ceramic element (generator) and electrical energy storage cell (capacitor). Upon receipt of a thermal signal from shock tube the small explosive charge in the booster detonator fires. This activates the piezo ceramic device, which in turn causes current to flow through the steering diode to the charge the storage capacitor. A voltage regulator provides a substantially constant voltage source to an oscillator to control the frequency (Example of this kind of system is DIGIDET™ or Ensign-Bickford, USA) The Programmable electronic detonator (Figure 3) utilizes standard lead as the input signal, which is transformed into electrical pulse through the use of principal component. Receipt of an electric signal causes current to flow through the steering diode to the charge the storage capacitor. A voltage regulator provides a substantially constant voltage source to an oscillator to control the frequency. A "power on reset" circuit preloads the counter upon the initial application of the input voltage. Once the voltage on the storage capacitor has increased beyond a threshold setting, the counter begin decrementing. As the counter digitally decrement past zero, the output to the firing switch activate and all remaining energy in the storage capacitor flows to the igniter. The end result is a delay in the electronic detonator.

3 ELECTRONIC DETONATOR

There are several types of electronics systems, all of which utilize some type of stored electrical energy device (e.g. capacitor) to provide energy for their firing or timing/firing circuits. Their differences include detonator construction, timing precision, communication protocol, blasting machines, tie-in, connectors, etc. Although they are each uniquely different from one another, there are certain design features that are common to all. It is essential that users become fully educated on the products, procedures and recommended practices prior to use. Electronic detonator systems are grouped into two basic categories:

- Factory Programmed Systems (fixed delay)
- Field Programmed Systems (variable delay).

Factory Programmed Systems, in most cases, have a close resemblance to the conventional hardware and components found with standard electric detonators. In some cases, the user may even have a difficult time differentiating a wired electronic detonator from a wired electric detonator. Even though these units may not appear to be different, electronic detonators generally cannot be fired or shot using conventional blasting machines or firing devices. Each system can have a unique firing code or communication protocol used to fire the detonators in the blast. Factory Programmed Systems can be further grouped into specific types or styles. There are Electrically Wired Systems, where each manufacturer has a specific wiring style or methodology; and Factory Programmed Systems that utilize shock tube technology to energize an electronic timing circuit within the detonator.

3.1 Factory Programmed Systems

Factory Programmed Systems utilize "fixed" delay periods for the blast design. Holes are generally loaded and hooked up in the same manner as standard electric or shock tube systems. Depending on the manufacturer, some type of surface connector may be utilized for ease of wiring, or maintenance of correct electrical polarity. With some systems, correct polarity must be observed when electronic detonators are attached to the firing circuit, otherwise a misfire may occur. In all cases though, users of these systems should always consult the manufacturer for specific application information and instructions.

3.2 Field Programmed Systems

Field Programmed Systems utilize electronic technology to program delay times at the blast site. Each system is manufactured for, or with, unique system architectures, styles, hardware and communication protocol. There are no fixed delay times associated with these detonators. These systems rely on direct communication with the detonator (either prior to loading, after loading, or just prior to firing) for the proper delay time and subsequent blast design. In general, these systems will utilize some type of electronic memory, which allows them to be reprogrammed at any time up until the fire command is given.

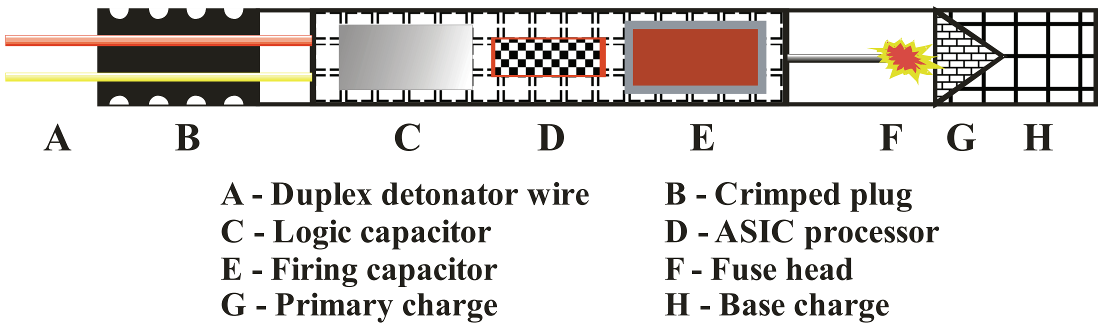

Figure 3: Cross section of Programmable Electronic Detonator

3.3 Characteristics of Electronic Detonators

The characteristics or important features of an electronic detonator are [12]:

- The detonator initially has no initiation energy of its own.
- The detonators can be programmable from 1 up to 20000 milliseconds (ms) in one-millisecond increments.
- The detonator cannot be made to detonate without a unique activation code.
- The detonator receives its initiation energy and activation code from the blasting machine.
- The detonator is equipped with over-voltage protection.
- The short delay time is 1 ms, long delay time is up to 20 seconds.
- The maximum number of detonators connected to each blasting machine can be over 1000 detonators.
- In comparison to shock tube initiation systems, the electronic detonators scatter percentage varies around 0.01 percent for any programmed delay period, where as the shock tube initiation systems has the scatter percentage variation of 3.5 to 5.5 %.
- The system has full two-way communication between detonators and control equipments.

3.4 Benefits of Electronic Detonators

It has been found that electronic detonators offer the following advantages [12]:

- Inherent safety with built in protection from static electricity, stray currents, radio frequency and high voltage.
- Electronic detonators can be programmed to fire at any time from 0 ms to 20000 ms in steps of 1 ms, which makes it possible to select the best delay time between holes and rows to suit the particular characteristics of each blast, rather than having to choose from set numbers such as 17 ms or 25 ms.
- A factory programmed security code unique to the operator that will provide more security and prevent unauthorized use.
- Interactive facilities with full two way communication ability as well as being programmed and armed by the system for checking the status of the detonator and making a circuit check before firing.
- The reduced delay and increased accuracy of the electronic detonators result in improving the fragmentation in surface mining with a reduction in the upper size classes (oversized material) and the fines, which in turn slash down the power consumption significantly in the primary and secondary crushers as well as total throughput,
- Reduced stock management – as electronic detonators are programmable, only one type of detonator is required to be stored in the magazine.
- The absolute accuracy of electronic detonators ensures each blast hole fires exactly when it is supposed to fire. All mines, which have used electronic detonator, have witnessed 10% or more relative improvement in casting.
- By selection of proper delay timings, blast vibration energy can be channeled such that predominant energy falls into higher frequency range and so it offers a tool for vibration control and frequency channeling.
- The flexibility of selecting the timing of holes offers blast designer to create separate muck pile of different grades to get ore and waste separation by re-establishing relief at any stage of progression of blast.

4 SIGNIFICANCE OF ACCURACY OF DELAY TIMING

The pyrotechnic detonator design is such that the average scatter of delayed firing is ±10 %. This implies that for a blast-hole that should fire at 25 ms from initiation, might fire at 22.5 ms or 27.5 ms. This may not seem like a huge variance, but the resultant effect is. The scatter on a 500 ms delay detonator will cause it to fire anytime from 450 ms to 550 ms i.e. a range of 100 ms. If taken into account that inter-hole delays of 10 ms are used on a blast, out of sequence hole firing may happen. In general, accurate and flexible timing allows blasters to make small hole-to-hole and row-to-row changes to account for drilling inaccuracies. Adjusting the blast design to actual conditions can improve safety and fragmentation, which can cut costs by optimizing the loading and hauling cycle, increasing crusher throughout and reducing the amount of oversize handling and secondary breaking. In addition, precise and variable delay timing manipulations enhances high-wall stability and bench crest preservation resulting in safer mines operations and also for reduction of blast induced ground vibration. These improvements allow for more accurate placement of boreholes for succeeding blasts. Optimization of the blast design to take greater advantage of the electronic detonator's precision expands the blast pattern and reduces the explosive consumption without negatively affecting production. Electronic detonators generally are programmable in 1ms increments and have delay accuracy (scattering) as small as ±0.5 ms. The control of blast vibrations is an increasingly important factor within the rock blasting industry. Much research work has looked at optimizing the inter-hole delay period to minimize vibration. The most commonly used technique utilizing inter-hole delays is Linear Superposition. This is a method whereby a vibration signal from a single- hole shot is combined with the firing times to simulate the vibration signal generated by a full-scale production blast. The simulation can be run many times with varying delay times to find the optimum value which will produce the minimum vibration level. Reamer et al. [10] give a very good description of this technique. The successful implementation of Linear Superposition relies on two very important assumptions:

- The firing time of each hole can be accurately controlled.
- The single-hole vibration signal is a good representation of the vibration produced by each hole in a production blast.

5 TRANSITION FROM CONVENTIONAL BLASTING TO NON-ELECTRIC SYSTEM IN CEROV LOG QUARRY

Two years ago we switched from conventional blasting (pyrotechnical detonators, pyrotechnical delayers and detonating cord) to non-electric system in the quarry of Cerov Log, firstly because of the negative effects, especially the air blast, on the surrounding environment, and secondly we expected the reduction of seismic vibrations and the increase of frequencies.

We have data from 73 blasting events. 55 events were carried out with conventional blasting and 28 events with non-electrical system. Measurements were performed in the house closest to the quarry. In the most cases the blasting operations were executed away from the measurement sites. That is 400-450 m and 720-770 m, respectively. Quantity of explosives was between 30 and 36 kg per each hole. The drilling patterns and delays between holes and rows were the same each and every time.

Table 1 present data collecting using non-electric system blasts.

Table 1: The most representative non-electric system blasting data

No.	Date	Peak particle velocities (mm/s)	Resultant particle velocities (mm/s)	Frequency (Hz)	Air Blast (Pa)	amount of explosive (kg)	kg/ hole lbs/hole	Distance from measure equipment (m)
1	19.9.2008	2,41	2,43	37	4	144	30	420
2	23.10.2008	1,08	1,19	17	4	960	32	430
3	19.9.2008	0,381	0,46	32	2	804	36	740
4	19.9.2008	0,826	0,826	43	2	156	30	770

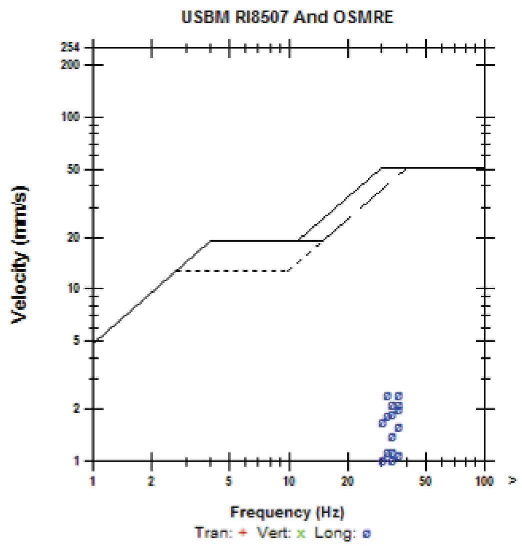

Figure 4: Blast no. 1 (USBM)

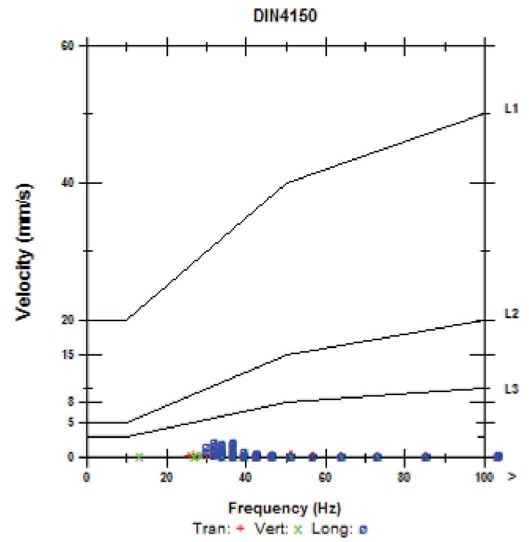

Figure 5: Blast no. 1 (DIN)

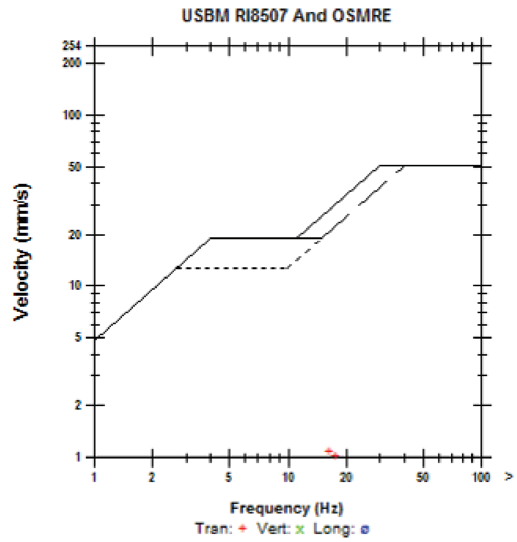

Figure 6: Blast no. 3 (USBM)

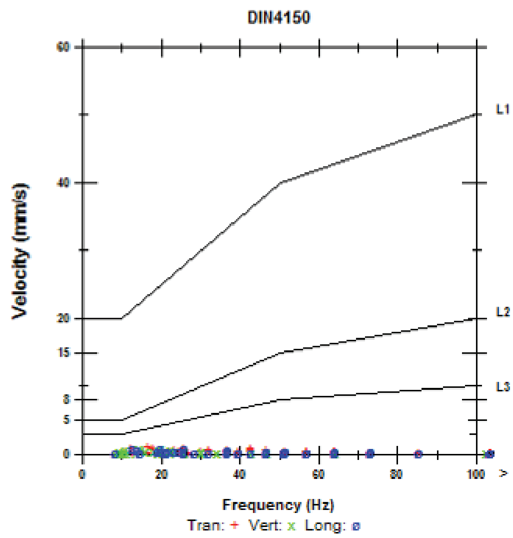

Figure 7: Blast no. 3 (DIN)

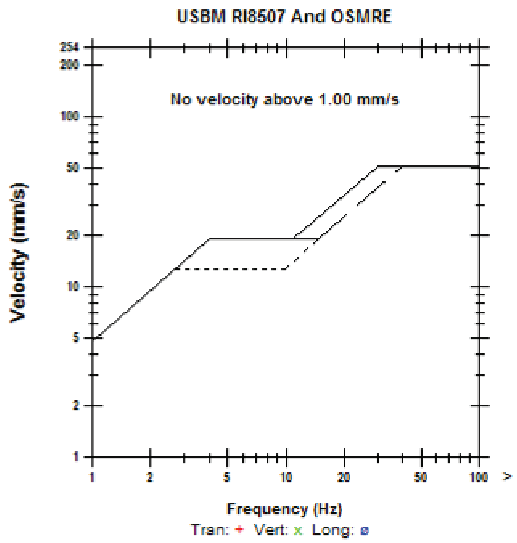

Figure 8: Blast no. 3 (USBM)

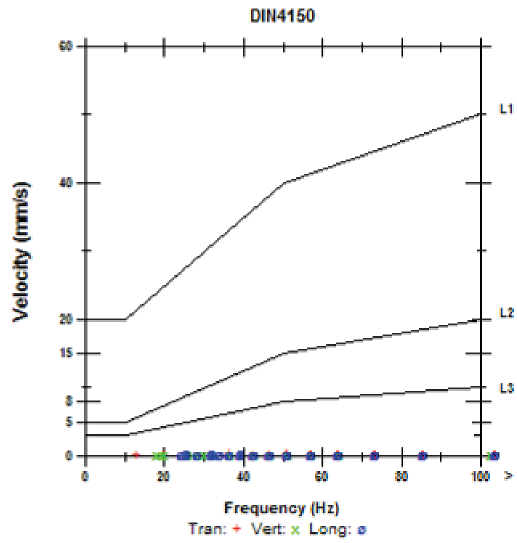

Figure 9: Blast no. 3 (DIN)

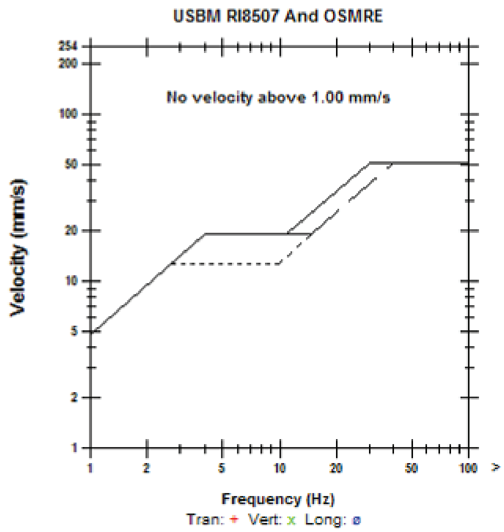

Figure 10: Blast no. 4 (USBM)

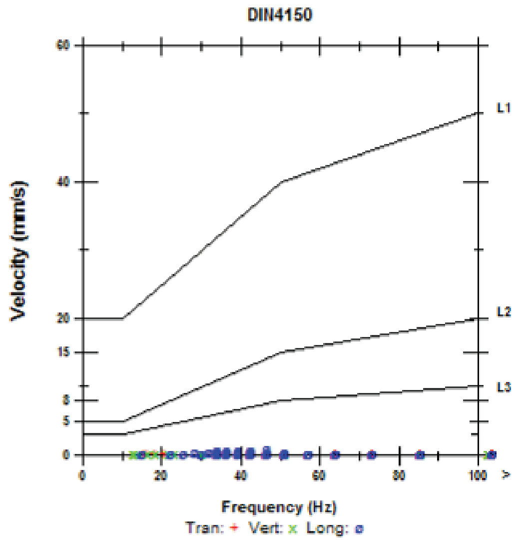

Figure 11: Blast no. 4 (DIN)

Table 2 present data collecting using conventional blasting (pyrotechnical detonators, pyrotechnical delayers and detonating cord).

Table 2: The most representative conventional blasting data (pyrotechnical detonators, pyrotechnical delayers and detonating cord)

	Date	Peak particle velocities (mm/s)	Resultant particle velocities (mm/s)	Frequency (Hz)	Air Blast (Pa)	amount of explosive (kg)	kg/hole lbs/hole	Distance from measure equipment (m)
5	23.1.2008	0,953	1,1	11	6	258	32	420
6	12.9.2007	0,7	0,778	15	10	288	32	415
7	8.12.2008	0,254	0,27	17	10	465	31	770
8	10.1.2008	0,32	0,38	11	2	667	34	750

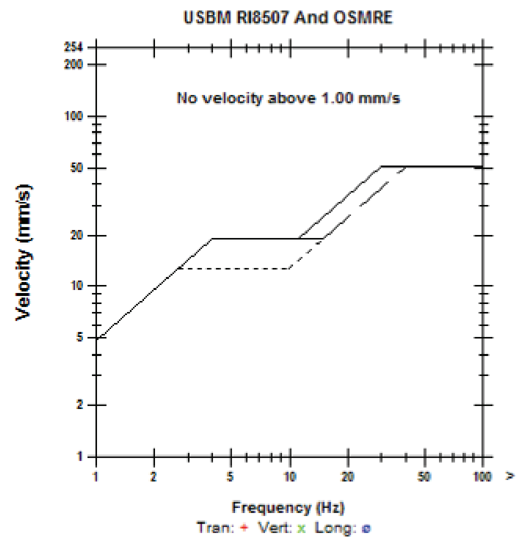

Figure 12: Blast no. 5 (USBM)

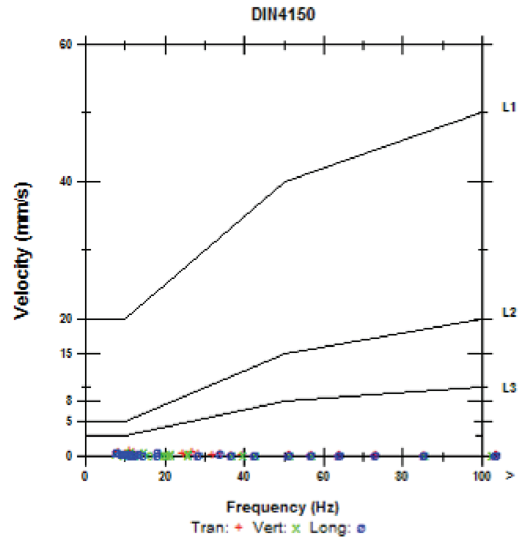

Figure 13: Blast no. 5 (DIN)

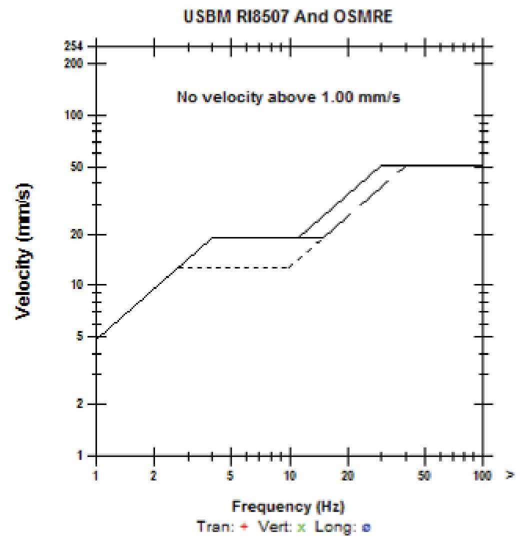

Figure 14: Blast no. 6 (USBM)

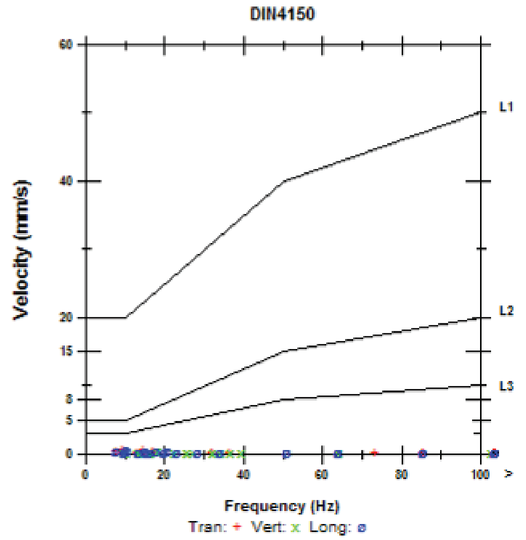

Figure 15: Blast no. 6 (DIN)

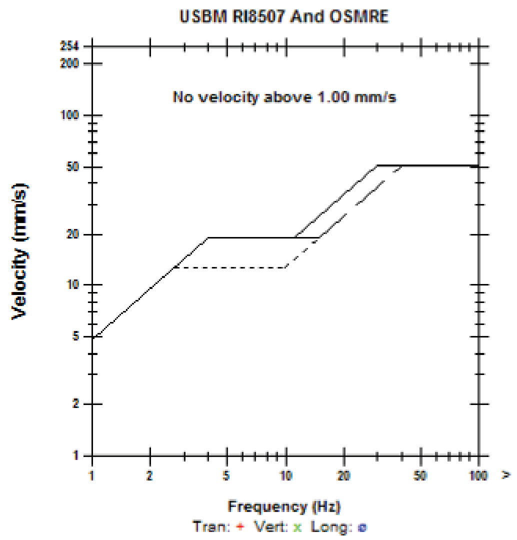

Figure 16: Blast no. 7 (USBM)

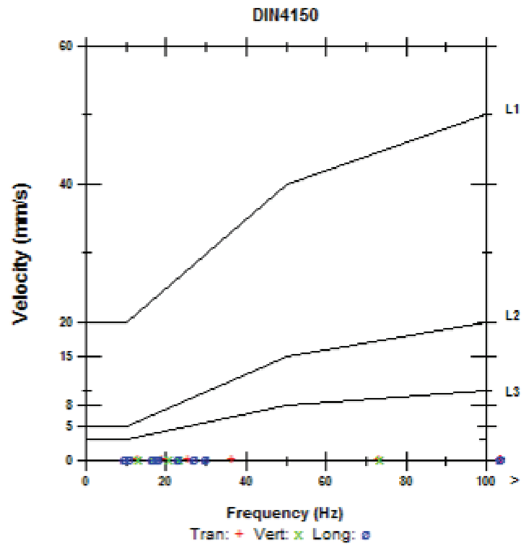

Figure 17: Blast no. 7 (DIN)

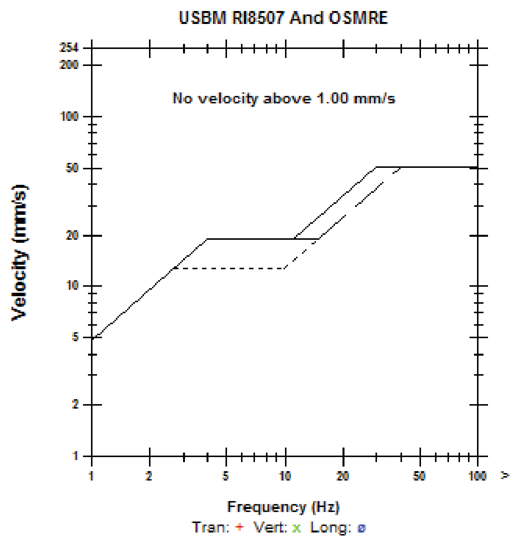

Figure 18: Blast no. 8 (USBM)

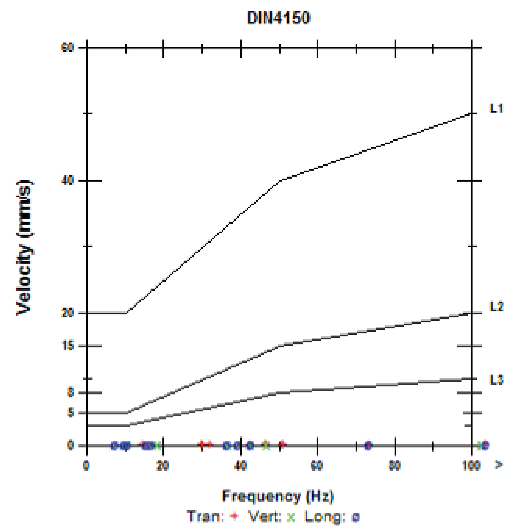

Figure 19: Blast no. 7 (DIN)

USBM RI8507 standard has the higher limit than the German DIN 4150 Standard. German DIN 4150 standard has 3 limits for vibration speed. L1 is for structures that are earthquake safe, L2 limit is for normal buildings, and L3 limit is for old buildings like churches, castles and very old houses. We were considering the most stringent one (L3).

The frequency tells us the number of cycles per second. Buildings placed on the surface will vibrate like tuning forks, when they are exposed to sufficient quantities of energy that causes vibration. The value of this frequency depends on the weight, height and strength of the building. Maximum response of the object is obtained, when the frequency coincides with the frequency of soil structure. However, we must not forget that the impact frequency is neglected, when having insufficient energy (particle velocity).

The relationship between delay time and the geology of the area has the greatest impact on the frequency and on the speed of particles. Geology of the area is usually constant, but varies with the progress of the quarry.

6 TEST RESULTS

With the transition from conventional blasting (pyrotechnical detonators and detonating cord) to the non-electrical system, we have reduced air blast from 6-10 Pa to 2-4 Pa (Pascal). The reduction between 150% - 300% is significant.

Frequency was increased from 11 – 17 Hz to 17- 43 Hz, which is very good, because structures are most vulnerable at low frequencies.

Peak particle velocities (PPV) became higher with the use of the non-electrical system. The enlargement is between 20% - 330 %, which is very worrying, however overall PPV are still well below limit lines of USBM and DIN standard.

Non-electrical system has proved to be a good replacement for conventional blasting technique. By increasing the speed of PPV, we encounter the new problems. According to experiences of others, this could be solved by the electronic initial system. Case studies show that lower values of PPV are attainable by using accurate delay time of electronic detonators and computer software.

7 REASONS FOR UNUSING OF ELECTRONIC DETONATORS IN SLOVENIAN MINIG INDUSTRY

We conducted a study within Slovenian mining industry. We asked them why they don`t use electronic initial system. Answers were:

- Lack of understanding of the negative implications of pyrotechnic scatter.
- Perception that they are over-priced.
- Budget-controlled management systems.
- Perceptions that the benefits of electronic systems are limited to some applications only.
- High cost of initial investment and high cost of detonators if you compare it with "classical" system (pyrotechnic, electric or non electric system)

8 CONCLUSIONS AND PLANS FOR FUTURE WORK

The indication from the literature is that Electronic Initiation Systems will offer benefits in ground vibration control, fragmentation control, muck pile contours, reduction in fly rock incidents, increase possible round sizes and presents an opportunities to develop new blasting methods. Of course with all new technology the benefits are offset to some extent by the drawbacks and electronic initiation is no exception. Electronic initiations have problems in that they can be very complex systems, which require lengthy training and are much more expensive than non-electric detonators, also the complexity of the systems increases the possible sources of risk of malfunction. As most of these systems are still being developed and proven there is still room to address these issues, the first two are economic which is a site specific decision where as the third is an issue of safety. Safety is not site specific and should be inherent in any new technology that it has a higher level of safety than the superseded technology. As shown, the next step in the development of PPV reduction in Cerov Log quarry, is the use of computer software and accurate time delay electronic detonators.The conclusion was that technically and operationally the electronic systems seem vary proficient and from the results of the various tests and case studies that have been carried out they have a great deal of benefit to offer the Slovenian mining industry.

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