Blast Timing ~ Anything Goes with Electronic Detonators

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1. Abstract

The recent insurgence into the New Zealand quarries market of the electronic detonator is being hailed as a success by many quarrying groups, eager to extract additional value from their operations, or ensure compliance of resource consent requirements from increasing pressures of urbanisation thereby ensuring the longevity of the operation. Whatever the driver for implementing electronic delay timing, many of New Zealand's key quarry operators are not looking back from their decision to convert to today's latest advances in blasting technology, the electronic detonator.

Although initial development of a super accurate detonator, began over 20 years ago, recent advances in production technology has resulted in the bulk manufacture of a reliable, safe and efficient detonator. The electronic detonator provides accuracy of firing to within 0.01% of a millisecond of the desired delay time, as compared to the more common non-electric (or pyrotechnic delay) which offers an accuracy of 3 – 5% of the delay time. However, the additional benefit of an electronic detonator is the ability to assign timing delays on 1 millisecond (ms) increments up to a maximum of 15,000 ms. This flexibility in timing means that 'the world is the blasting engineers and shotfirers oyster' when it comes to the flexibility of blast design capability. Whether it be vibration management, increased fragmentation, final wall control or management of neighbours perception, the flexibility of timing and developed intellectual property is taking drill and blast operations to a higher level.

This paper reviews some of the recent New Zealand quarry market success which have evolved through the implementation of blasting IP and the electronic detonator.

2. Introduction

Electronic detonators have been freely available from commercial explosives suppliers within New Zealand for over 5 years. While the inherent safety features, increased delay accuracy and two way communication systems have been known since their inception, it has only been within the last 2 – 3 years that the true application benefits are being discovered. While the additional cost of the electronic detonator has caused many to shy away from trialing of this new offering, for those that have, benefits above and beyond the cost of implementation are being realised.

While not all sites are able to achieve the successes most commonly realised from an electronic detonator, the quarries market, by their very nature, with relatively high rock strength, high urbanisation, and minimal operating margins are one of the key sectors reaping the application benefits of electronic detonators.

This paper examines three operations throughout the New Zealand quarries market and their varied reasons for implementing electronic detonators to assist them in optimising their operation. While some of the results were predicted, others have seen additional benefits that go beyond their initial success indicators.

3. Case Studies

3.1 Blackheads Group – Logan Point & Mt Kettle Quarries

Blackheads Quarry group operate a number of quarries throughout the south island of New Zealand. While some of these quarries are far from neighbours and therefore have little requirement to control vibration and neighbours perception, two quarries, Logan Point and Mt Kettle are within the city limits of the picturesque Dunedin. Logan Point, Blackheads largest quarry faces directly toward the city of Dunedin with neighbours surrounding the operation to within 300m on all sides. Additionally, the site hosts Allied Concretes Cement plant and Fulton Hogan's Asphalt plant within 20 m of the operating quarry benches.

Blackheads initially looked to use electronic detonators for;

1. Improving neighbour relations through the control of blast induced vibrations, and
2. To enable to the quarry to fire 89mm blastholes without the normal back break associated with this hole diameter.

3.1.1 The Situation

As the Logan Point quarry is closely bounded by neighbours (to within 300m) the need to reduce peak particle velocity (PPV) and also control neighbours perception of blast vibration was essential. Typical firing with pyrotechnic delays would cause the double up of blasthole (ie firing within an 8ms time window) and thus an increase in MIC (Maximum Instantaneous Charge weight). As there is a direct relationship between charge weight (amount of explosives going off within an 8ms time window), distance to the neighbours house and the resultant PPV, as shown by equation 1, it was necessary to ensure that only one blasthole was initiated within the 8ms time window.

$$\text{Vibration (mm/s)} = K \times \left(\frac{\text{distance}}{\sqrt{\text{MIC}}}\right)^{-b}$$

Where 'distance' is the distance between the blast and the monitor
'MIC' is the Maximum Instantaneous Charge -the total kg of explosive fired per delay
The inside of the brackets is known as the 'Scaled Distance'

Previously single blasthole firing had been controlled to some extent with limited blast sizes and smaller blasthole diameters (to limit the charge weight). However, with the use of electronic detonators, blast size was no longer limited as the timing delay for each blasthole could be set such as to ensure no two blastholes would initiate within the same 8ms time window. Figure 1 shows the 8ms time window for a typical blast at Blackhead's Logan Point Quarry. The two highlighted blastholes show that they are initiating within the same 8ms time window and thus are considered to be firing simultaneously, thereby increasing the instantaneous charge weight, and therefore the anticipated PPV for the blast.

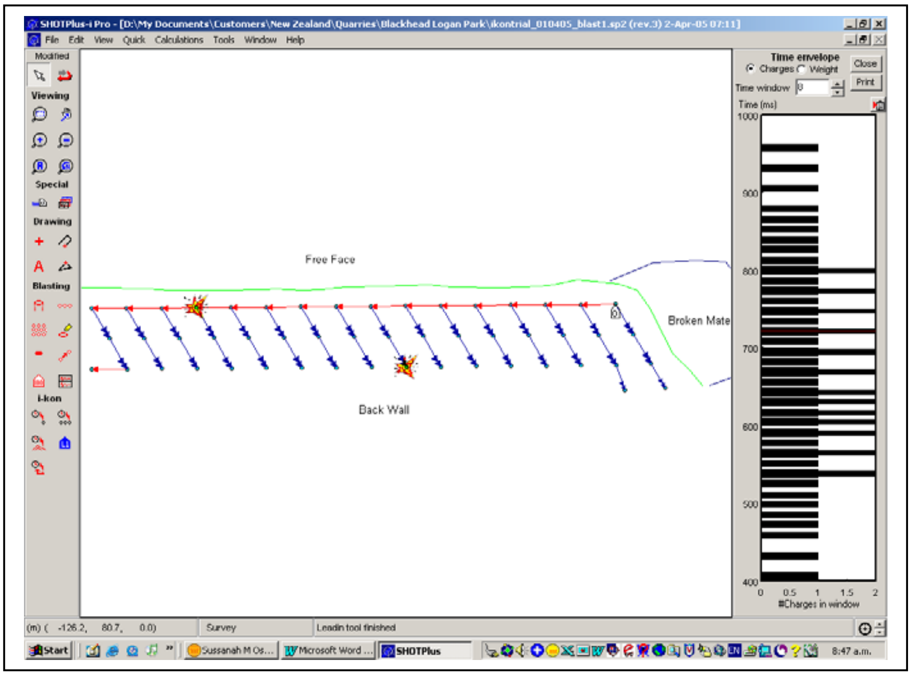

Figure 1: 8 millisecond time window for a typical pyrotechnic detonator blast at Blackheads Quarry. The highlighted blastholes show two blastholes initiating within the 8 millisecond time window.

Figure 2 shows the 8ms time window for the same blast when initiated with electronic detonators. It can be seen in this figure that only one blasthole is initiated within 8ms.

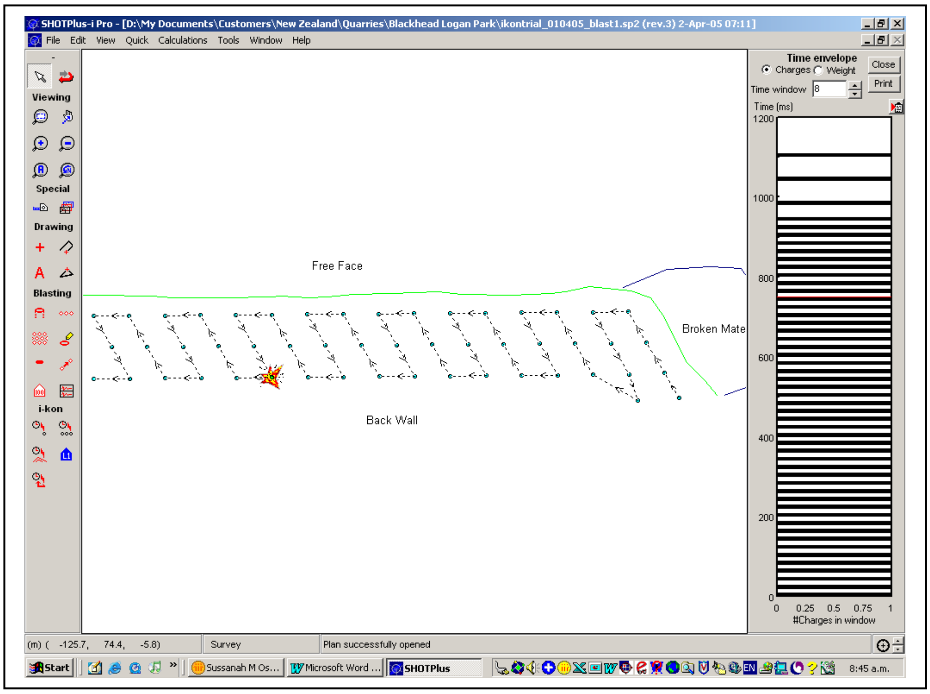

Figure 2: 8 ms time window for an electronic detonator blast at Blackheads Quarry. The highlighted blastholes show only one blasthole initiating within the 8 millisecond time window.

In addition to ensuring single blasthole firing, novel timing was used to produce ‘frequency channelling’. As there is a direct relationship between frequency and time, inter-hole blast timing may optimised to channel the resulting blast frequencies into the higher frequency ranges. The benefit of achieving higher blast frequency ranges is that neighbours’ perception of the feel of the blast is altered. This may be explained by the difference that is felt on a boat in low frequency, rolling waves, where each wave that passes under the boat is felt, as compared to high frequency, choppy waves passing under the boat, where individual waves are not felt.

3.1.2 The Outcome

The first trial with electronic timing aimed purely at reducing PPV and improving neighbours perception to blasting at Logan Point quarry was a measured success. Typically, blast vibration results expected at the near neighbours house would be in the order of 3 – 4 mm/s, with the neighbour commenting on the severity of the blast vibration. The first trial reduced blast vibration to 1.8 mm/s and also achieved the additional outcome, of changing the perception of blast outcome through obtaining frequency channelling at the desired 50 Hz (see Figure 3). By pushing more of the blast vibration into the higher frequency range, the blast vibration attenuation is reduced, and the neighbours feel of the blast is improved.

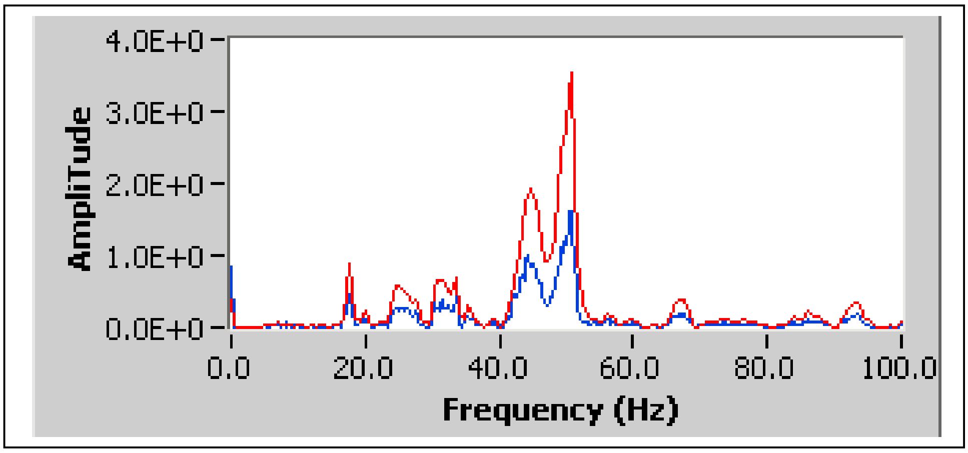

Figure 3: Frequency channelling diagram. The target of 50 Hz was achieved at Blackheads Logan Point quarry through the use of novel blast timing.

In addition to the successful outcome in terms of vibration management, the quarry also recognised two other key benefits. Through implementing electronic timing, the quarry was able to successfully fire 89mm blastholes without the backbreak that they had traditionally received as seen in Plate 1.

Plate 1: A successful result in terms of improved fragmentation and reduced backbreak resulting from blasting with 89mm blastholes and electronic detonators.

By being able to safely fire 89mm blastholes without exceeding the MIC, and minimising backbreak meant, that the quarries overall drill and blast costs were reduced due to cost savings from reduced number of blastholes required to be drilled, charged and fired. Further, improvements in fragmentation were also noted with a 20% improvement in load and haul rates.

Blackheads Logan Point and Mt Kettle quarries have both converted to electronic detonators based on the successful trials.

3.2 Winstone Aggregates – Hunua Quarry

Winstone Aggregates' Hunua Quarry is New Zealand's largest operating quarry. The quarry produces over one million cubic metres of crushed rock annually for the Auckland and North Island roading and construction markets. The quarry sits nestled within the Hunua Gorge shielded from neighbours, only a one-hour drive from the Auckland Central Business District. Due to the location, Winstone's focus is to efficiently extract rock from their quarrying operation, whilst ensuring environmental issues are managed.

3.2.1 The Situation

Hunua's impressive greywacke deposit is a mixed bag of hard and soft rock types with numerous faults (slippery backs) tracing throughout. The variable structure and geology coupled with the dominant faults has cause a number of issues with backbreak from blasting activities. Typically, where faults run perpendicular to blast faces, backbreak can be up to 10 metres due to blast energy travelling back along the 'slippery backs', causing access issues on the narrow haul roads through slumping and humps.

While a numerous trials had been conducted to assist the Quarry Manager with backbreak, including down loading of blastholes, reduced blast size and variable timing, it was not until a trial with electronic detonators did the quarry see real improvements in the management of blast related back break.

A trial with electronic detonators was conducted at Winstone's Hunua Quarry where a blast with two major faults and a smaller one in the centre of the blast was the challenge that lay ahead. The width of the haul road was crucial as any loss of the haul road through backbreak would result in the loss of access for haul trucks. Through the use of novel electronic timing, the blasting engineer designed the blast timing so as to 'push energy' into the faults, rather than along them, and thus reduce the effect of gases and explosive energy destroying the final walls. In effect, the idea was to 'cut like a knife' along the back of the blast, by using the initiation design to work with the fault orientation, rather than against them.

3.2.2 The Outcome

The trial was an outstanding success with no backbreak at all resulting in a fully maintained haul road. Upon firing, the piles of drill cuttings were noted at the back of the blast indicating where the original blastholes had been located. These are normally always lost, this being a significant success indicator of the of the trial. Plate 2 shows the resulting final wall, and lack of backbreak.

Plate 2: A successful electronic blast at Winstone's Hunua Quarry where no backbreak resulted in an area that typically gets up to 10 metres backbreak.

Following the success of the trial, Winstone's Hunua Quarry Operations Team Leader has recommended that all blasts in high risk areas are to be fired with electronic detonators to ensure the integrity of the final wall.

3.3 Golden Bay – Wilsonville Quarry

Golden Bay Cement is supplied by two of their own quarries, namely Wilsonville and Portland Quarries. While both quarries are located within 25 kilometres of each other, only the Wilsonville Quarry abuts residential properties. Due to the location of the quarry, the effects of blast vibration are often felt by nearby residents. As part of a major project being conducted the at Wilsonville quarry, a series of electronic detonator trials were undertaken.

3.3.1 The Situation

The Wilsonville Quarry sits aside the township of Hikurangi, approximately 200 kilometres north of Auckland. The township abuts the quarry with blasting operations conducted within 300m of the quarries nearest neighbours. The neighbours have expressed concern with regards to disturbance caused from blasting operations, and as such Golden Bay have embarked on a major study of blast vibration and neighbour disturbance. The initial studies of vibration results showed that blast vibrations (PPV) were typically low in level (well below the resource consent requirements of 5 mm/s) and also consisted of low frequencies (refer to Figure 4).

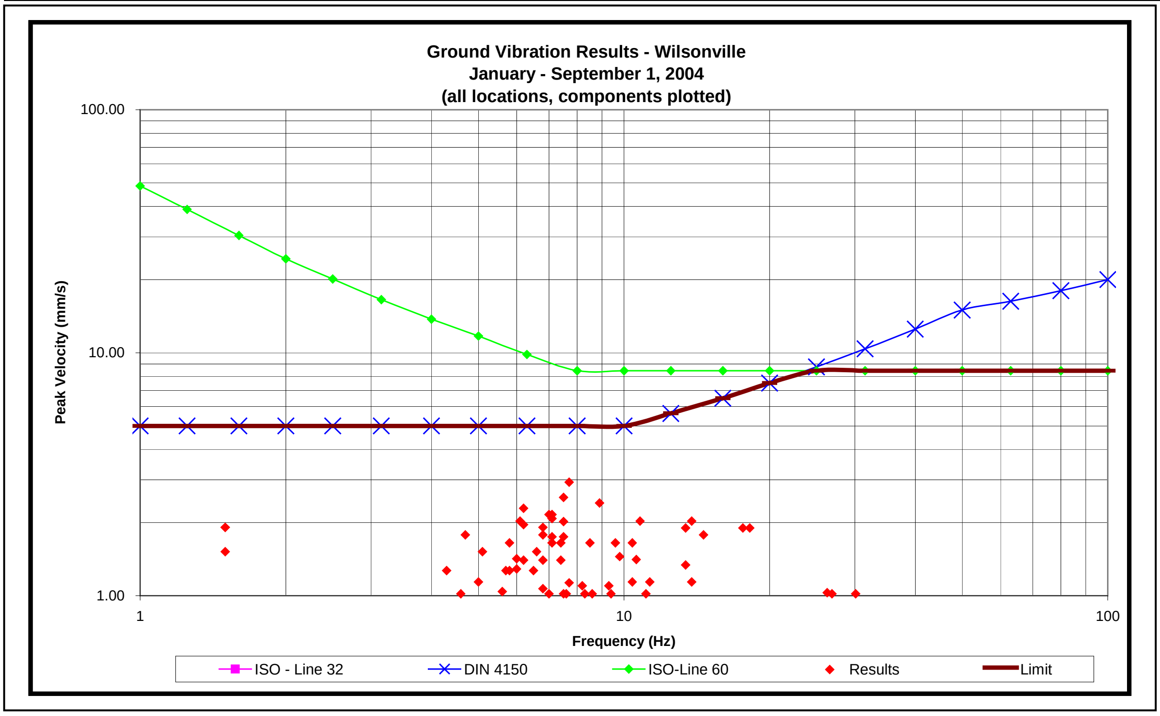

Figure 4: Blast vibration and frequency results for blasting operations at Golden Bay's Wilsonville Quarry.

With the knowledge of blast frequency manipulation and PPV maintenance, an electronic trial was established to both reduce the resultant PPV at the monitoring locations, as well as manipulate the 'feel' of the blast for neighbours.

The trialing phase initially consisted of a direct comparison between traditional pyrotechnic delays, and electronic delays with two blasts fired within a short time interval of each other. This allowed neighbours the opportunity to experience first hand the difference in the feel of each blast. Additionally, the direct comparison between the closely spaced blasts allowed a review of PPV management with electronic delays.

The second phase of the trial looked to optimise blast fragmentation and blast size while maintaining the ability to manipulate blast frequencies and manage PPV. At the time of publication, this project is still under way and although the results look promising, they are yet to be finalised.

3.3.2 The Outcome

In the first trial the effect of frequency manipulation was clearly demonstrated by the most affected neighbour when he responded with regards to the electronic blast, (The blast felt like) “gentle rocking , like a truck had passed by. No swaying from side to side like last shot”. Orica’s aim is to maintain this perception of blast vibration through the use of novel timing.

Additionally, the initial trials have shown that the PPV is likely to be reduced with the use of electronic detonators (refer to Figure 5). This is due to the systems ability to guarantee single hole firing. As a result of this the quarry has now been able to increase blast size without the risk of PPV exceedence and maintaining the ability to manipulate the ‘feel’ of blast vibration. These improvements have brought cost reductions to the quarry through economies of scales .

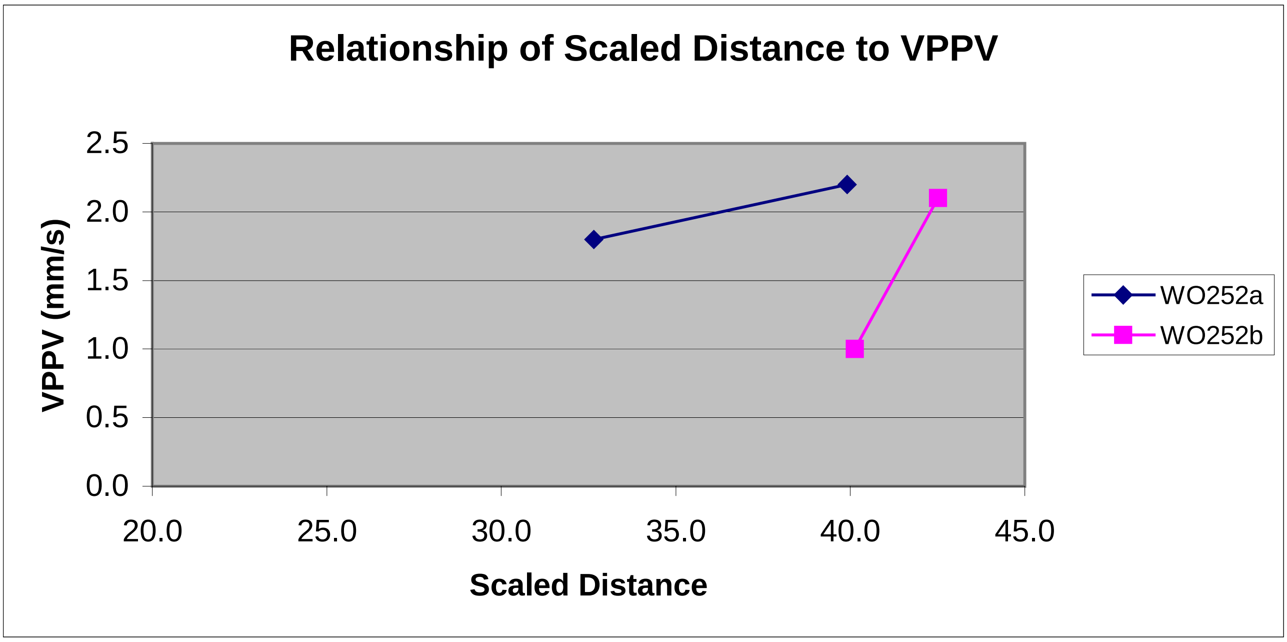

Figure 5: Relationship between scaled distance and VPPV.

4. Conclusion

In a time when rapid technological advances are being made in all industries, the ability of the New Zealand quarries market to embrace and capture the benefits of electronic detonators has been shown, with a number of the markets leading industry players riding the wave of blast optimisation and quarry longevity. While many of the application benefits are being further refined, advances continue to be made in the ability to achieve better wall control, improved blast fragmentation and operational optimisation through redefining the square within which the blasting rules were written.