Electronic Detonator Success: An African Story

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Abstract

In contrast to global trends, African, especially South African, surface mining operations have shown a significant rate of adoption of Electronic Detonators (ED's) over the last few years. Proven benefits of converting to ED's from pyrotechnic initiation systems have aided this market conversion. These benefits are experienced throughout the mining operation.

Benchmarking exercises, prior to the introduction of ED's, form part of the conversion process and allow for quantifying improvements. Extensive work has been done on quantifying the benefits of converting to ED's and have shown that results can be reproducible.

Improvements have been experienced in many applications and include environmental impact control, improved mining efficiencies, increased cast benefit and improved size distribution. These step changes in blasting results, in conjunction with the adoption of ED technology have aided the rapid conversion of the African surface market.

Introduction

There has been a slow rate of global adoption of Electronic Detonators (ED's), with reasons such as disbelief in the proven results as well as perceptions that ED's are a niche product or can only be used in certain applications (Bartley et al, 2003; Cunningham, 2003). In contrast, African, especially South African, surface mining operations have shown a significant rate of adoption of ED's over the last few years. To illustrate this, in the past three years DetNet's sales have increased from 1 million to 2.6 million units a year. Proven benefits of converting to ED's from pyrotechnic initiation systems have aided this market conversion.

These benefits include productivity and efficiency improvements throughout the mining operation, as well as reduced environmental impacts. Benchmarking exercises, prior to the introduction of ED's, form part of the conversion process and allow for quantifying such improvements.

DetNet Solutions and its African channel partner, AEL, have done extensive work on quantifying the benefits of converting to ED's. This paper details a selection of these value propositions which have been experienced at different locations throughout Africa. This is by no means exhaustive as there are many mines and quarries that have been converted to ED's and the benefits described here are not limited to the mine or quarry where they were measured.

Environmental Impact Control

Location

Coedmore Quarry (Quartzite and sand) is situated in the City of Durban, South Africa. It conducts blasting within 100m (328ft) of a built up neighbourhood (in the suburb of Clairwood) and approximately 800m (½ mile) from a national highway.

Reason for Converting to ED's

Before converting to ED's, the quarry blasted with shock tube and used intra row delays of 25ms and inter row delays of 42ms. Due to the proximity of the neighbours, Coedmore decided to trial ED's in order to control environmental impact of blasting practices and to enhance good neighbour relationships.

Data Used for Comparison

The focus was on the environmental impacts of blasting and how using ED's can control these. Discussions were also held with plant personnel in order to understand the benefits gained in their areas. After these discussions, it was decided that there were too many variables and changes other than only replacing shock tube with electronics in the blasts, to be certain of improvements or benefits gained in the primary and secondary crushers. This does not mean there were no gains: only that it was inappropriate to try to extract valid data related to fragmentation.

For each blast seismographs were placed at neighbours' houses and within the pit. The measured Peak Particle Velocities (PPV's), frequencies and airblast levels were recorded in a blast report that included the seismograph location (distance from blast) and blast parameters, e.g. mass of explosives per delay.

These records covered five years of blasting and included both shock tube and ED initiated blasts. This 5 years of data allowed for a comparison between 156 Shock Tube and 167 ED blasts. (The quarry converted from shock tube to ED's in the middle of 2001). The timing of the blasts initially mimicked that of Shock Tube but as the users became more proficient they changed the timing to suit conditions.

Comparison

As there were not sufficient data points at each seismograph location or per bench to gain a statistically representative result, all the data were combined and analysed. There were some readings that did not have a location recorded or there was some data missing, thus these were excluded from the analysis. Therefore, there were 131 data points for shock tube and 118 for electronics.

The following parameters were analysed and then compared, for shock tube vs. electronic blast results:

- Peak Particle Velocity & Frequency
- Airblast
- Number of "no triggers", i.e the number of blasts that did not trigger the seismographs.

The PPV, Frequency and airblast levels were plotted against the scaled distance $= \frac{\text{Distance from Blast}}{\sqrt{\text{Mass of explosives per delay}}}$, in order to provide a more accurate comparison.

Results

PPV:

Figure 1 shows that ED initiated blasts generated lower PPV levels, especially at smaller scaled distances. This implies that the closer the blast to critical structures, the more important it becomes to use ED's. The "No Triggers" events have been excluded for better visualisation.

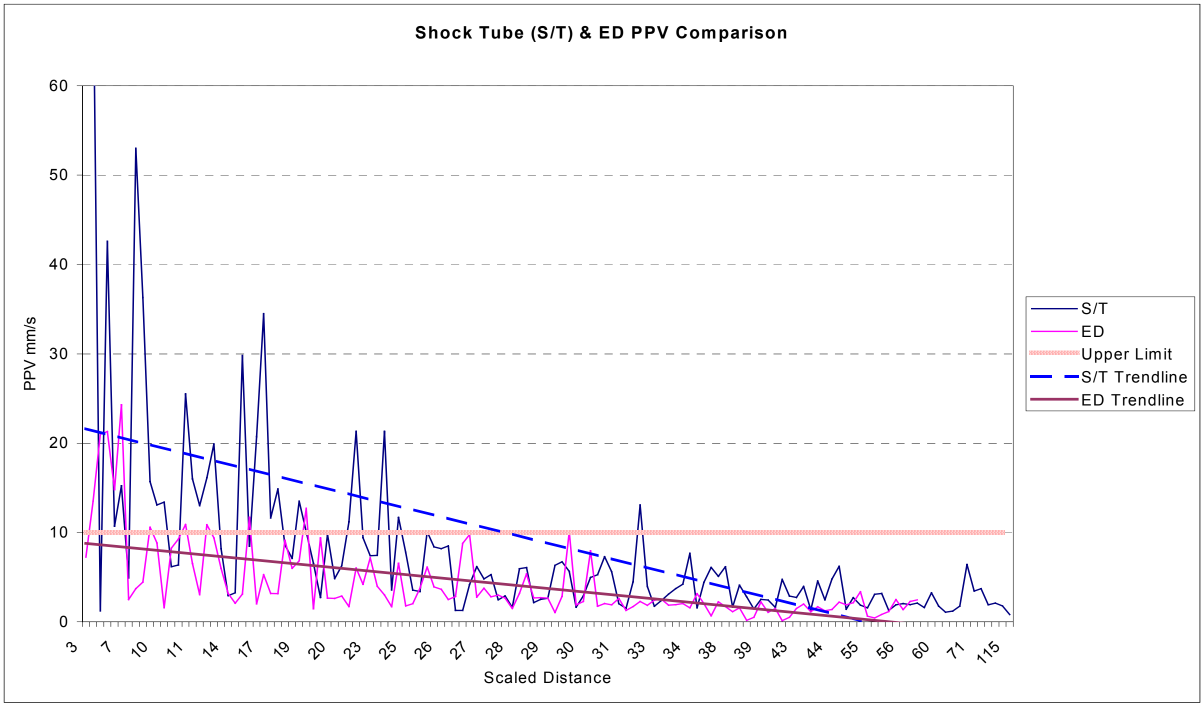

Figure 1 – PPV vs. Scaled Distance

Figure 2 shows the average PPV recorded for blasts initiated with each initiation system. It also shows the target limit of 10mm/s (0.39ips), set by Coedmore, as well as the United States Bureau of Mines (USBM) recommended maximum level.

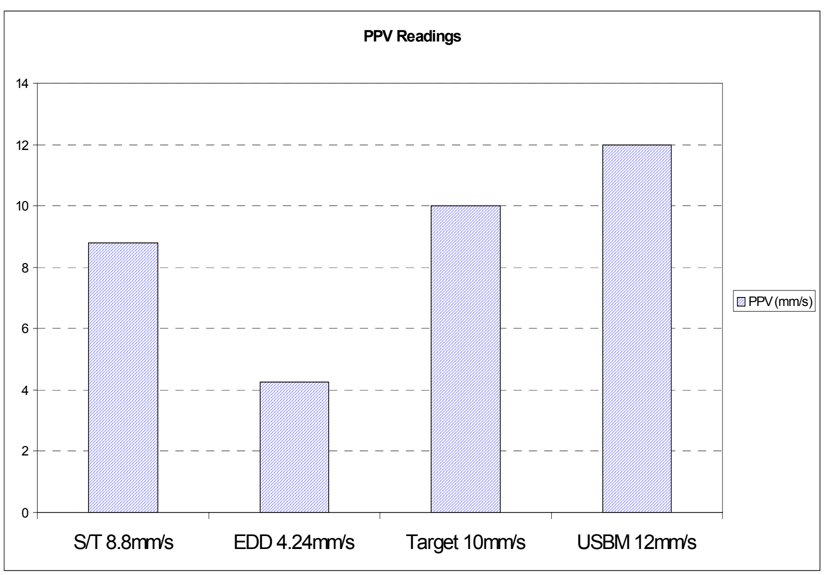

Figure 2 – Average PPV Readings

The average scaled distance for shock tube blasts was lower than that for ED initiated blasts, as the mass of explosives per delay was higher. This would be due to the limited choice of delay using shock tube as opposed to the flexibility allowed by electronic initiation systems. This, in conjunction with the precision gained from ED's, allowed single hole firing during the blasts using ED's.

Table 1 summarises the above information and highlights the reduction in PPV levels and number of triggered events when converting to ED's. The reduced number of triggered events (a % of the total number of blasts with each initiation system) indicates the control gained over environmental impacts from blasting. The trigger levels were kept constant at 1mm/s (0.039ips).

Measurement	Shock Tube	ED's	% Change
% below 10mm/s	79%	91%	↑ 15%
Min PPV (mm/s)	0.80 (0.031ips)	0.13 (0.005ips)	↓ 84%
Ave PPV (mm/s)	8.80 (0.34ips)	4.24 (0.17ips)	↓ 52%
Max PPV (mm/s)	152 (5.93ips)	24.30 (0.95ips)	↓ 84%
% No triggers	16%	29%	↑ 81%

Table 1 – Summary of PPV data

Frequency:
Frequency must be considered in conjunction with PPV in order to assess the damage potential (to structures) of a blast.

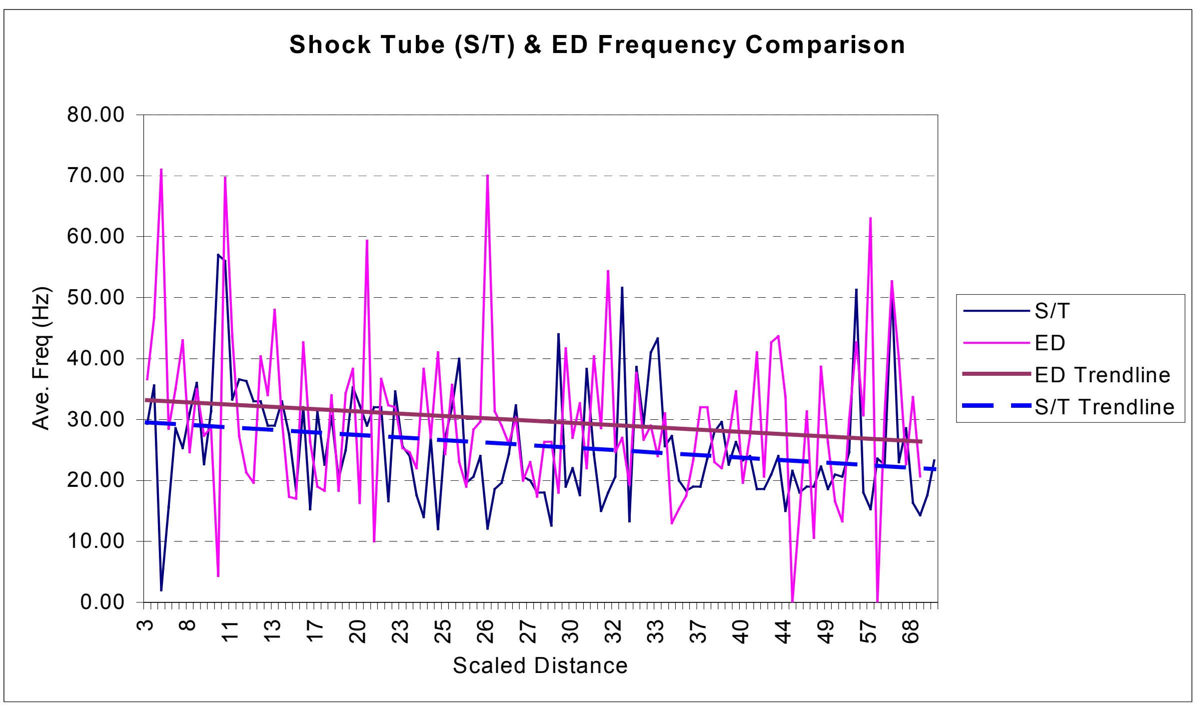

Figure 3 – Frequency vs Scaled Distance

In general, the higher the frequency the better, as damage potential decreases as frequency increases (depending on the resonant frequency of the structures of concern).

Figure 3 shows that the frequency generated by ED's is higher than that of shock tube systems. It also shows that lower frequencies travel further than higher frequencies.

Figure 4 highlights the different frequencies generated by both initiation systems. The "No Triggers" events have been excluded for better visualisation.

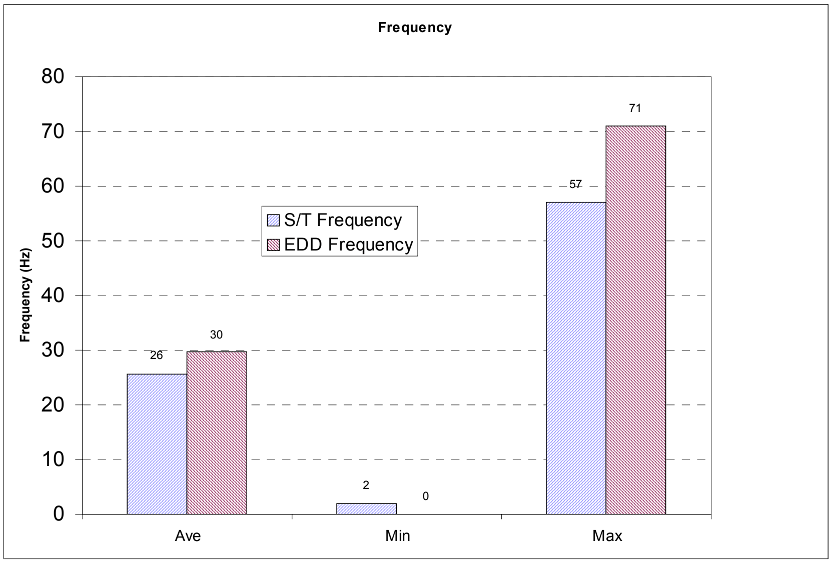

Figure 4 – Min, Ave & Max Frequencies

Airblast:

Figure 5 shows that the airblast levels recorded were lower during blasts initiated with electronic detonators than those with shock tube (3% on average).

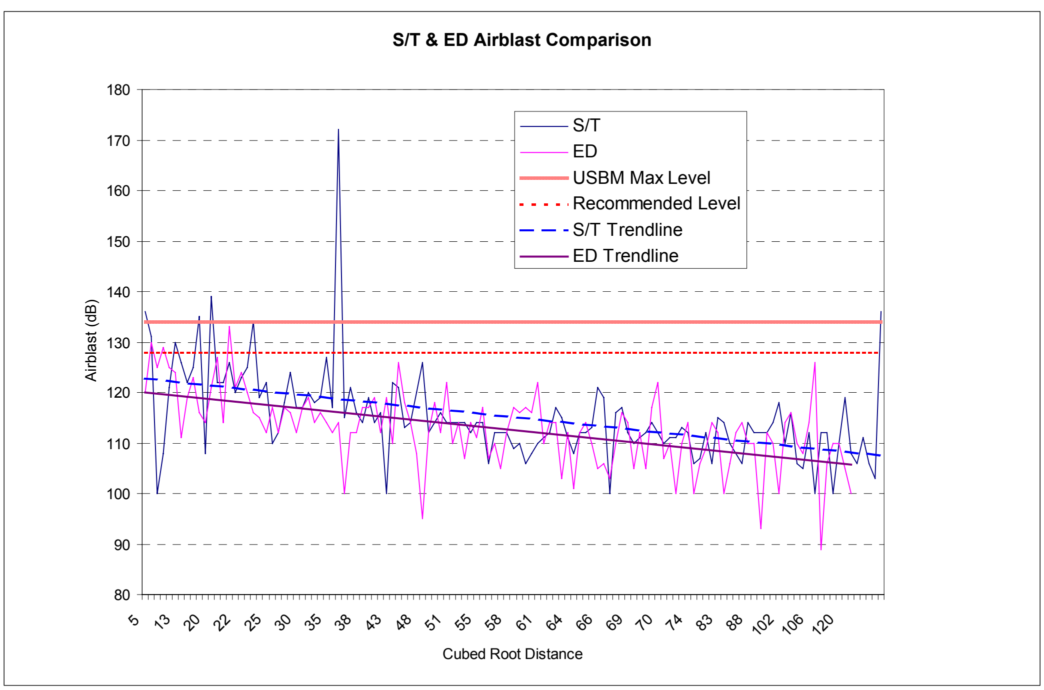

Figure 5 – Airblast vs. Cubed Root Distance

In general we would expect this result, as airblast is exacerbated by tight breaking resulting from the crowding of intervals, which are inevitable with pyrotechnic delays. The “No Triggers” events have been excluded for better visualisation.

Other References
A Benefit Selling Report prepared by quarry management concluded with the following: "… the intelligent use of programmable, accurate delay times results in consistent levels of blast vibration, and lower amplitudes, at better frequencies ..... indirect benefits to the quarry operation were improved production bench stability and looser muck piles.”

Improved Mining Efficiencies

Location

Damang Mine, an open pit gold operation, located 180km (112miles) west of Accra in the Ashanti Gold Belt in Ghana has a diverse geology making it difficult to create consistent fragmentation, thus affecting downstream processes such as crusher throughput. It mines 17 Million tonnes annually and has an annual gold output of 322000 ounces, with the mining operation performed by a contractor.

Reason for Converting to ED’s

The mine was looking to improve fragmentation particularly in the Phyllite and Dolerite and reduce the number of boulders in the Rogan Fault zone, which in turn would increase the crusher throughput and loading rates.

The blasts are large, which makes timing with shock tube difficult with respect to cut-off’s and inadequate burning fronts, therefore a more reliable and accurate product was needed. A further benefit of moving to ED’s was that any product order had a lead-time of 3 months. This meant that there would be a 3 month delay before different timing options could be tried with Shock Tube. With ED’s the timing could be changed for each blast (Baka Abu, 2002).

Data Used for Comparison

Blasting with ED’s began in September 2000 and they have initiated more than 100000 ED’s to date. The first stage of the implementation of ED’s was to compare the results of shock tube and ED initiated blasts on the same bench, with alternate blasts being initiated by either system. This phase entailed initiating 2119 ED’s. The benefits gained allowed for a 2nd (7717 ED’s) and third phase (12295 ED’s). During the third phase the mine took ownership of the system and started full scale blasting.

Results

There were visual differences between adjacent Shock Tube and ED blasts in terms of improved fragmentation. The machine operators also gave positive feedback when loading out the ED blasts.

The quantified results are those as given to the contractor by the mine. These included increases in loader productivity of 11% in Phyllite, 21% in Sandstone and 22% in Dolerite. A further benefit was a 10% increase in crusher throughput. These benefits can be attributed to improvements in the fragmentation distribution.

Other benefits, which were either not quantified or the results were not available, were a reduction in secondary breaking at the crusher, shorter loading and hauling cycle times due to better floor conditions, minimised wear and tear of the crusher cone as well as reduced operating costs of the load and haul fleet

The mine also benefited from improved control over the environmental effects of blasting. Thus was seen in a 50 % reduction in Peak Particle Velocities and airblast levels were reduced from 127dB to 108dB (15%) (Baka Abu, 2002).

Increased Cast Benefit

Location

New Clydesdale Colliery is a mini-pit located 30km (19miles) south of Witbank, South Africa. The mine utilises truck and shovels for the their load and haul operations, with the drill and blast operation being outsourced to mining contractors.

The overburden bench heights range between 22m (72ft) to 38m (125ft) with 200mm (7.87inches) diameter holes drilled to the top of the underlying coal seam. The initiation system that was used prior to ED's was "down-the-hole" shock tube with detonating cord on surface. The delays between rows ranged from 0ms to 375ms and all holes within rows were fired instantaneously, hence a "line blasting" method. A pre-split was fired before the main blast.

Reason for Converting to ED's

The decision to use ED's was based on the assumption that precise timing could increase cast benefit. The bonus earned by the contractor from additional cast benefit would offset the increased cost of ED's.

The precise firing of ED's would eliminate out-of-sequence firing that occurs with shock tube and the timing flexibility allowed the mine to adopt different timing patterns to optimise cast. The firing of the pre-split before the main blast caused movement of strata in the designated blasting block and resulted in difficult drilling conditions, re-drilling and the sleeving of blast holes to prevent runaway explosives. With the use of ED's, the pre-split could be fired together with the main blast.

Data Used for Comparison

A meeting held between the stakeholders planned the way forward and the target was to increase cast benefit from 47% to 53%. The exercise consisted of a benchmarking exercise whereby the results of 3 shock tube blasts would be documented and serve as the benchmark for the exercise. A further 4 blasts would be done using ED's and the results compared to the benchmark. The mine performed the data collection and recording so as to ensure data integrity and remove supplier and customer interference.

The drill and blast contractor's remuneration was proportional to the percentage cast benefit achieved and a 53% cast benefit was found to be economically feasible to implement ED's. Percentage cast benefit refers to the amount of material that does not require re-handling, as shown in Figure 6. Less re-handled material results in more efficient utilisation of machinery.

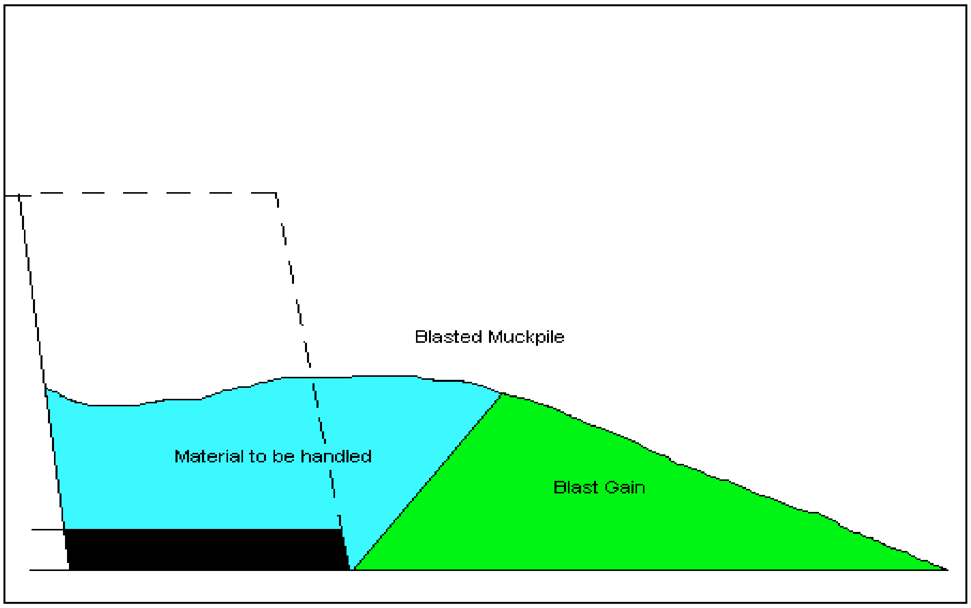

Figure 6 – Blast Gain

The in-situ volume of the designated block to be blasted was calculated prior to blasting. The blasted muckpile was then surveyed in 25m (82ft) sections along the face to determine effective cast area (the area that does not require material to be re-handled). The survey and calculation was done by the surveyors employed by the mine and used to determine the contractor's remuneration. Bonus remuneration was earned for cast achieved beyond the stipulated minimum.

Comparison

The first ED blast mimicked the benchmarked shock tube blasts, i.e. all blast parameters were kept constant. Changes, with the consent of the customer, to the blast design in the subsequent blasts were made to one variable at a time, thus allowing measurement of the effect of the change.

The average cast benefit achieved with the benchmarked shock tube blasts was 49%.

Results

Figure 7 shows how ED blasting improved over time, both relative to Shock tube initiation, and with learning.

- The 1st ED blast mimicked the benchmarked shock tube blasts. By only replacing shock tube with ED's the cast benefit increased to 51%.
- In the 2nd ED blast, a delay of 9ms between holes within a row was introduced whilst the rest of the blast parameters remained unchanged. This resulted in a further increase to 54.7% cast benefit.
- In the 3rd ED blast, the inter row delays were changed. The 3rd row was initiated 25ms faster than originally designed. The cast gain increased even further to 60.5%
- The 4th ED blast replicated the 3rd with very similar results.

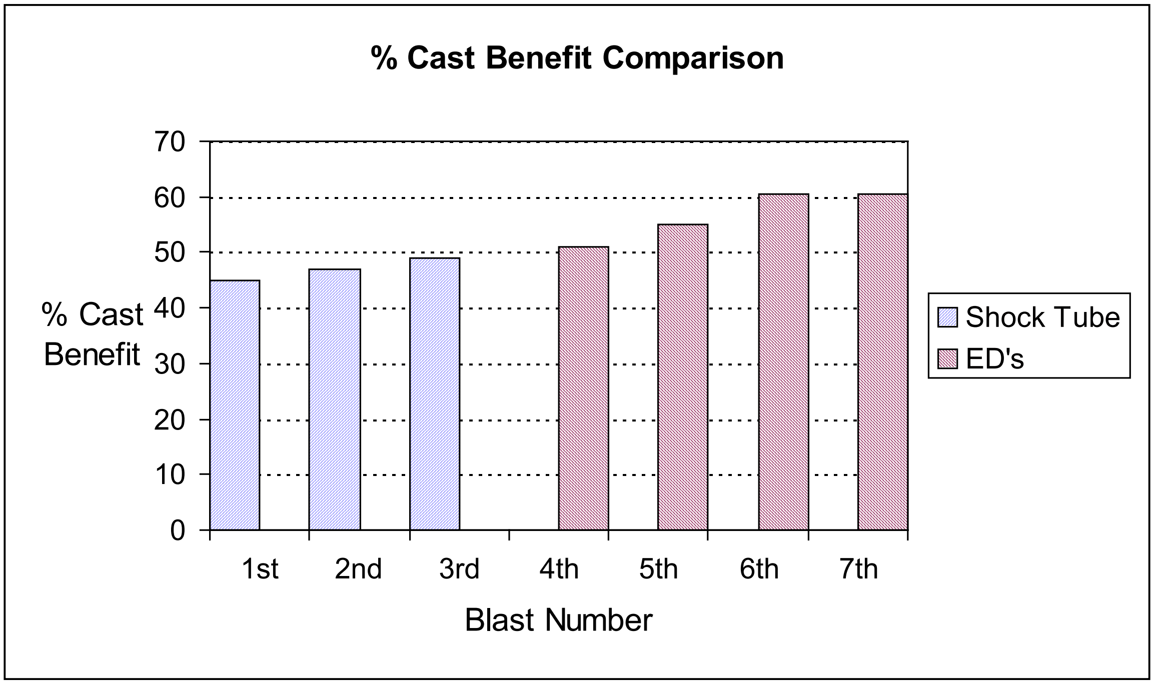

Figure 7 – Blast Gain Comparison

The firing of the pre-split with the main blast was experimental. Initially it was fired directly after the main blast. It was then fired at 475ms, which was 100ms after the last row. The final test resulted in the pre-split line being fired after the 3rd line of the main blast, which was at 300ms.

This did not consistently produce good results and more experimentation was required to obtain the optimal timing.

The primary objective of increasing cast benefit, however, was achieved and a further benefit was the elimination of one D11 dozer used for pushback.

Improved Fragmentation

Location

Peak Quarry is situated about 15km (9.32 miles) west of Somerset West, Western Cape, in South Africa. The main rock type is Hornfels, part of the Tygerberg formation of the Malmesbury group, and the rock is highly folded and bedding planes vary in intervals of 50cm (20inches) to 150cm (59inches) apart.

Reason for Converting to ED's

An increase in demand for crusher dust or fines (-6.75mm, -0.27inches), due to a shortage of quality building sand in the Western Cape Peninsula, prompted Peak Quarry to assess means of altering their product to suit the market demand.

After considering the costs of alterations to the crushing plant, it was decided that providing fine material through blasting would be more cost effective (higher volumes at a lower manufacturing cost).

Due to the flexibility and precision of ED's, the quarry personnel understood that they could alter the blast results by changing the timing of the blast.

The objectives of the project were to gain a high yield of natural fines from blasting, reduce the quantity of over size, maximise the crushing operation efficiency, maintain an effective throughput with a reduced fleet and to vary product split to changes in demand (Bedser, 2000).

Data Used for Comparison

All the measurements and data capturing was performed by the quarry. As one of the main objectives was to increase the percentage of fine material, fragmentation analysis was performed so as to quantify the changes in size distribution. Fragmentation analysis and throughput per hour were measured through belt cuts, as well as weightometer and weighbridge readings.

Drilling, blasting and secondary work costs and efficiencies were determined from existing information, whilst loading, hauling and crushing efficiencies were determined through time studies (Bedser, 2000).

Comparison

The only blast parameter to change was the timing of the blast, with each change being maintained for 3 blasts. The timing was calculated so as to ensure 8mm/s between holes and 15mm/s between rows. The Shock Tube blasts had an inter hole and inter row timing of 35 and 42ms respectively.

By keeping the timing constant for 3 blasts at a time, it was possible to perform a sensitivity analysis in order to assess the results of each change.

The following constraints were also in place:

- Oversize material was classified as greater than 0.912m^3 (32.3ft^3) or 2.48 ton (5467lbs) and a limit of less than 1% of the total blast volume.
- Powder factor ≤ 0.42kg/m^3 (0.026lb/ft^3)
- Single hole firing or mass per delay ≤ 230kg (507lbs)

The blast results were then compared to those that were initiated with Shock Tube.

Results

Figure 8 shows that the mean fragmentation size of the run of mine material at the in-pit crusher dropped by 50% from 53mm (2.08inches) to 26.5 mm (1.04inches).

This improvement in fragmentation had the following results:

- Blast fines increased from 13% to 33%
- Oversize reduced to less than 0.2%
- 11% increase in truck fill factors - from 27 to 30 tonnes (59524 to 66138lbs).
- A 25% increase in diggability, resulting in the removal of one dump truck
- A 10% reduction in the primary crusher setting with no impact on throughput
- Frequency and cost of liner changes in the primary crusher decreased by 50%
- A 25% reduction in the secondary crusher setting with no change in throughput

(Bedser, 2000)

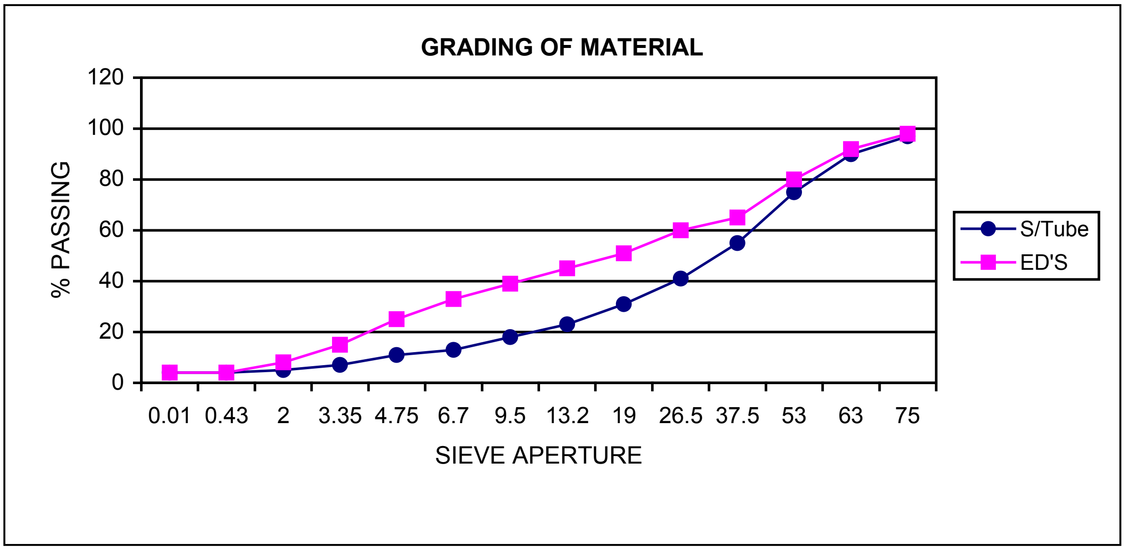

Figure 8 – Size Distribution (Adapted from: Bedser, 2000)

Conclusion

Although not every benefit of converting to ED's have been discussed in this paper, there is enough evidence and experience in Africa to show the global marketplace that ED's can add value to mining and quarrying operations. This practical evidence serves to support the technical argument for converting to ED's and should also serve to allay sceptics fears. The downstream benefits have also been shown to outweigh the additional cost of ED's.

Part of this African success has been due to the openness of personnel, throughout the mining and quarrying hierarchy, to new technology, their willingness to allow for experimentation and their sharing of information. The successes have been gained through a process of introduction, evaluation, implementation, feedback and improvement. It has also been highlighted that converted operations are able to continually improve their blasting results and downstream efficiencies by harnessing this technology.

The conclusions are clear and definitive - the replacement of pyrotechnic shock tube with ED's has delivered step changes in blasting results and has allowed for new approaches to the science of blasting. These proven results are actively enjoyed by numerous mining operations, each with their own mining challenges.

Acknowledgements

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