CASE STUDY

Minimising the Environment Impacts of Tunnel Blasting

Busan-Ulsan City Railway Project, South Korea

Site Profile

The Busan – Ulsan City Railway Project is a new 6.5km section of railway between the cities of Busan and Ulsan in South Korea. The project included the development of 3.5km's of tunnel; a 200m section of this tunnel was only 68m away from a very sensitive Precision Facility and several residential apartment buildings were only 500m away from the tunnel portal. As a result very strict ground vibration and noise control limits were placed on this section of the tunnel. Initially the excavation of this 200m section of tunnel was to be undertaken using mechanical excavation techniques and hydraulic rock splitters.

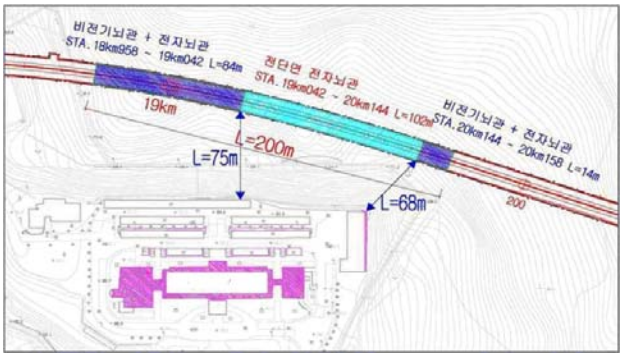

Figure 1 Plan view showing the sensitive 200m tunnel section and its proximity to the Precision Facility

The Situation

SK Engineering and Construction (the project managers) determined that excavating the rock by mechanical excavation techniques, using hydraulic splitters, would take approximately 10 months and would be extremely expensive.

In order to meet the project construction schedule and to reduce project costs, SK Engineering and Construction investigated the possibility of using drill and blast techniques to excavate this section of the tunnel.

Approval to use drill and blast methods was granted with the following conditions:

i. Ground vibration at the Precision Facility should not exceed 0.05cm/sec, and
ii. Air overpressure at the apartment buildings should not exceed 78dB (A).

Blasting Issues

Drilling and blasting techniques are often thought of as offering higher risk solutions, particularly in terms of meeting strict environmental limits. Drill and blast methods are preferred though since they deliver faster and less costly tunnel development when compared to most mechanical methods.

The environmental limits are normally managed as follows:

i. Ground Vibration – strict control of the charge weights and their relative initiation times, reduced drill depth, increased hole numbers to improve explosive distribution and reduce confinement, improved void ratios to reduce confinement.
ii. Air overpressure in a tunnel is normally managed by adding blast doors and curtains at, and prior to, the tunnel portal.

For the Busan – Ulsan City Rail Project, the main concern with the drill and blast approach was due to the limitations of conventional pyrotechnic initiation systems. These concerns are summarised as follows:

i. Inherently high delay scatter within the delay ranges;
ii. Limited delay numbers - multiple blastholes must be fired on the same delay and adds complexity to the tie in process requiring bunching and surface delays.

In short conventional pyrotechnic initiation systems make it difficult to accurately manage Maximum Instantaneous Charge (MIC) and therefore limit the potential for ground vibration reduction. Additionally since MIC cannot be accurately managed, engineers are forced to limit or reduce the charge weight and ultimately reduce the advance rate.

Although drill and blast was the preferred method of tunnel excavation, SK Engineering and Construction understood that it would be difficult to achieve using conventional pyrotechnic initiation systems, given the strict ground vibration limits set for the project.

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Technical Solutions

In order to comply with the strict ground vibration limits SK Engineering and Construction commissioned the use of long length 362mm void holes and contacted Orica to arrange for the use of the newly released eDev™ Electronic Tunnelling System.

The commercial use of the eDev™ Electronic Tunnelling System by SK Engineering and Construction would be a world first. The eDev™ Electronic Tunnelling System had completed field testing in Australia and Canada. During field testing the ease of use, flexibility and potential of the eDev™ Electronic Tunnelling System was immediately apparent, so it was with confidence that the eDev™ Electronic Tunnelling System was offered as a Technical Solution for the Busan – Ulsan City Rail Tunnel Project.

The eDev™ Electronic Tunnelling System offers fully programmable electronic detonators and a unique "timing by numbers" approach to delay number assignment at the working face. This means:

i. Electronic accuracy of 0.1% of assigned delay time (Korean conventional pyrotechnics 4% to 10% of delay scatter);
ii. Single hole initiation, with unique eDev™ approach to delay assignment;
iii. Potential to have as many individual delay numbers as required, with delay offsets within each delay number, huge potential to manage MIC and to optimise blast designs;
iv. Easy to learn system and use at the face;
v. Improved safety, security and testability of completed work.

SK Engineering and Construction recognised the need for training in the use of the eDev™ Electronic Tunnelling System. This was arranged as follows:

i. Two day theory and practical session in the class room;
ii. Five days of "hands on" experience at the tunnel face under the guidance of an eDev™ Trainer; and
iii. Final practical assessment.

The eDev™ Electronic Tunnelling System proved to be easily understood and adapted to local work practices and safe working procedures. Three local Blasting Engineers undertook the training and each of them was considered competent to safely use the system within the first week of operation.

SK Engineering and Construction Blasting Engineers successfully employed the system without requesting further training or support and reported no technical issues that they could not overcome onsite.

The system was in use from early May 2009 through to the 20th of August 2009, when the sensitive 200m section of tunnel was complete.

Blasting Engineers now had the flexibility and accuracy of electronic initiation, which in practical terms meant that blast designs could be optimised to ensure that energy, could be released in a controlled sequence, using optimum breakout progressions, not compromised by delay limitations inherent in pyrotechnic systems.

Designs could now be optimised so that all full face eDev™ tunnel blasts would have true single blasthole firing. This improves the ability to manage MIC and optimised delay intervals between blastholes to limit ground vibration.

Each blasting event was monitored and the resulting ground vibration traces analysed, making it possible for the Blasting Engineers to optimise each blast design based on actual blast results, in the current ground condition. This demonstrates the adaptability and flexibility of the eDev™ Electronic Tunnelling System, since designs can quickly and easily be adapted to changing ground conditions for optimal results.

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Figure 2: Attaching the harness wire loop prior to scanning.

Figure 3: Scanning eDev™ barcodes safely and efficiently.

Blasting Engineers also used the flexibility of the eDev™ Electronic Tunnelling System, to investigate the use of Hybrid Electronic and Pyrotechnic initiating systems in less sensitive blast areas. This allowed the Blasting Engineers to analyse vibration outcomes to determine where the blast is most affected by confinement causing increased vibration.

Having determined where in the ground vibration was most likely to exceed during the face blast, the Blasting Engineers designed the blast such that the high risk section of the face was initiated with eDev™ Electronic Tunnelling System. The remaining sections of the face where ground vibration is low can be initiated with Pyrotechnic detonators.

These designs where called “Hybrid” blasts, examples of both full face eDev™ Electronic Tunnelling System and Hybrid designs are shown below.

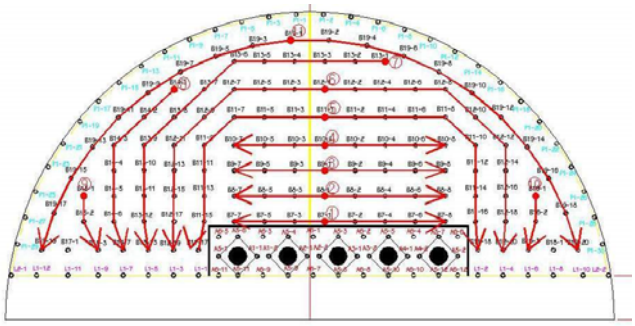

Figure 4 Full face eDev™ Electronic Tunnelling System

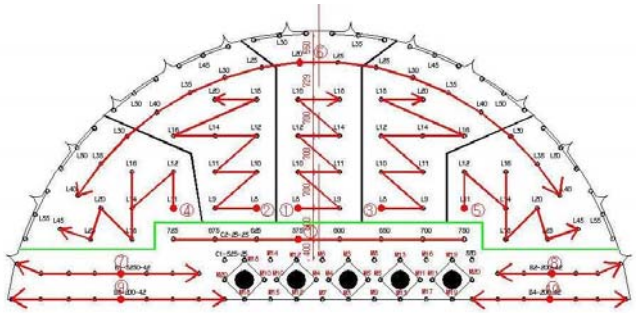

Figure 5 Hybrid (eDev™+ Pyrotechnic).

The Results

The results of ten test blasts, comparing the outcomes of full face eDev™ Electronic Tunnelling System and Hybrid designs are compiled in the following charts. Full face pyrotechnic are not included, since these results were collected during actual work in the sensitive section of tunnel, where full face pyrotechnic initiation was excluded.

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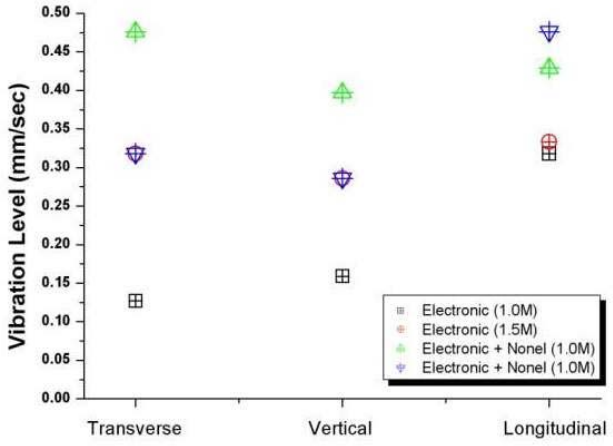

Figure 6: Peak Particle Velocity comparison. Note Hybrid designs restricted to 1.0m blastholes due to MIC issues in the pyrotechnic section of the blast.

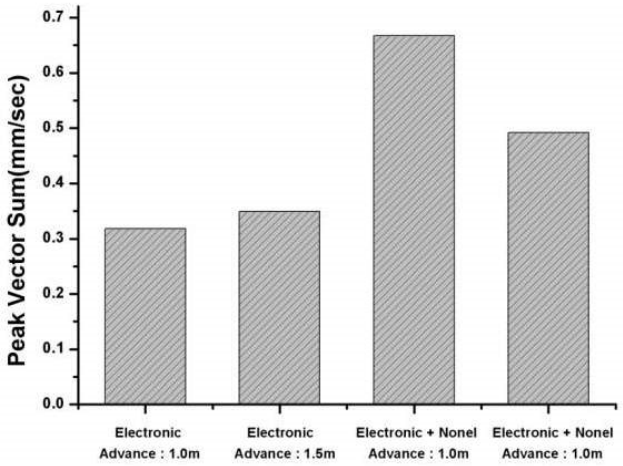

Figure 7 Peak Vector Sum comparison, Hybrid outcomes variable due to design variability and the delay limitations inherent in the pyrotechnic detonators.

Using eDev™ Electronic Tunnelling System SK Engineering and Construction, Blasting Engineers were able to optimise their blast designs to maximise advance rates while staying under the strict 0.05cm/sec ground vibration limit measured at the Precision Facility.

Full face eDev™ Electronic Tunnelling System blasts limited ground vibration to between 0.3mm/sec and 0.4mm/sec in both the 1.0m and 1.5m blastholes. Full face eDev™ Electronic Tunnelling System designs were used when the tunnel was closest to the Precision Facility. Further optimisation of blast designs using the eDev™ Electronic Tunnelling System will most likely result In improved advance rates while complying with strict ground vibration limits, where full face eDev™ designs are investigated.

The eDev™ Electronic Tunnelling System has been specifically designed to work in a way that is familiar to most Shotfirers and their crews. Cycle times did not increase, in fact crews found the eDev™ Electronic Tunnelling System both safe and easy to use and at least as fast to load and prepare for firing as conventional pyrotechnic detonators.

The 200m section of sensitive tunnel was completed in 4 months rather than the 10 months originally proposed had mechanical tunnelling techniques been used. This resulted in significant cost savings.

Acknowledgements

Mr. Hyo Lee, Deputy General Manager GEOTASK Team, SK Engineering and Construction
Mr. Sang Hun Lee, Manager, GEOTASK Team, SK Engineering and Construction.

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