CASE STUDY

Managing blast vibration whilst increasing tunnel advance rates

Anei River, Toyota City, Japan

Site Profile

Toyota City is located in north-central Aichi Prefecture, Japan. Toyota City is home of the car manufacturing giant, Toyota, hosting the global head office, technical center and several key manufacturing plants.

Some low lying areas of Toyota City are prone to flooding. The Anei River, which was built in the 1700s, is the existing water course which drains flood water from these areas. However at times of heavy rainfall flooding still occurs.

The entrance to the Anei River Tunnel.

The Situation

To address the issue of flooding in Toyota City, Kajima Corporation were contracted to excavate what is known as the Anei River Tunnel – an 85m^2, 1.86km long tunnel – to increase drainage capacity from 10m^3/s to 90m^3/s.

The initial plan was to excavate the Anei River tunnel by mechanical means but the granite rock present proved too hard for mechanical excavation. Blasting was the obvious solution for such hard rock however, as shown in the picture below, the tunnel ran directly beneath a residential area. The project's License to Operate (LTO) depended heavily on the City of Toyota and neighbours' acceptance of construction activities with complaints from neighbors having the potential to bring excavation to a halt. Blasting in the Anei River tunnel commenced with a local supplier's pre-programmed delay detonators.

However Kajima received numerous complaints from neighbors about the blasting activities. Attempts to lessen the impact of blasting by reducing the Maximum Instantaneous Charge (MIC) were costly for excavation productivity and did not eliminate complaints.

Technical Solutions

Managing Vibration

Kajima approached Orica for a solution that would reduce vibration enabling them to maintain their LTO. Orica proposed the use of the eDev™ II Electronic Tunnel Blasting System. The accuracy of the system (to 0.01% of its nominated firing time and programmable in 1 ms increments from 0 ms to 20,000 ms) combined with Orica's SHOTPlus™ T software for design, modeling and vibration analysis allowed Kajima to customize their initiation sequence to suit the neighbors' perceptions of "low vibration".

Low frequency ground vibration is comparatively more noticeable and can be representative of tectonic activity which is intolerable for Japanese locals who have experienced earthquakes. By programming blasts to produce high frequency vibration waveforms and shorter blast duration, daily blasting operations became far less perceptible. In direct consultation with neighbours the engineering team also developed a technique dubbed "knock the door". This refers to firing three distinct charges, representative of knocking on the door, to give prior notice before firing the entire blast in less than one second.

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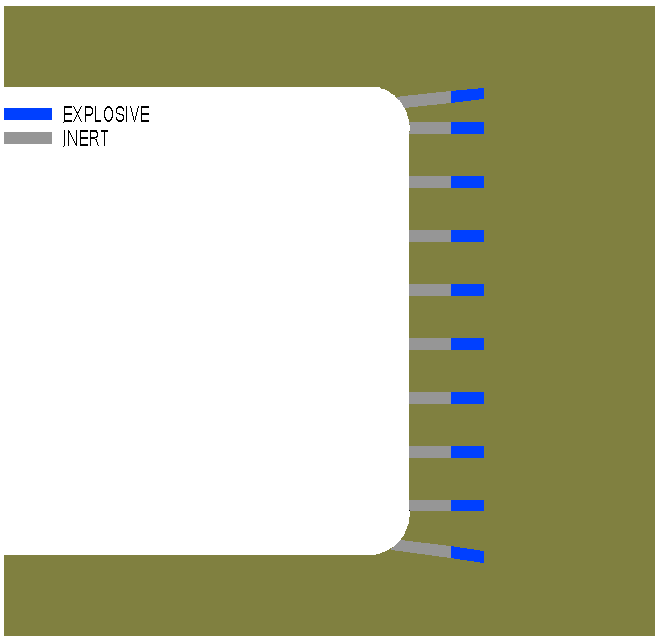
Advanced Technical Solutions

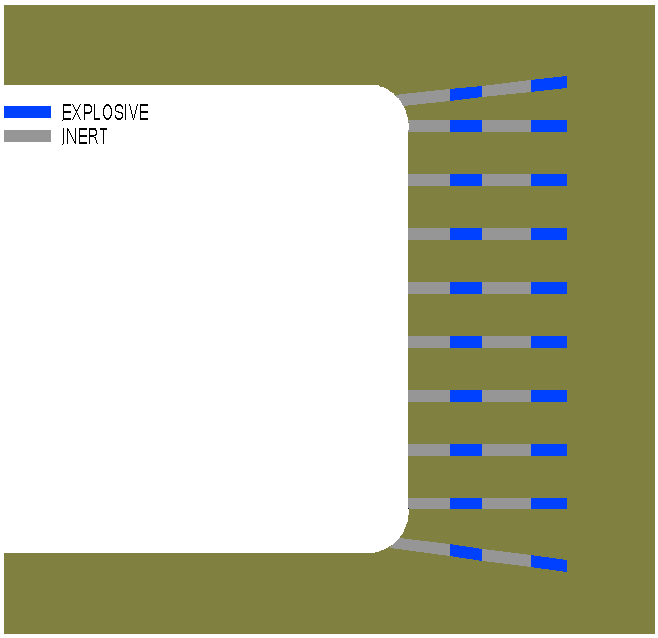
Increasing advance rates

The MIC is normally the amount of explosive loaded in a single blast hole. When blasting in a vibration sensitive environment, such as Anei River, the MIC often becomes restricted. This restricts the maximum blast hole length and subsequently the advance achieved per blast. While this reduces the impact (vibration) of each individual blast, it has the adverse effect of increasing the overall number of blasts and the time required to complete the tunnel. Unfortunately this means neighbors endure more blasts and longer project duration.



Conventional (single deck) charge layout.

With the eDev™ II system in place it became evident the project could achieve a greater rate of advance, further reducing the impact on neighbors. The user-friendly delay-by-numbers software coupled with the vast range of available delays meant that a far greater number of individual explosive charges could be managed within a single blast. By drilling to a depth that allowed use of multiple independent charges within a single blast hole the peak level of ground vibration could be controlled while eliminating the adverse impacts of a small MIC and shorter round lengths. This technique is referred to as “Multi Deck Tunnel Blasting”. Each explosive charge is assigned an accurate individual firing time such that the MIC, peak vibration and frequency is consistent with a conventional blast.



Multi Deck Charge layout.

The Result

The initial introduction of eDev™ II reduced the impact on neighbors and allowed a productive level of blasting to continue. The system’s simple delay-by-numbers user interface and safe at-face testability meant the system was quickly adopted by the existing blast crew.

Following the introduction, Kajima’s technical team realized much greater value in the eDev™ II Electronic

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Blasting System as an enabler for advanced blasting techniques. With support from Orica's Global Technical Team, Kajima fired Japan's first ever Multi Deck Tunnel Blast in September 2013, achieving an astounding 4.0 m round with an MIC of only 0.8kg compared to the standard of 2.0 m for the same MIC using the conventional blasting technique.

Shotfirer programming the blast. Yellow and red clips indicate the front and rear decks respectively.

Employing the Multi Deck Blasting technique allowed Kajima to blast through the most sensitive areas of the project with half the amount of blasts that might have been required using the conventional blasting technique, minimizing delays to both neighbors and construction activities, wiping months off the project's critical path.

Testimonial

Following is the response from Kajima Anei River project management. Deputy Project Manager, Mr. Sueyoshi:

"If we only consider the cost of explosives the use of eDev™ II would be difficult to justify. However we must also consider the impact we have on the communities in which we operate along with our overall efficiency and time to completion.

At the Anei River tunnel, eDev™ II allowed us to minimize disturbance to our neighbors while blasting operations continued. Further, by employing the Multi Deck Blasting technique we fired fewer blasts which resulted in fewer opportunities to disturb our neighbors and we also realized increased productivity in other aspects of the tunnel cycle. Less blasts meant less down time due to tunnel evacuation for firing and ventilation. Less blasts meant less faces to scale and make safe for our men to work at. Less blasts meant the drill trammed and navigated less times. Less blasts meant our shotcrete equipment set up less times. On a square meter basis it is more efficient to shotcrete a 4 m tunnel section than a 2 m section and every time we blast there is always some overlap required so the total surface area of shotcrete required is reduced. Ultimately eDev™ II and the Multi Deck Blasting technique enabled less blasts and subsequently our overall efficiency and rate of advance increased."

Project Manager, Mr. Koshikawa: "There are many misconceptions about blasting being out of control. Two way testability at the face means our blasts are never delayed, they are fired on time every time. Further, having the ability to 'knock-the-door' or blast to any beat demonstrates that we have complete control and gives our neighbors comfort. In fact eDev™ II can make any rhythm such as Samba, Tango and Eight Beat, whatever you want. For our final blast we are planning to program to the beat of the Japanese Drum and fire during a community event".

Acknowledgements

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