BLASTING WITH PRECISION

Scott G. Giltner and Alex Schwenk, Dyno Nobel, examine how accurate blast design technologies succeeded in extending the lifespan of a mine and accessing US$1 billion of ore.

The lifespan of a mine can be as short as a few years or as long as several decades, depending not just on the size of the ore body, but the feasibility of extracting it. In areas with difficult geology, neighbouring towns, economic pressures, and other challenges, mines that are unable to overcome these issues face closure long before the ore deposit is depleted.

With cutting-edge technology, blast designs that put the right energy, in the right place, at the right time, and environmentally conscious processes, operations that may have otherwise had to leave ore behind in their closure are able to extend their life and continue mining for many years. In a recent project conducted by Dyno Nobel, the DynoConsult team worked with an operation to drastically extend the lifespan of a mine and free millions of tonnes of ore with a value of over US$1 billion.

An iron mine seeks to expand pit near structures

An iron operation in the US needed to expand its pit to extend the life of the mine. A successful pit pushback would allow for many additional years of mining and free millions of tonnes of ore. However, there were a few key challenges that presented an obstacle to the expansion.

The primary challenge was based on the location of the pit. The blasting area was near several existing structures, as well as a neighbouring town. The mine also faced challenges due to the geology at the mine. The operation turned to DynoConsult in December 2023 to provide guidance on the designs of the blasts, which commenced in January 2024.

Nearby structures and challenging geology

The mine identified four sensitive structures, with the two structures of the greatest concern being a public highway within 80 m (250 ft) of the blast site and a sewage treatment plant within 244 m (800 ft). These structures would require the site to blast with great precision and accuracy to avoid excessive vibration and flyrock.

The geology at the mine site consisted of the Biwabik Iron Formation dipping on a 7˚ angle to the southeast. This iron-rich sedimentary rock layer has historically presented a challenge to the mines in the region due to the weak contact between the different rock types and weathered joint sets. The mine also faced complications due to the variation in hole depth within any given blast. For the initial sinking shot, the hole depths varied from 6.4 m (21 ft) to 12.5 m (41 ft). In subsequent blasts, the hole depths could vary up to 5.8 m (19 ft). This variation in hole depth presented additional challenges in properly developing blast designs.

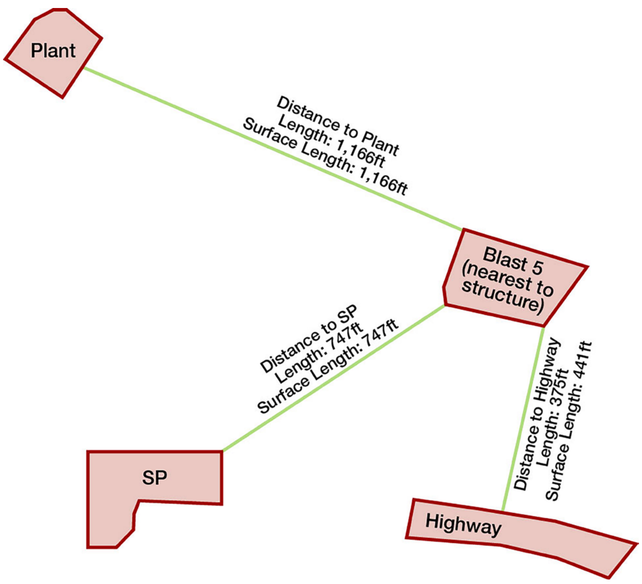

Figure 1. Spatial relationship of blasting to areas of concern.

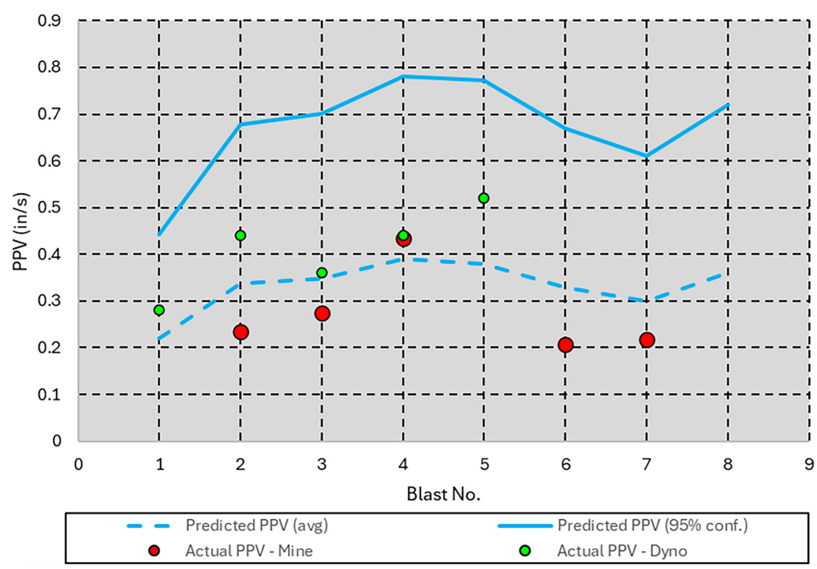

Figure 2. Comparison of predicted vibration levels to actual vibration levels.

Project goals

To safely and effectively expand the area of the pit, the two primary goals for blasting in this project were to minimise vibration at the structures and eliminate flyrock. At the sewage treatment plant in particular, the mine desired to keep blast vibrations as low as possible, specifically below 19 mm/s (0.75 in/s). Provided those two goals were achieved, fragmentation of the muckpile was the next priority.

Developing new blast designs

To properly design the blast to ensure that there was no flyrock and vibration was kept to a minimum, the team used a variety of tools.

Unmanned aerial vehicle (UAV) profiles were used for each blast in the pushback. These surveys provided a 3D representation of the free faces and bench surface, which could then be used to measure the shape of the free faces. This allowed the team to establish the proper placement of the crest holes and then develop a custom explosive load for each blasthole. The UAV profiles also increased the team's confidence in controlling flyrock along the open face of each blast by maintaining the minimum face burdens on each blasthole.

To ensure control of the crest, the team used Dyno Nobel's Delta E^2 (ΔE^2) Preload software to ensure the explosive density was matched to the actual 3D burden and allow a hole-by-hole collar height adjustment. This allowed for a technical approach to the blast designs, while maintaining a simple loading process for the blast crew on the bench.

When designing the burden and spacing, the DynoConsult team began by opening the lift shot in waste rock to create a new permanent ramp system. This gave them the opportunity to start blasting at the furthest point from the sensitive structures.

Next, the team transitioned to a staggered pattern in waste rock. This allowed them to trial the hard ore blast design to ensure they achieved the desired level of control. To enable ground vibration compliance and minimise any effects on the nearby community, the team then reduced the blasthole diameter and used a slightly smaller staggered pattern.

Identifying the ideal timing

Because of the structures near the pit, particularly the sewage treatment plant, it was important to minimise blast vibrations. To properly control vibrations, the team elected to use electronic detonators because of their accuracy and precision in timing.

For each development blast, signature hole analysis (SHA) was performed. The optimal timing combination for minimising vibration was identified, but this timing did not always achieve the other goals of securing an acceptable level of fragmentation and maintaining flyrock control. To balance these needs, the team established a specific range of delay time combinations that would achieve the desired fragmentation while controlling flyrock. When a SHA was performed, the delay timing within the determined range that achieved the lowest vibration was selected.

Finally, the team used a regression analysis of the available vibration data to predict the peak particle velocity (PPV) for each blast. This helped ensure that the vibration from the designed blasts was projected to fall below the mine's desired levels.

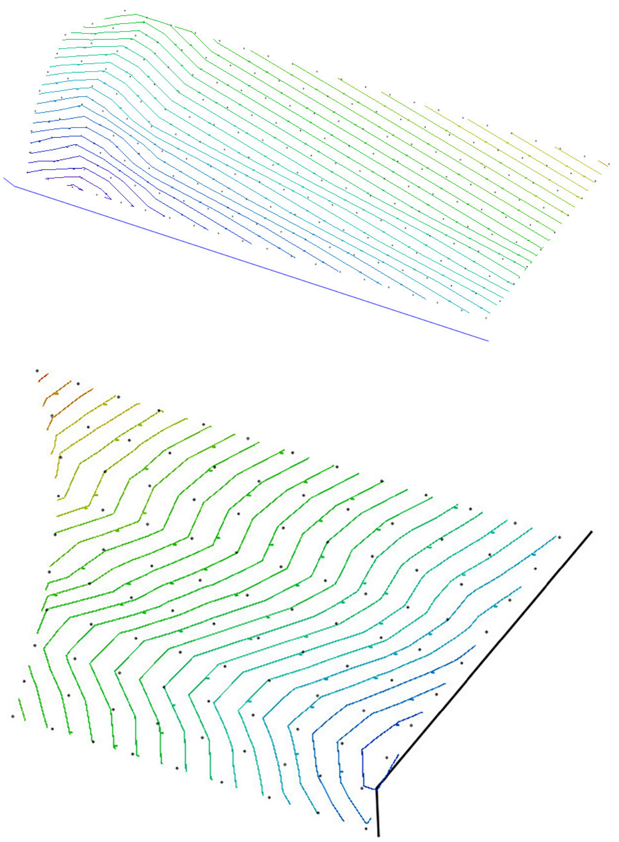

Figure 3. Timing contours for two blasts at the mine.

Figure 4. Controlled rock movement during blast.

Technology

To ensure the blasts were initiated with accurate and precise timing, Dyno Nobel's DigiShot electronic detonators were used. Electronic detonators offer unmatched millisecond timing accuracy, and implementing them allowed the team to achieve the necessary control over vibration, flyrock, and fragmentation for optimised blast results.

Dyno Nobel's TITAN 1000 DIFFERENTIAL ENERGY (ΔE) Emulsion and ΔE^2 technology were used for all blasts. TITAN 1000 ΔE was selected because it allows operations to customise the explosive energy between blastholes, and throughout the individual blastholes themselves. ΔE^2 uses data from drills and other sources that characterise rock properties to allow targeted placement of energy in the blasthole.

The Preload software sends loading plans directly to the equipment to ensure each hole is loaded as designed. With tight vibration and flyrock limits, this provided the DynoConsult team with additional control over the implementation of the blast design to ensure the results were as close to the mine's goals as possible.

Minimised vibration and flyrock allow mine to expand pit and access US$1 billion of ore

The blasts completed at the mine were successful. To measure blast vibrations and ensure they were effectively minimised, Dyno Nobel team members conducted seismograph readings at each of the structures of concern. The peak vibration level at the sewage treatment plant was 10 mm/s (0.40 in/s), well under the stated limit of 19 mm/s (0.75 in/s).

When compared to the regression analysis the team used to predict vibration for each blast, the measured PPVs were all lower than the predicted PPVs with a 95% confidence interval. This demonstrates that the regression analyses performed by the team were valuable tools in guiding blast designs to ensure the PPV for each blast was satisfactory.

The methodology developed by DynoConsult for these blasts were also successful in preventing flyrock. In all blasts in which Dyno Nobel's designs were followed, no flyrock occurred. In addition to achieving the vibration and flyrock goals, the blast designs produced well-fragmented muckpiles, with reports from the shovel indicating that they dug well.

Because the blasts successfully produced the desired results, the operation was able to safely and effectively expand the area of the pit. This added many years to the life of the mine and freed 143 million long tons of ore for a value of over US$1 billion. As the mine continues to expand the pit, the blast design techniques established during this project will be implemented for years to come. GMR