Technical Services – Explosives & Dangerous Goods

Recent Examples of Blast Vibration Control in Pilbara Iron Ore Mines

October 2013

Production blast at Hope Downs 1 mine

Contents page

1. Introduction

Explosives are charged into drilled holes and fired to break and loosen intact rock, so that ore and other material can be excavated and delivered to the processing plant, a stockpile, or a waste dump. Rio Tinto Iron Ore utilises around 200,000 tonnes of explosives each year in blasting across its Pilbara mines.

Uncontrolled ground vibrations from blasting can lead to damage or adverse effects to sensitive sites, so the blast planning process includes risks assessment and, where required, implementation of specific management plans to control blast vibrations.

This document highlights some recent examples of programs implemented by Rio Tinto's Pilbara mines to control blast vibrations and achieve a required risk level.

2. Blast vibration overview

Ground vibrations are generated from blasting buried explosives, and these travel through the ground in much the same way that sound travels through air. There are several types of waves generated (e.g. compressive, shear and surface waves), and the sum of these waves can be detected and measured using geophones, accelerometers or other sensors with appropriate data acquisition equipment.

A geophone glued to rock mass, ready to capture blast vibration data

Blast vibration is often expressed as a 'peak particle velocity', measured in millimetres per second. The vibration may be expressed in terms of the three orthogonal components (e.g. longitudinal, transverse and vertical), or the vector sum of these components. Key measures are defined in Appendix J of AS2187.2–2006.

The magnitude of measured blast vibrations depends on the size of the explosives charge fired, the blast timing (i.e. the layout and delays between firing successive holes), the distance from the blast to the monitoring location, the topography and the geological properties of the ground.

Table 1 shows the typical vibration levels associated with potential negative impacts to sensitive sites, and limits typically applied by Rio Tinto to prevent vibration-induced damage.

Table 1. Potential adverse effects from blast vibration

	Typical vibration levels (PCPV) associated with adverse effects	**Typical vibration control levels applied by Rio Tinto in Pilbara mines**
Human discomfort (residential areas)	> 5 mm/s	N/A (no residential areas directly impacted)
Human discomfort (industrial areas)	> 25 mm/s	< 25 mm/s
Minor damage to sensitive heritage sites (e.g. rock shelters with recognised heritage importance)	> 50 mm/s	< 25 mm/s (95% confidence)
Damage to buried gas pipeline	> 50 to 100 mm/s	< 10 mm/s (95% confidence)
Cosmetic damage to reinforced or framed structures (Industrial and heavy commercial buildings)	> 50 mm/s (as per Table J4.4.2.1 of AS2187.2)	< 25 mm/s (95% confidence)
Structural damage to buildings of reinforced concrete or steel construction	> 100 mm/s (as per Table J4.5(b) of AS2187.2)	< 50 mm/s (95% confidence)
Damage to communications or other key infrastructure	> 50 to 100 mm/s	< 25 to 50 mm/s (95% confidence)
Fracturing of intact rock	Typ. 250 - 1000 mm/s	

Notes: These values are examples only; in practice the vibration limits will be based on specific risk assessment, with due consideration of structural design, potential mechanical resonance and other factors. PCPV is the peak component particle velocity, defined in Appendix J of AS2187.2–2006.

2.1 Blast vibration modelling

Models can be developed to predict vibration, and refined over time as new data comes to hand and as pit conditions change. Figure 1 shows an example of a ‘scaled distance’ plot from a recent Rio Tinto vibration control project.

3. Recent examples of blast control in Pilbara operations

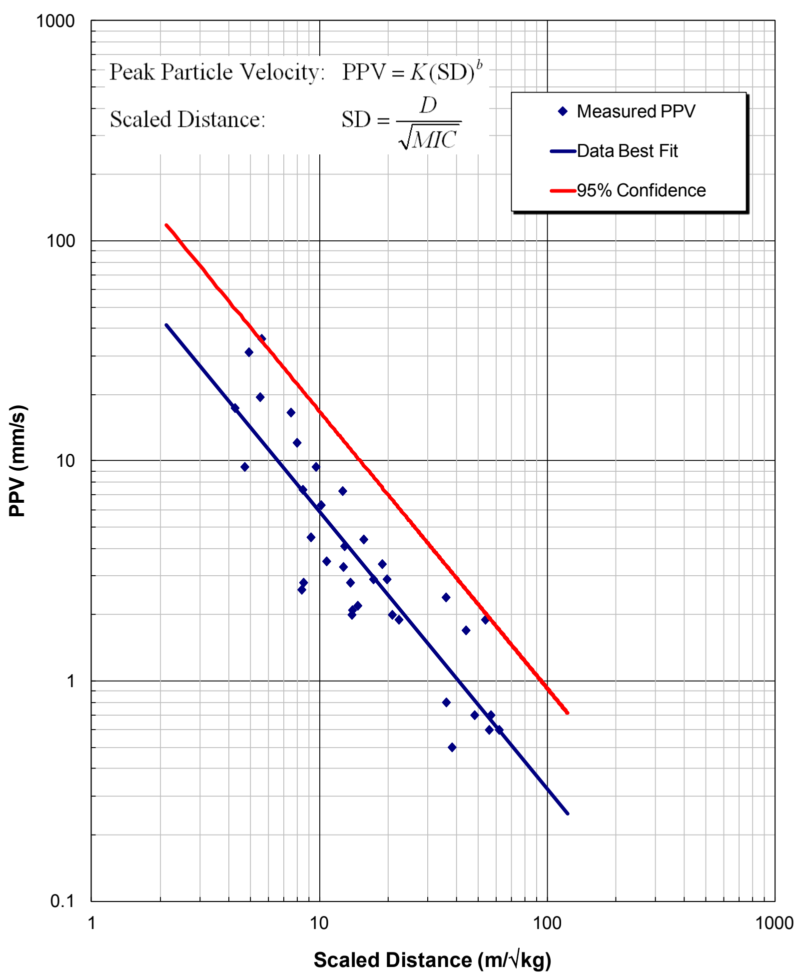
Vibration control and management projects are regularly established to protect sensitive sites. The projects may apply to a small number of blasts, or through a large mining area and last a number of years. The level of rigour applied is commensurate with the risk.

In a number of specific cases, Blast Vibration Management Plans have been put into effect to ensure that accountabilities and responsibilities are clear, appropriate test work is conducted, blast vibration is monitored and controlled through the blast design and execution phases, and review and reporting is completed to share insights.

3.1 Culturally sensitive sites

A number of rock shelters in the Pilbara are designated as having high cultural significance to the traditional owners. The proximity of some of these sites to mine pit limits means that tight vibration control is required to ensure the integrity of the sites. Current examples include sites on the Hope Downs 1, West Angelas and Tom Price mining leases.

Figure 1. Example of a Scaled Distance plot for monitoring & predicting blast vibration



Best Fit: $PPV = 107\ (SD)^{-1.26}$

$R^2 = 0.78$

95% Confidence: $PPV = 305\ (SD)^{-1.26}$

Measured Data				Measured Data			
Distance (m)	**Charge (8ms)**	**PPV (mm/s)**	**SD**	**Distance (m)**	**Charge (8ms)**	**PPV (mm/s)**	**SD**
51	46.5	16.6	7.5	160	158.4	3.3	12.7
95	46.5	2.1	13.9	453	158.4	0.8	36.0
152	46.5	1.9	22.3	62	160.8	31.2	4.9
419	46.5	0.6	61.4	107	160.8	7.4	8.4
48	76.8	19.5	5.5	160	160.8	7.3	12.6
94	76.8	3.5	10.7	455	160.8	2.4	35.9
151	76.8	2.9	17.2	68	73.1	12.1	8.0
420	76.8	0.7	47.9	110	73.1	4.1	12.9
47	122.4	17.4	4.2	161	73.1	3.4	18.8
94	122.4	2.8	8.5	457	73.1	1.9	53.5
151	122.4	2.8	13.6	76	68.9	4.5	9.2
422	122.4	0.5	38.1	115	68.9	2.0	13.9
57	105.0	35.9	5.6	164	68.9	2.9	19.8
104	105.0	6.3	10.1	461	68.9	0.6	55.5
160	105.0	4.4	15.6	80	68.9	9.4	9.6
450	105.0	1.7	43.9	122	68.9	2.2	14.7
59	158.4	9.4	4.7	173	68.9	2.0	20.8
105	158.4	2.6	8.3	469	68.9	0.7	56.5

A recent example is a rock shelter at West Angelas Deposit E. A management plan has been developed that defines limits on explosives charge per hole and per delay interval; quality assurance and control requirements; site access control; and monitoring and reporting expectations. The drill and blast engineers, blast crew and other personnel involved are all trained in the vibration control process.

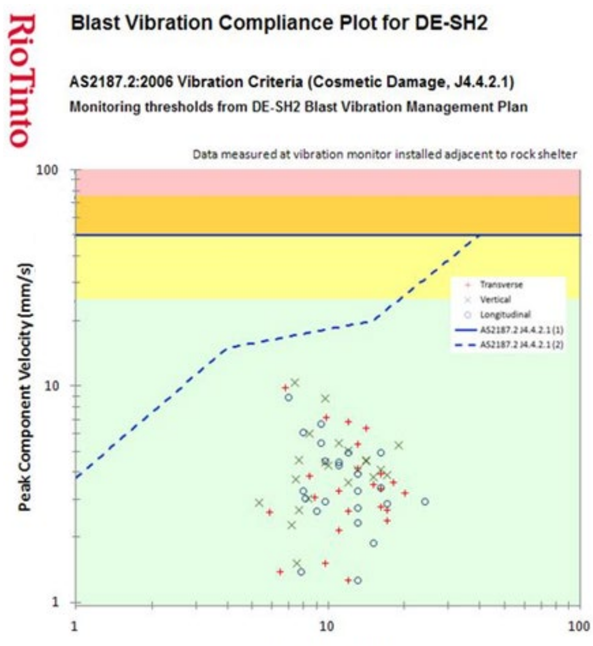
To establish the vibration criteria, a geotechnical survey was conducted to assess stability of the rock shelter and specific structures. In line with current best practice, a set of trial blast holes were individually fired to set a baseline for a vibration model.

To the end of October 2013, almost forty blasts have been conducted under the management plan, with no vibration readings outside of the target range. Figure 2 shows peak vibration through many blasts as measured adjacent to the rock shelter (blasts less than 1 mm/s are not visible).

The blast vibration model is regularly reviewed and adjusted to account for changing pit topography (e.g. the vibration response varies depending on the direction from a blast to the monitoring location).

Following the management plan will enable mining to within 60 metres of the rock shelter.

Figure 2. Example of Blast vibration data from West Angelas Deposit E rock shelter



3.2 High pressure gas pipeline at Eastern Range

A 10 MPa gas pipeline runs close to the Eastern Range mining area near Paraburdoo. Damage to the pipeline could lead to a rupture of the pipeline resulting in a loss of gas and the potential for an explosion.

A vibration control program was established in 2010 following test work in 2009. The test work involved development of a scaled distance vibration model, plus use of advanced vibration analysis tools to assess the 'worst case' vibration potential. The blast vibration management plan placed a vibration limit of 10 mm/s at the surface above the buried pipeline. With blasts as close as 120 metres from the pipeline, a number of controls had to be established, including strict limits on the explosives charge per hole and per delay, reduced blast sizes, a custom quality assurance program and a strict reporting regime.

3.3 Protecting Troglobitic fauna at Mesa A

'Troglofauna' species and populations have been identified at the Mesa A mine. Blasting activities during mining have the potential to cause collapses of strata and other features such as mesocaverns in the retained portion of the mesa formation. There is also the possibility of direct impacts on fauna close to blasting activity through direct physical effects.

A blast management program was established at Mesa A to ensure that blast vibrations are controlled and potential for damage beyond the defined 'mining exclusion zone' is limited. This program is ongoing to ensure that the troglofauna are protected.

3.4 Communications tower at Yandicoogina

At the Yandicoogina central pit, a key communications tower is located less than 30 metres from the pit crest. Due to the resonant nature of the tall structure, a blast vibration control program was put in place whilst blasting within 100 metres of the tower, to ensure that blasts were engineered to avoid undesirable vibration frequencies that could induce significant mechanical stress.

Small scale test blasts were conducted to identify the dispersion and attenuation characteristics of the rock mass, and to characterise the frequency response of the tower. Blasts were simulated to assess the dominant frequencies that the blast would produce, and the blast timing adjusted until requirements were met.

The subsequent production blasts were conducted without any damage to the tower.

3.5 Cape Lambert Port B Construction Blasting

The construction of Cape Lambert Port B necessitated blasting within close proximity of critical port and infrastructure and ongoing construction works. These included blasting:

- within 10m of live rail;
- within 2m of concrete;
- immediately under live water mains;
- within 30m of a gas pipeline;
- within 30m of a diesel line;
- within 50m of office buildings;
- for shallow trenches whilst managing fly rock; and
- for presplit rock faces to minimise construction footprint.

A variety of techniques including varying drill hole diameters, drill angles, uncharged holes, deck loading and air decking were combined with careful initiation sequencing to ensure all blasting met required rock fragmentation without exceeding blast vibration limits, fly rock occurrences, whilst controlling shear force acting on the existing infrastructure from blast muckpile displacement.

Blast design parameters to predict PPV limits were calibrated through a heavily observed blasting monitoring program. The monitoring included video surveillance and ground vibration monitors for every blast on site.

A stringent blast management plan was also put in place to ensure all personnel involved in the blast were safely evacuated behind blast radiuses. Blast wardens were elected and trained for every contractor and RTIO department affected by the blasting.

3.6 Pit walls

The underlying intent of blasting is to break rock for subsequent excavation; this is in direct opposition to the need to maintain structural integrity of pit walls for safe and economic mining. Vibration monitoring programs have been setup at a number of mines to establish criteria for safe and effective blasting that minimises unwanted damage to pit walls. In these cases, the use of vibration measurement equipment forms a key part of the monitoring and review elements of the continuous improvement cycle.

4. Conclusion

Rio Tinto follows best practice methodology in managing blast vibration risks to people, cultural heritage, threatened species and other environmental concerns. AS2187.2–2006 provides guidance on vibration control and management, and this represents the baseline (minimum requirement) for vibration management in Rio Tinto's Pilbara operations. Advanced vibration analysis techniques are used where required.

Rio Tinto has developed strong internal vibration control capability and knowledge across the mining teams. The examples provided in this report are a selection of projects across Rio Tinto's Pilbara iron ore mines where blast vibration control allows safe, effective and sustainable mining.

4.1 References

AS2187.2–2006 Explosives – Storage and use; Part 2: Use of explosives; Standards Australia, 2006.