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# Unlocking iron ore by controlling environmental effects using advanced blasting systems

*Ground vibration and air over pressure are both undesirable but inevitable by-products of blasting operations. The vibration energy that travels beyond the zone of rock breakage can cause damage to surface structures and annoyance to residents in the vicinity. This paper presents a critical analysis of the observations and results obtained during work done at Joda East Iron Mine, Tata Steel, India, to unlock iron ore using advanced blast modelling and electronic blasting systems for minimizing the environmental effects. The blast patterns were designed after understanding the geology of the area and a Monte Carlo model was used for simulation of the different blast designs to achieve the desired vibration levels.*

## 1. Introduction

### 1.1 Joda East iron mine

Joda East Iron Mine (JEIM) is one of the captive iron ore mines of Tata Steel in India. It is an open pit mine spread over an area of almost 8 $km^2$ and is located around 250 km north of Bhubaneswar in the state of Odisha, India. The annual production of the mine is 8.5 Mt and accounts for nearly 40% of the current requirement of iron ore for steel production at Tata Steel's Jamshedpur plant. The ore body is hard and massive with an average ore grade of 66.5%.

### 1.2 Situation

Tata Steel is planning to increase its steel production from 9 Mt to 15 Mt by 2015. To meet the increasing demand for raw material, JEIM needs to increase its iron ore production by 40%. Banspani Hill is one of the seven sectors of JEIM and has almost 40 Mt of high grade hard-ore deposits. The mining operations on Banspani Hill were closed for almost two years due to opposition by inhabitants of nearby Banspani and Kunthpani villages to blast induced vibrations, noise and flyrock (Fig.1). As hard ore is getting depleted from other sectors of JEIM, production from the Banspani sector has become crucial for JEIM. Orica in partnership with Tata Steel undertook the task of assisting the JEIM team to conduct blasting at Banspani hill while controlling the environmental impacts.

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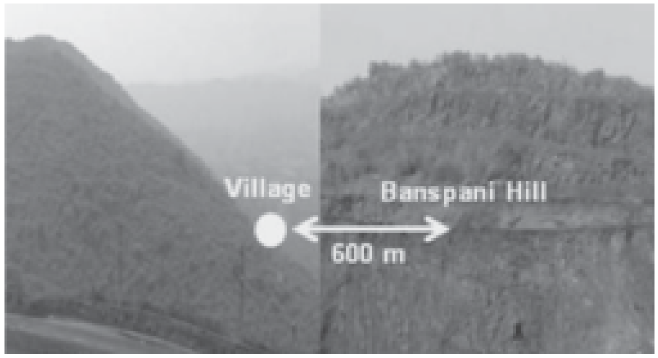

Fig.1 Kunthpani village at the foot hill of Banspani hill

## 2. Blast induced vibrations

One of the unwanted by-products of blasting operations is ground vibration that results from the sudden release of explosive energy into the surrounding ground. This vibration places stress and strain in the surrounding rock mass, which in turn disturbs the surface structures and may create nuisance to the nearby inhabitants. Blasting vibrations are generally characterised by the PPV and the dominant frequencies. If the frequencies are low, greater displacement is produced at a given PPV level. Therefore, to reduce the impact due to blast vibrations it is necessary to either decrease the peak particle velocity (PPV) or increase the blast vibration frequencies, or both. The frequencies that are measured at the monitoring point depend on the nature of the ground between the blast and the monitor. Sometimes, the ground only supports low frequencies. In addition, if the blast induced vibrations are produced at frequencies which are in the range of natural frequencies of the structure, they can cause structures to resonate leading to large strains even at low PPV. The Directorate General of Mines Safety (DGMS), India, has established the permissible limits of vibrations (Table1) that the mines must comply with for continuing their operations.

## 3. Vibration prediction

Site law regression and statistical prediction modelling are predictive tools that can be used to increase the confidence of complying with limits of blast induced vibration in environmentally sensitive areas. Ground vibrations from blasting are a function of many factors and therefore they can be difficult to predict accurately using simple regression formulas. The most significant controllable variables are explosive charge per delay and initiation sequence. On the other hand, the most critical uncontrollable variables are rock mass characteristics and the distance of each blast hole from the monitor. Both of these factors may vary significantly between and within blasts.

During this project, Monte Carlo simulations were used to predict the vibration with greater confidence levels. The flowchart (Fig.2) below describes the different stages of the project.

Table 1: DGMS prescribed permissible limits for ground vibration in India

| Type of structure | Dominant frequency | | |
|---|---|---|---|
| | <8 Hz | 8-25 Hz | >25 Hz |
| 1. Building/structures not belongings to owner | | | |
| 1.1 Domestic houses/structures | 5 mm/s | 10 mm/s | 15 mm/s |

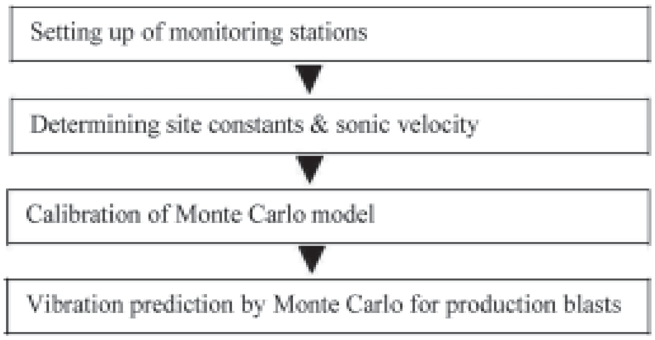


Fig.2 Steps involved in the process of the project

During the course of work, the following tools and apparatus were employed for analysis:

- Instantel Minimate Blast Monitor, with external geophone
- SHOTPlus® 5 Professional - proprietary blast design and vibration prediction software
- CycadTM blast vibration waveform analysis software
- Survey equipment

### 3.1 Monte Carlo model

Monte Carlo methods are a broad class of computational algorithms that rely on repeated random sampling to obtain numerical results by running simulations many times over. Orica's proprietary blast design software SHOTPlus® 5 Professional runs Monte Carlo simulations for predicting vibrations at given points of interest. This model sums vibration from each blast hole at the respective points of interest and gives the cumulative vector result.

The main inputs of the model are:

a. Site constants;
b. Seed wave showing the single hole vibration trace;
c. Screening and damage parameters;
d. Blast pattern and initiation sequence;
e. Co-ordinates of point of interest;
f. P-wave velocity

Accurate location of the monitoring points and blast holes is essential. Therefore, a survey pick-up of all monitoring stations (Fig.3) and blast holes was made to assist the model in predicting the vibration accurately.

One of the screenshots of vibration predicted by Monte Carlo model can be seen in Fig.4.

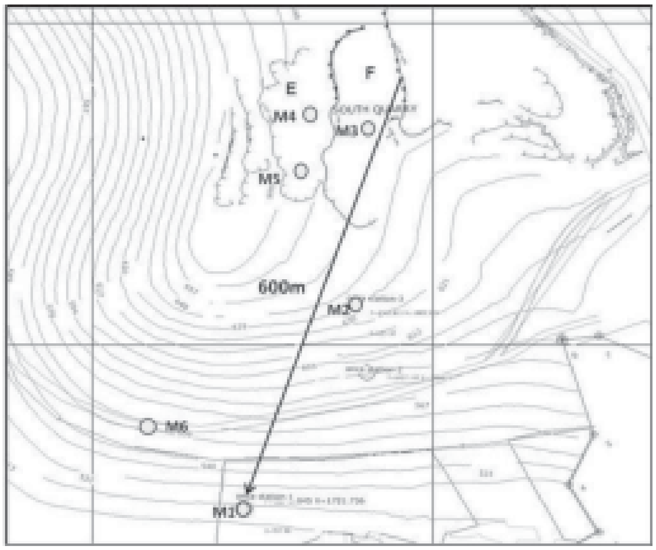


Fig.3 Location of six monitoring stations used during the project

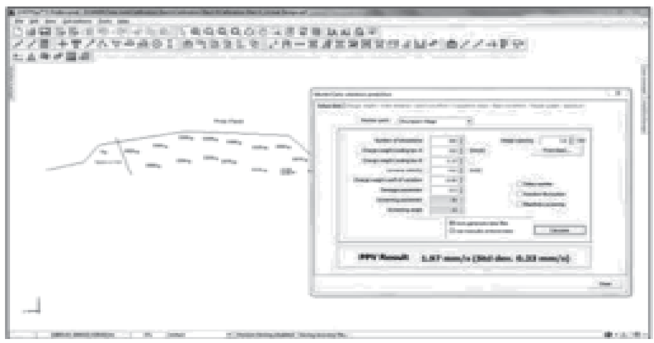

Fig.4 Snapshot of Monte Carlo model predicting vibration

## 4. Signature blasts

The Monte Carlo model uses waveforms from single holes to predict the vibration from larger blasts. These single hole waveforms are called "signature blasts" or "seed waveforms".

A series of signature blasts were fired and blast waveform was captured by Instantel Minimate blast monitor installed at various stations (Fig.5). The Orica proprietary blast vibration analysis software CycadTM was used to analyze waveform

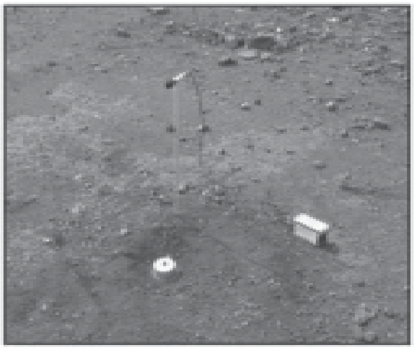

Fig.5 Setup of monitoring station

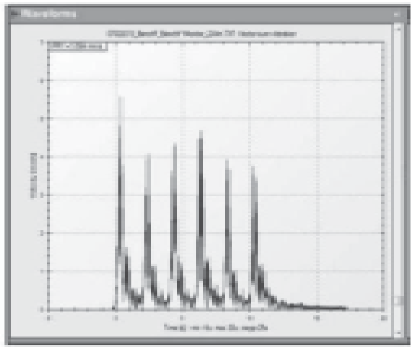

Fig.6 Waveform from one of signature shots

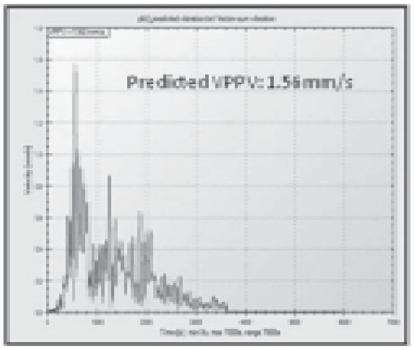


Fig.7 Predicted vibration for production shot

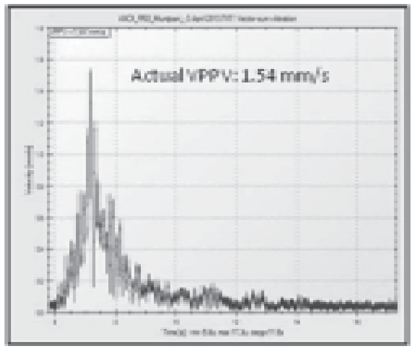


Fig.8 Actual vibration for production shot

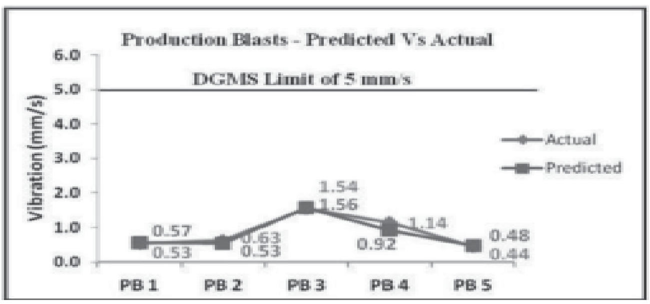


Fig.9 Predicted vs actual vibration levels within DGMS limits

(Fig.6) to determine the site constants, P-wave velocity and natural frequency of the ground.

The findings of the signature blasts were:

i. The site constants K & n were found to 152 and -1.12 respectively
ii. The P-wave velocity of the ground was around 411 m/s
iii. Natural frequency of the ground was in the range of 8-10 Hz

## 5. Calibration and production blasts

### 5.1 Calibration blasts

To ensure the Monte Carlo model accurately represented the site's specific geology and rock characteristics, a series of five small calibration blasts of less than twenty holes each were fired. The field data generated from these blasts was analyzed to determine the difference between the actual vibration observed and the Monte Carlo prediction. This process was performed to calibrate the model by adjusting rock damage and screening parameters.

### 5.2 Production blasts

The ultimate goal of the project was to accurately predict vibration from large production blasts of more than 90 holes. The production blasts were designed in the SHOTPlus® 5 software and the calibrated Monte Carlo model was run to understand the implications of the design on vibration levels. The vibration levels predicted by Monte Carlo during production blasts were found to have a strong correlation with actual results (Fig.7 and Fig.8) and were well below the statutory limit of 5 mm/s (Fig.9).

## 6. Conclusions

Advanced blast modelling techniques and electronic blasting systems can help to precisely predict the vibration from a production blasts. Accurate and precise predictions require careful fieldwork to collect representation signature waveforms from single holes, and calibration of the model by comparing predictions with actual results over a series of observations.

By using these methods, Tata Steel's Joda East Iron Ore Mine is now able to access reserves that had previously been considered too difficult to mine without conflict with neighbouring villages.

## 7. Acknowledgements

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