WEBINAR:
Reduce ore loss and dilution: Measurement and modelling of blast movement

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Introduction

- Drilling and blasting is required in most open pit mines to fragment and loosen the in-situ rock mass
- The nature of blasting results in the movement of the rock mass
- Not accounting for blast movement in post-blast grade boundaries can cause ore loss and dilution
- Ore loss occurs when valuable mineral is sent to the waste dumps
- Dilution occurs when waste material is mischaracterised as ore and sent for processing
Causes of Ore loss and Dilution

- In-accurate definition of ore body
- Improper blast design
- Blast induced movement
- In-appropriate excavation methods
- Excavation equipment size
- Method and direction of digging
Blast Induced Movement

- **Top flitch**
- **Bottom flitch**
- **High grade**
- **Low grade**
- **100m**
- **Ore**
- **Resource**
- **Pre-blast**
- **Post-blast**
- **LGWH**
- **H G W LG**
- **Open Pit**
- **Ore Loss**
- **Dilution**
Factors affecting Blast Movement

- Rock mass geology (density, strength, structure)
- Blast Confinement
- Blast Design (PF, geometry)
- Initiation sequence
- Blast QA/QC (stemming, charge weights)
Case Studies – Why measure

- Zhang et al. (1994) conducted a survey of 27 Nevada gold mines.
- Found that most mines used smaller powder factors to control blast movement.
- Only a few operating mines actively monitored blast-induced rock movement.
- Of the mines that monitored blast movement, only one was found to occasionally adjust pre-blast grade boundaries to account for movement.
Case Studies – Why measure blast movement


- Found ore control grades were consistently higher an average 7.6%, and occasionally up to 25%.

- Taylor estimated that, if the Coeur Rochester mine had accounted for blast-induced movement during 1994 alone:
  - the mine could have produced an additional 4,560 ounces of gold and 200,000 ounces of silver.
  - Would have added US$2.7 million in annual revenues (at a gold price of US$380/ounce and silver price of US$4.80/ounce).
Case Studies – Why measure blast movement

- At the Tallering Peak Mount Gibson iron mine, Belfield (2007) estimated the economic impact of not accounting for blast-induced ore block movement was:
  - Ore loss equal to about 28% 
  - A value of approximately AU$46,000 per blast.
How to Measure Blast Movement

Visual surface markers (paint, flagging tape, drums, poly-pipe, stakes)

Coloured sandbags

Electronic methods (ground penetrating radar, metal detection)

Blast Movement Monitors (BMMs)
What we know about Blast Movement

**Magnitude**

- Direction of horizontal movement is typically perpendicular to timing contours.
- Movement is greatest in mid-bench region.
- Inconsistent free face conditions result in variable movement in front few blast rows.
- Higher variability in direction of surface movement due to less confinement.

**Direction**

- Movement in the body of blast is relatively consistent.
Modelling Blast Movement

- Direct Measurement: every blast (bmms, stakes, flags)
- Movement Templates
- Stochastic Model
- 3D Blast Model
Case Studies – Direct Measurement

BMMs

- Centerra Gold Mount Milligan Mine, recovered over US$600,000 of ore in one blast, 2018.
- Dalgaranga Gold Mine, reduces ore loss, adding A$151,522 of value in one blast, 2019.

Movement Templates

- Most sites:
  - 4 to 6 standard blast designs (in ore)
  - If blast design doesn’t change, rock type remains consistent, same confinement conditions, then --> **blast movement should stay the same**.

- Movement templates work by applying an average movement vector (distance & direction) to pre-blast ore boundaries.
Case Studies - Movement Templates

- Fitzgerald et al. (2011) detail an example of where the template approach reduced ore loss by up to 7.4% at the Fimiston Open Pit Gold Mine (Superpit), operated by Kalgoorlie Consolidated Gold Mines (KCGM) in Australia.
Rogers et al. (2012), implemented the movement template approach at the Ahafo gold mine in Ghana.

Data from 2011 to 2012 showed a better reconciliation between the mine to mill grade and a reduction in diluted tonnes.

Template method is simple and effective

Limitations - It doesn’t consider variability in blast movement vectors; it doesn’t account for variability in blast design inputs.
Stochastic Model

- The term ‘stochastic’ is applied when there is a random component to a model.
- For example, when values for the input variables are uncertain or sampled from a statistical distribution.
- Most common sampling technique is the Monte Carlo method.
- This method relies on random sampling from a probability distribution.
- Monte Carlo sampling can model hundreds or thousands of combinations of input parameters and quantify the statistical distribution of outcomes (blast movement).
Stochastic Model

Inputs: The magnitude and direction of blast movement are described as statistical functions based on the measured data.

Output: The simulation outputs the predicted grade boundary displacement envelopes for the given confidence intervals.

Simulations: Monte-carlo simulations are run to generate a range of possible outcomes defined by the distribution functions.
Stochastic Model
Stochastic Model - Advantages

- Simple and effective like the template method
- Incorporates measured variability in blast design and blast movement vectors
- No longer need to measure blast movement for every blast
3D Muckpile Movement

- MMS – BRC, UQ, Australia, now JKVBOC
- TBT Simulator – Thierry Bernard Technologie, France
Conclusions

- The magnitude and direction of blast movement are site specific and depend on a number of parameters including blast design, blast geometry, confinement conditions, and geology.

- Inherent variability in these inputs causes uncertainty in blast movement predictions.

- The uncertainty in input parameters is what makes a stochastic approach better suited.

- Stochastic model alleviates the need to continually measure blast movement.
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Questions?