Gravity Flow: Stochastic Modelling for Mining Optimisation

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Abstract

Material flow analysis is required where rock is moved from its initial position to an extraction point by gravity, such as in mining by sublevel, panel or block caving. Appropriate gravity flow modelling can help reduce ore contamination from adjacent or overlying waste. Stochastic methods provide a powerful tool for modelling gravity flow, allowing for optimisation of extraction, reduction in dilution and maximisation of mine revenue.

Introduction

Rules and probabilities are the bases of stochastic methods for describing phenomena, they do not have a foundation on a physical principle that “forces” the math to produce the right results (for example the Finite Element Method minimising potential energy to derive the equations used to solve the problem). Stochastic models for gravity flow only use conservation of mass.

Despite the weak formulation, stochastic methods can be very powerful tools to solve material flow problems in cave mining, and some of the merits, limitations and pitfalls of these methods are explored in this article.

Description of the Method

Stochastic methods are modelling tools for estimating outcomes by allowing for random variations in one or more inputs over time. When material is removed from a drawpoint, a void is created that is filled with material from above the void. The exact source of that material is unknown; therefore a random location is assigned.

Figure 1 shows a plan view of a grid describing this concept. When part of the material is removed from a cell below the centre of the grid, the void is filled from any of the seven cells above, as shown on Figure 1. This process is random, making stochastic models ideal for this type of problem solving. In this particular case, a probability is assigned to each cell indicating the chances that the void will be filled with material from the cell immediately above (70%) or any of the surrounding cells (5%); percentages given as an example only.

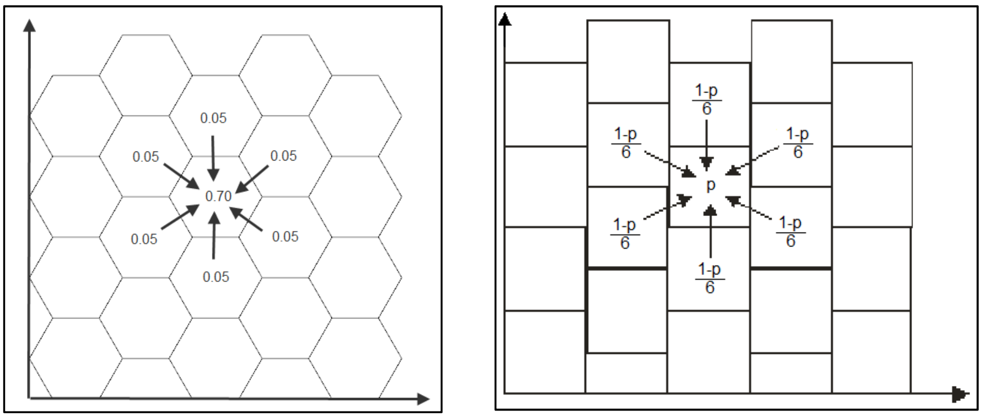

Figure 1: Plan view of hexagonal prisms grid and plan view of a cube grid

Figure 1 shows a grid that combines the simple geometry of cubes and the circular location of hexagonal prisms. MFlow, an in-house software developed by SRK (Gibson, 2014), uses this configuration of cells. The probability that material will be transferred from the cell above is represented by **p**. The probability that one of the cells around the central cell can transfer material to the void below is represented by (1-p)/6.

The **p** parameter plays an important role in modelling the width of the extraction column; it has been observed that the width of the draw column is related to rock mass quality, becoming wider as the good rock mass quality increases (Laubscher, 1994).

This effect can be visualised in a 3D model of two independent drawpoints in a uniform material. Figure 2 shows the mobilised ellipsoids, clearly illustrating the effect of parameter p on the width of the ellipsoid of extraction. This is an observed behaviour that, depending on physical properties of the broken rock, is controlled by the width for the ellipsoid of extraction.

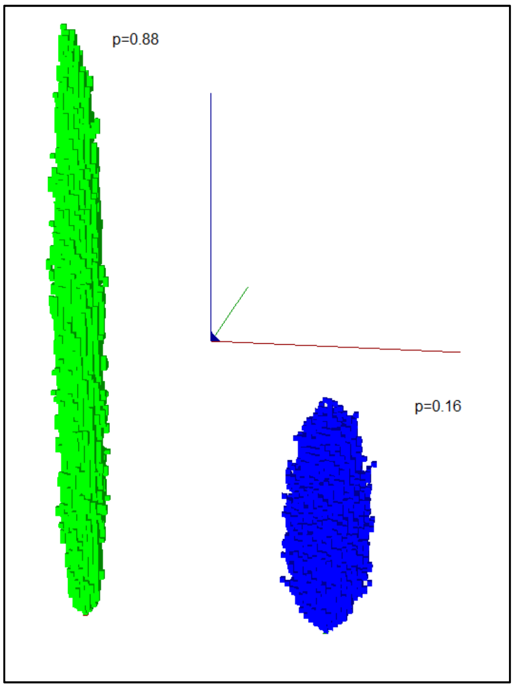

Figure 2: Extraction column widths for different p values

Stochastic modelling capabilities

Despite the simplicity of the formulation of stochastic models, they can address complex behaviour of materials. In the previous paragraph it was shown how different extraction width columns can be modelled.

Another important characteristic of the gravity flow is that fine materials move faster than coarse material moving in the same draw column. This type of phenomenon can be included in the model by introducing a weighting factor (**w**) that modifies the probability of material moving from one cell to another.

A value of w=0 renders the material unaffected by draw and it does not flow. This can be used to define the limits of the draw rings in Sublevel Caving (SLC) if it is assumed that material outside of the blasted ring will not move. A value of w=1 allows the material to move freely.

Values between 0 and 1 can therefore be used to control the speed of material flow in the model. To show the effect of the parameter **w**, on the results, the model shown in Figure 3 was built. Above extraction point A there is fine ore under coarse waste, above extraction point B the fine material is on top of the coarse material.

The results are shown in Figure 3 and Figure 4. There is a reduction in ore extraction in drawpoint B due to a higher dilution of fine material travelling faster than the ore.

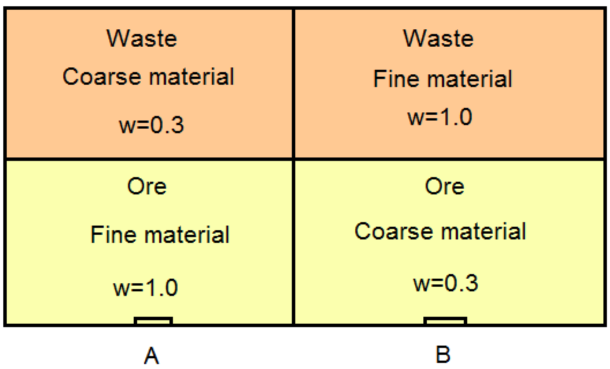

Figure 3: Simple model to show the effect of fine material on extraction

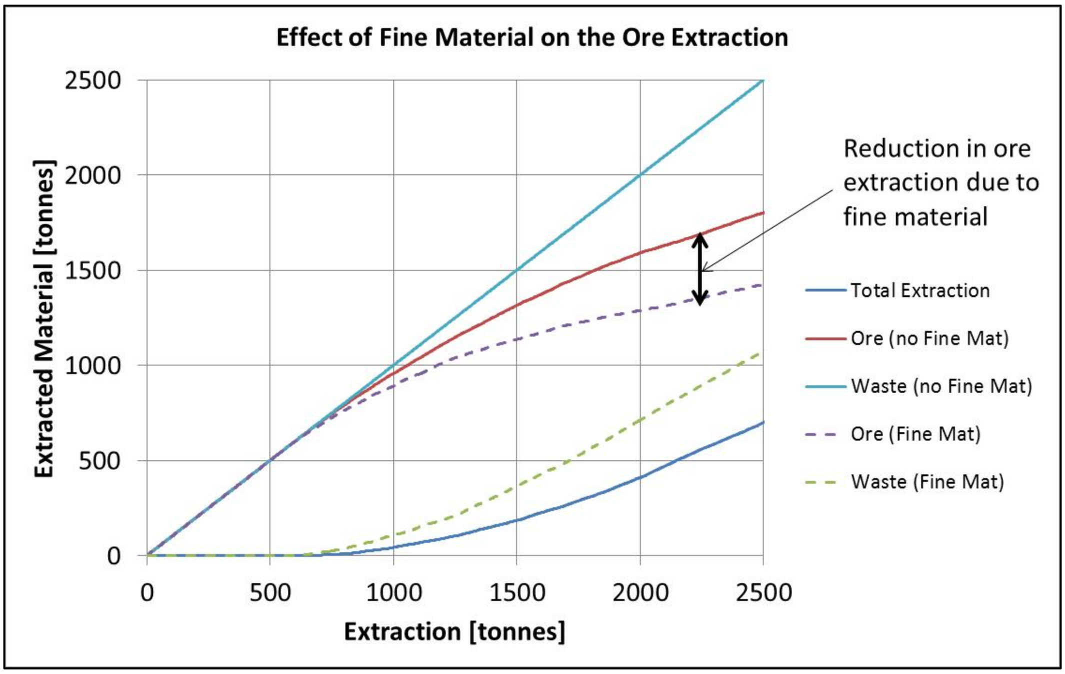

Figure 4: Effect of fine material on extraction

Conclusions

Stochastic models have a much easier formulation than other methods such as the Finite Element Method. However, the lack of formulation based on a physical principle makes them more difficult to set up unless information about the rock mass to be modelled is available, thus enabling the modeller to calibrate the model.

Despite the limitations and the weak formulation, stochastic models can be used to describe complex behaviour such as accelerated flow of fine material, width of draw column and dilution; all of them key parameters required in a gravity flow assessment in order to optimise extraction by reducing dilution.

References

Gibson, W, 2014, Stochastic Models for Gravity Flow: Numerical Considerations, in *Proceedings Third International Symposium on Block and Sublevel Caving* (ed: R Castro), pp 337-347 (Universidad de Chile: Santiago).

Laubscher, D H, 1994, Cave mining – the state of the art, *The Journal of the South African Institute of Mining and Metallurgy*, October 1994, pp. 278-293.