Retic Systems

FILL SAFE FILL SMART

STOPE FILL 1.2

Supporting Information

Developed by D Coulton & L Wall

Retic Systems

Retic Systems is an engineering consultancy within the mining industry specialising in backfill system design and operation. We leverage inhouse software packages to not only streamline the design process but provide cost optimised solutions, as well as developing SCADA integrated real-time reticulation monitoring systems.

Founded by David Coulton, who has over 5 years' experience designing and providing operational support for backfill systems across Europe, Asia, and Africa. David studied as a mining engineer and has a deep understanding of the challenges associated with underground mining. Throughout his time working in the industry he has developed numerous connections with site engineers, mine design software developers, and plant operators. Endowing him with strong insights as to the current needs and difficulties with implementing backfill in mining operations.

Services

Retic Systems offers four distinct service packages, each providing solutions to operational and design problems with the reticulation networks associated with hydraulic and paste backfill systems.

Retic Router

A patent pending reticulation system design and management package, that develops an optimised branched network to deliver backfill from a surface preparation plant to all underground stopes. Utilising the mine design spatial data, the software package finds the optimal network to connect all the stopes. Retic Router considers both the capital cost (pipe purchase and installation) as well as operating expenditures, to ensure the solution delivers backfill at the lowest unit cost for the life of the mine.

Stope Fill

Stope Fill is a free backfill analysis and pour design tool developed by Retic Systems, it is a lightweight 3D environment providing real-time visualisation and customisation of your stope designs. Select the stress analysis methodology and Stope Fill will analysis the stope and calculate the strength requirement, easily include cap and plug pours just specify the thickness and strength requirement for each, a liquefaction limit can also be applied to set the minimum strength requirement. Stope Fill segments the stope into discrete pours, optimising the binder usage for each segment and outputting a composite pour, detailing pour volumes and binder dosage rates for each segment.

Active Retic Monitoring

Determining if a system is in slack flow traditionally requires accurate hydraulic models and survey data of the pipe routing, these are difficult to obtain due to the high dynamic nature of mining operations. Additionally, it is difficult to convey the outputs of these hydraulic models to system operators, as it normally entails monitoring dozens of pressure sensor values simultaneously. We offer several solutions, unconstrained by accurate survey data nor rheological models, that automate this detection process by utilising the pressure sensor data directly within the SCADA system.

Material Mapping

Our approach to design, and the material testing required as a basis for that design, starts with understanding your process variability. We map your material to a multivariant probability density function which defines the strength and rheological properties of your backfill across the entire operating window. By undertaking a streamlined and highly targeted testing campaign, we develop statistical models of the variance each process parameter has on the backfill.

Tele / WhatsApp: *+44 7821 297018*
Email: *stope.fill@reticsystems.com*

Contents

1. Introduction

Stope Fill is a free desktop application developed by Retic Systems to simplify the backfill and pour design process. As part of this software package, stress analysis is carried out on filling voxels (cubes that subdivide a stope model space). This document sets out to explain the strength analysis methodologies used within Stope Fill.

2. Strength Analysis Methodologies

There are currently two strength analysis methodologies included in Stope Fill 1.2:

- Geostatic Load, and
- Modified Mitchell's

2.1. Geostatic Stress

Geostatic Stress is a very simplicity and conservative estimate of the stress within the paste mass, assuming a hydrostatic stress environment (see Equation below).

Equation 1: Geostatic Stress Calculation

$$Stress\ (kPa) = FoS \times \rho \times g \times h$$

$$where: FoS = Factor\ of\ Safety$$

$$\rho = Bulk\ Density\ (t/m3)$$

$$g = Gravitational\ Acceleration\ = 9.81\ (ms^{-2})$$

$$H = Depth\ Below\ Surface\ of\ Paste\ Mass\ (m)$$

2.2. Modified Mitchell

Modified Mitchell analysis considers a shear failure and is solved by considering the mechanics of a sliding wedge block (see Figure 1 overleaf). The implementation of Mitchell Analysis used within Stope Fill considers both frictional and cohesive shear resistance forces, Equation 2 and Equation 3 provide a stability inequality with respect

Tele / WhatsApp: +44 7821 297018
Email: stope.fill@reticsystems.com

to Cohesion. To convert this to Uniaxial Compressive Strength (UCS) use the Mohr-Columb failure criterion (Equation 4).

For non-square stopes, exposure orientation can significantly affect the strength requirements. The example shown in Figure 1 is a Longitudinal Exposure as such it would be dependent on the Stope Transverse Length (L), Equation 3. The stope dimension required for Mitchell Analysis is normal to the exposure face.

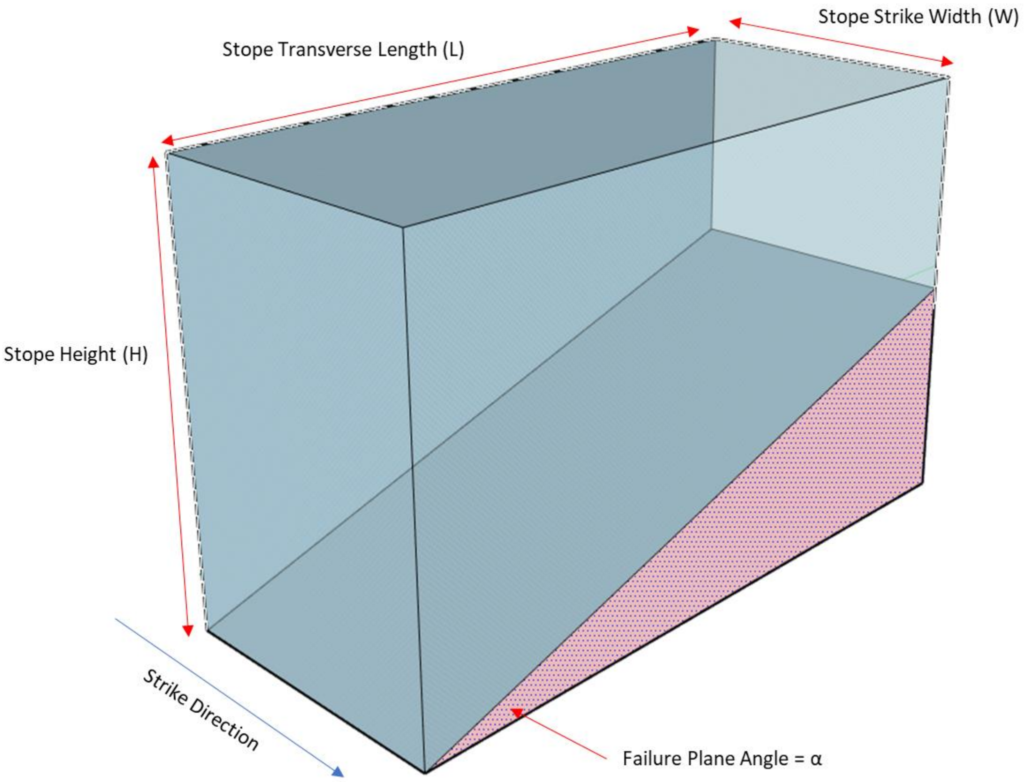

Figure 1:Mitchell's Sliding Block Shear Failure

Equation 2: Modified Mitchell – Transverse Exposure

$$For: W \tan\tan\alpha < H$$

$$Cohesion\ (kPa) \geq \frac{\rho g \cos\cos\alpha\ (2H - W \tan\tan\alpha)}{2}(\sin\sin\alpha - \cos\cos\alpha\ \tan\tan\varphi)$$

$$and\ For: W \tan\tan\alpha \geq H$$

$$Cohesion\ (kPa) \geq \frac{H\rho g \cos\cos\alpha}{2}(\sin\sin\alpha - \cos\cos\alpha\ \tan\tan\varphi)$$

$$where: \alpha = Failure\ Plane\ Angle\ (°)$$

$$W = Stope\ Width\ (m)$$

$$\varphi = Internal\ Friction\ Angle\ of\ the\ Paste\ (°)$$

Equation 3: Modified Mitchell – Longitudinal Exposure

$$Cohesion\ (kPa) \geq \frac{\rho g \cos \cos \alpha\ (2H - L \tan \tan \alpha\ )}{2} (\sin \sin \alpha\ - \cos \cos \alpha\ \tan \tan \varphi\ )$$

$$where: \alpha = failure\ plane\ angle$$

$$and: L \tan \tan \alpha < H$$

$$for: L \tan \tan \alpha\ \geq H$$

$$Cohesion\ (kPa) \geq \frac{H\rho g \cos \cos \alpha}{2} (\sin \sin \alpha\ - \cos \cos \alpha\ \tan \tan \varphi\ )$$

Equation 4: Mohr-Coulomb Failure Criterion in UCS Form

$$UCS = \frac{Cohesion \times 2 \cos \cos \varphi}{1 - \sin \sin \varphi}$$

$$when: \varphi\ (Internal\ Friction\ Angle) = 0°$$

$$UCS = 2 \times Cohesion$$

2.2.1. Failure Plane Angle

Classically the failure plane angle has been set to 45° or twice in the internal friction angle, these are reasonable estimates. However, within the implementation in Stope Fill the most onerous failure plane angle is determined and used. Derivation of the calculations are detailed below in Equation 5 and Equation 6.

Equation 5: Most Onerous Failure Plane Angle – Back Face Plane Intercept

$$For: W \tan \tan \alpha\ < H\ or\ L \tan \tan \alpha\ < H$$

$$UCS\ (kPa) = \frac{\rho g \cos \cos \alpha\ (2H - L \tan \tan \alpha\ )}{2} (\sin \sin \alpha\ - \cos \cos \alpha\ \tan \tan \varphi\ ) \left(\frac{2 \cos \cos \varphi}{1 - \sin \sin \varphi} \right)$$

$$f(\alpha) = \frac{UCS \times (1 - \sin \sin \varphi\ )}{\rho g \cos \cos \varphi} = (2H - L \tan \tan \alpha\ )(\sin \sin \alpha\ - \cos \cos \alpha\ \tan \tan \varphi\ )$$

$$f(\alpha) = (2H + L \tan \tan \varphi\ ) \sin \sin \alpha\ \cos \cos \alpha\ - W\alpha\ - 2H \tan \tan \varphi\ \alpha$$

$$f(\alpha) = A \sin \sin \alpha\ \cos \cos \alpha\ + B\alpha\ + C\alpha$$

Tele / WhatsApp: *+44 7821 297018*
Email: *stope.fill@reticsystems.com*

$$f'(\alpha) = (2B - 2C)\sin\sin\alpha\ \cos\cos\alpha\ - A\alpha\ + A\alpha$$

$$f'(\alpha) = A\ \cos\cos 2\alpha\ + (\ B - C)\sin\sin 2\alpha$$

$$f'(\alpha) = 0 = A + (B - C)\tan\tan 2\alpha$$

$$\tan\tan 2\alpha\ = \frac{-A}{B - C} = \frac{-2H - L\tan\tan\varphi}{2H\tan\tan\varphi\ - L}$$

Equation 6: Most Onerous Failure Plane Angle – Top Face Plane Intercept

$$For: W\ \tan\tan\alpha\ \geq H\ or\ L\tan\tan\alpha\ \geq H$$

$$UCS\ (kPa) = \rho g\cos\cos\alpha\ H(\sin\sin\alpha\ -\cos\cos\alpha\ \tan\tan\varphi\ )\left(\frac{\cos\cos\varphi}{1 - \sin\sin\varphi}\right)$$

$$f(\alpha) = \sin\sin\alpha\ \cos\cos\alpha\ - \tan\tan\varphi\ \alpha$$

$$f'(\alpha) = 2\tan\tan\varphi\ \sin\sin\alpha\ \cos\cos\alpha\ - \alpha\ + \alpha$$

$$f'(\alpha) = 0 = \cos\cos 2\alpha\ + \tan\tan\varphi\ \sin\sin 2\alpha$$

$$\tan\tan 2\alpha\ = \frac{-1}{\tan\tan\varphi}$$