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JAMES COOK UNIVERSITY

James Cook University

SCHOOL OF ENGINEERING

CIVIL AND ENVIRONMENTAL ENGINEERING

Effects of Blasting on the Stability of Paste Fill Stopes at Cannington Mine

Thesis Submitted by

Bronwyn Susan van Gool BE(Hons)

In September 2007

for the degree of Doctor of Philosophy

in the School of Engineering

James Cook University

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Bronwyn van Gool

10/9/07

Date

Statement on the Contribution of Others

This thesis included the following contribution of others:

Grants: This work was supported by a grant from the Australian Research Council (#C00107460)

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Abstract

Paste fill is a cemented backfill used to fill the void left by mining to provide stability to the mine. It consists of tailings mixed with a small percentage of cement and water. As the mining sequence progresses and stopes adjacent to the fill are mined, the fill is subjected to blasting loads, and subsequently exposed. The purpose of this thesis was to study the effects of blast loading on paste fill, and the research consisted of experimental and numerical modelling components and some field work at Cannington mine.

The field work involved monitoring of paste fill during production blasts, in situ tests in paste fill at Cannington mine and laboratory tests on the paste fill samples. Triaxial geophones were installed in stope 4261 at Cannington Mine, which had previously been mined and filled with paste fill. These geophones were used to measure the velocity waveforms produced in the stope during the blasting in two adjacent stopes. The data collected as part of this field work resulted in the estimation of a peak particle velocity at which paste fill begins to fail.

The in situ tests involved monitoring the explosion of 9 blast holes in paste fill. Triaxial geophones were used to measure the velocity profile of each blast. The blast holes were detonated individually in order to obtain separate velocity profiles. The results were used to obtain a relationship between the peak particle velocity and the scaled distance from the blast.

The laboratory tests were conducted to measure the attenuation of a wave as it travels through a column of paste fill. Paste fill was poured into a 2.7 m long column in which 4 accelerometers were installed. A wave was induced in the column by striking the end of a column with a hammer and the particle acceleration was measured. The results were used to show the effect of paste fill mix on the attenuation of a wave.

The finite element method based numerical modelling package, ABAQUS/Explicit, was used to model the behaviour of paste fill due to adjacent blasting in an underground mine. The first numerical model consisted of a single column of explosive detonated in paste fill. The results of this model were validated against the data obtained in the field tests. Once validated, the model was run for different mixes of paste fill to observe the effect of cement and solids content of the paste fill on its behaviour. A model of a single column of explosive in rock was also developed and validated using the same method. The model was then extended to include a single column of explosive detonated in rock adjacent to a paste fill stope. This model was run for a variety of blasting conditions to observe the changes in paste fill behaviour due to different blasting conditions. These different blasting conditions included varying distances between the explosive column and the rock/paste fill interface and various positions of the explosive column in relation to the paste fill stope. The model was finally extended to include a row of explosive columns parallel to the face of a paste fill stope. This model was run for a variety of blasting patterns and delay intervals to determine their effect on damage to paste fill. The model results showed that the peak particle velocity and therefore the damage to the paste fill reduced for increased cement contents of the fill. Similar results were observed for increased solids content, but to a lesser extent. The model results also indicated that the order of detonation and the delay time between the detonation of blast holes has little effect on the damage to the paste fill.

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Nomenclature

a	Attenuation coefficient
b_1	Damping coefficient
b_2	Damping coefficient
c	Wave velocity
c_p	Velocity of a p-wave
c_s	Velocity of a s-wave
d	Cohesion
e_{mo}	Initial energy per mass unit
f	Frequency
g	A deviatoric stress measure
h	Height
i	The increment number
j	The third invariant of deviatoric stress
k	A site specific constant for the charge-weight scaling law
l_e	An element characteristic length
m	The equivalent pressure stress
n	An integer
p	Pressure
p_{bv1}	Bulk viscosity pressure in the form of damping of the "ringing" in the highest element frequency
p_{bv2}	Bulk viscosity pressure in the form of damping in solid continuum elements
ppv	Peak particle velocity
q	The Mises equivalent stress
r	Pulse travel distance
s_1	The gain of the reference accelerometer
s_2	The gain of the accelerometer being calibrated
t	Time

u^N	A degree of freedom (displacement or rotation component)
$\dot{u}$	Velocity
$\ddot{u}$	Acceleration
v	The magnitude of the resultant particle velocity
v_{radial}	The particle velocity in the radial direction
$v_{transverse}$	The particle velocity in the transverse direction
$v_{vertical}$	The particle velocity in the vertical direction
w	Strike length
A	Amplitude
B	Material constant for the JWL equation of state
C	Constant, experimentally estimated to be 0.53 ± 0.04
D	Distance between hanging wall and foot wall
E	Young's Modulus
F	The discrete Fourier transform output
G	Yield criteria
H	The height of the explosive in the blast hole
I^J	The internal force vector
J	Material constant for the JWL equation of state
K	The ratio of the yield stress in triaxial tension to the yield stress in triaxial compression
L	Linear charge density
M^{NJ}	The mass matrix
N	The total number of discrete samples taken in the time domain
P^J	The applied load vector
Q	Quality factor
R	Distance
S1, S2 and S3	The principal stresses on the deviatoric plane
T	Total sampling time

U_1	the output of the reference accelerometer
U_2	The output of the accelerometer being calibrated
W	Weight
α	Site specific constant for the charge-weight scaling law
β	Site specific constant for the charge-weight scaling law
χ_R	Factor for mass proportional damping
δ_R	Factor for stiffness proportional damping
ε	Strain
$\dot{\varepsilon}_{vol}$	Volumetric strain
ϕ	Friction angle
γ	Unit weight
η	The slope of the linear yield surface in the p-t stress plane commonly referred to as the friction angle of the material
φ	Decay factor
κ	Geometric attenuation exponent
λ	Lame's Constants
μ	Lame's Constants
ν	Poisson's Ratio
θ	Angle of failure plate from horizontal = $45+\phi/2$
ρ	Density
σ	Stress
τ_f	Shear strength
ϖ	The angle for the column version of the charge-weight scaling law (see Figure 2.3)
ω	Natural frequency
ξ	Fraction of critical damping
ψ	The dilation angle in the p-t plane
Φ	Factor of Safety

Θ	Material constant for the JWL equation of state
Ω	The pulse rise time
Ψ_1	Material constant for the JWL equation of state
Ψ_2	Material constant for the JWL equation of state