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DEVELOPMENT OF TWO AND THREE-DIMENSIONAL METHOD OF FRAGMENTS TO ANALYSE DRAINAGE BEHAVIOR IN HYDRAULIC FILL STOPES

Thesis submitted by

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in September 2007

for the degree of Doctor of Philosophy
in the School of Engineering
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Acknowledgements

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Abstract

The extraction and processing of most mineral ores, result in the generation of large volumes of finer residue or tailings. The safe disposal of such material is of prime environmental, safety and economical concern to the management of mining operations. In underground metaliferous mining operations, where backfilling of mining voids is necessary, one option is to fill these voids with a tailings-based engineered product. In cases where the fill is placed as a slurry and the fill contains free water, permeable barricades are generally constructed to contain the fill within the mining void whilst providing a suitable means for the drainage water to escape from the fill. Recent barricade failures, resulting from poor drainage, have led to an immediate need for an increased understanding of the pore pressure developments and flow rates throughout the filling operation. This thesis presents simple analytical solutions, based on the 'method of fragments,' for estimating discharge and maximum pore pressure for two and three-dimensional hydraulically filled stopes. Shape factors were developed to account for the inherent individuality associated with stope and drain geometry. The influence of scaling on discharge and pore pressure measurements is also investigated. The proposed solutions are verified against solutions derived from a finite difference program and physical modelling of a scaled mine stope and results showed excellent agreement. Using these analytical solutions developed for flow through three-dimensional hydraulic fill stopes, a user-friendly EXCEL model was developed to accurately and efficiently model the drainage behaviour in three-dimensional stopes. The model simulates the complete filling and draining of the stopes and was verified using the finite difference software FLAC^{3D}. The variation and sensitivity in drainage behaviour and pore water pressure measurements with, the variation in geometry, fill properties and filling-cycles of a three-dimensional hydraulic fill stope was also investigated.

List of Publications

Journals

Rankine, K.S. and Sivakugan N. (2007) "Application of Method of Fragments in Three-Dimensional Hydraulic Fill Stopes." *Journal of the Geotechnical Division ASCE*, *Under Review 3rd draft*

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List of Symbols

A = cross-sectional area

a = air content

B = stope width

C = Hazen's constant

C_{slurry} = percent solids of slurry

C_u = coefficient of uniformity

C_v = viscosity coefficient

C_0 = Terzaghi (1925) shape factor

C_2 = Kozeny-Carman (1938) shape factor

C_3 = Taylor (1948) shape factor

C_4 = Samarasinghe (1982) constant

C_5 = Amer and Awad (via Das, 2002) constant

c' = effective cohesional stress

D = drain height

D_r = relative density

D_s = effective particle dimeter

D_5 = the grain size for which 5% of the particles are finer

D_{10} = the grain size for which 10% of the particles are finer; effective grain size

D_{30} = the grain size for which 30% of the particles are finer

D_{50} = the grain size for which 50% of the particles are finer

D_{60}, = the grain size for which 60% of the particles are finer

$E_{1,}$ E_2 = material property constants, Carrier et al. (1983)

e = void ratio

e_{max} = maximum void ratio

e_{min} = minimum void ratio

F = drain width

Fr = Froude number

f = soil fabric

G = equivalent drain height

G_s = Specific gravity

g = acceleration due to gravity

H = height

H_w = height of water

h_i = head loss in i^{th} fragment

h_L = head loss

Δh = change in head between two points

i = hydraulic gradient

i_{entry} = entry hydraulic gradient

i_{exit} = exit hydraulic gradient

J = fill height increase per hour

K_0 = horizontal pressure coefficient (assumed to be 0.5)

k = permeability

$k_{0.85}$ = permeability at void ratio of 0.85

k_e = effective permeability

k_{equiv} = equivalent permeability for a layered system

k_h = permeability in the horizontal direction

k_v = permeability in the vertical direction

L = length

L_a = length of ancillary drain

m = soil compressibility

m_s = mass of solids

m_w = mass of water

N_d = number of equipotential drops

N_f = number of flow channels

n = porosity

n_{eff} = effective porosity

P_b = pressure exerted by the bulkhead on the fill

Q = discharge

q = discharge per unit length

Re = Reynold’s number

R_s = solids filling rate

S = saturation

S_s = specific surface area of grains

S_v = grain surface per unit volume

s = shape factor

T = temperature

t = time

u = pore water pressure

u_{max} = maximum pore water pressure

v = discharge velocity

$V_{drained}$ = volume of water that has drained

V_f = volume of fill

V_{free} = total free water that is drainable

V_{in} = volume of water entering stope

V_{out} = volume of water draining from the stope

$V_{residual}$ = volume of residual water

V_s = volume of solids

$V_{to\text{-}drain}$ = volume of water that is yet to drain

V_v = volume of voids

V_w =volume of water

W = stope thickness

w = water content

w_{res} = residual water content

w_{sat} = saturated water content

w_{slurry} = water content of hydraulic fill slurry

X = drain length

α_{2D} = fraction of the head loss within fragment 2 for a two-dimensional stope that takes place in the horizontal segment of the largest stream line

α_{3D} = fraction of the head loss within fragment 2 for a three-dimensional stope that takes place in the horizontal segment of the largest stream line

Δh = change in head between two points

Φ = two-dimensional form factor for i^{th} fragment

Γ_i = three-dimensional form factor for i^{th} fragment

γ_t = total bulk unit weight of fill

γ_w = unit weight of water

η = dynamic viscosity

φ = effective frictional stress

κ = intrinsic permeability

μ = water viscosity

μ_T = water viscosity at T degrees Celsius

μ_{10} = water viscosity at 10 degrees Celsius

ρ_d = dry density

ρ_s = soil grain density

ρ_w = density of water

σ_h = horizontal/ barricade pressure

σ_h' = effective horizontal pressure

σ_v' = effective vertical pressure

τ_w = shear strength of rock-fill interface

ω = fluid surface tension