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JAMES COOK UNIVERSITY
AUSTRALIA

AN INVESTIGATION INTO THE DRAINAGE CHARACTERISTICS AND BEHAVIOUR OF HYDRAULICALLY PLACED MINE BACKFILL AND PERMEABLE MINEFILL BARRICADES

Thesis submitted by

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in November 2005

for the degree of Doctor of Philosophy
in the School of Engineering
James Cook University

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Acknowledgements

The author wishes to thank,

Mum, Dad and the family, – I would not have half the life I do, if I could not share the laughter, the tears, my frustrations and achievements with you all. Thank you so much. I appreciate every minute.

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This work is dedicated to my wonderful family

Abstract

Hydraulic fills are quite popular as backfilling materials for underground voids created in the process of mining. For ease of transport through pipes, they are placed in the form of slurry and allowed to settle freely under self weight. Stopes can be approximated as rectangular prisms, and may extend as high as 200 metres. The horizontal access drives, used for transporting the ore, are blocked by porous barricade bricks before backfilling. Failures of barricades, and subsequent in-rush of wet hydraulic fill into the mines, have claimed several lives and contributed to severe economic loss world-wide.

The objective of this research is to carry out a thorough experimental study of the hydraulic fills and barricade bricks, with particular emphasis on load-deformation and drainage characteristics. Two separate numerical models were developed in FLAC and FLAC^{3D}, to simulate the backfilling process and to monitor the pore water pressure developments, fill and water heights and discharge rates. So far, the findings of the research were disseminated through four journal papers, a book chapter and seven papers in refereed international conferences. Overall, this study will improve the current state-of-the-art in hydraulic filling of mine stopes significantly.

More than 25 different hydraulic fills, from five different mines, were studied. All Australian hydraulic fills fall within a narrow band of grain size distribution and are classified as silty sands or sandy silts. Their specific gravity values range from 2.8 to 4.5. Constant head and falling head tests were carried out on reconstituted samples, produced from the hydraulic fill slurry, in a process that replicates the sedimentation process in the mine. The hydraulic fills settled to a porosity of 37%-48%, void ratio of 0.58-0.93, dry density (g/cm^3) of 0.58 times the specific gravity and relative density of 50%-80%. These values are in very good agreement with those measured in situ in Australia and U.S. The permeability values of the hydraulic fills, as determined in the laboratory, ranged from 10 mm/hr to 30 mm/hr, significantly less than the 100 mm/hr preferred for use in design by the mining industry. In situ, hydraulic fills with these permeabilities have performed satisfactorily with adequate drainage in the mine stope, implying that the 100 mm/hr limit may be excessively conservative when mine efficiency is considered.

Full barricade bricks, cylindrical samples cored from the bricks, and specially cast samples were tested for uniaxial strength, Young's modulus, failure strain and permeability. Uniaxial compression tests were performed on more than 50 cores in an attempt to carry out an extensive statistical analysis. Beta distributions were fitted to describe the strength, stiffness and failure strain. It is shown that wetting the bricks reduces the strength by about 25%. A unique permeameter was developed to simulate one-dimensional flow through the bricks and to measure the permeability. This was the first ever attempt to measure the permeability of barricade bricks, and it was shown that barricade bricks are 2-3 orders of magnitude more permeable than the hydraulic fill, thus justifying the assumption in the numerical models that the fill-barricade boundary is free draining.

A 2-dimensional numerical model was developed in *FLAC* that compared very well with Isaacs and Carter model, while having better features. The model simulates hydraulic filling process in the mines, and monitors the pore pressure developments throughout the stope, fill height and water height at all times. This model was extended to three dimensions using *FLAC*^{3D}.

List of Publications

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"Geotechnical Considerations in Mine Backfilling"
Sivakugan, N, Rankine, R.M., Rankine, K.J. and Rankine, K.S. (2005). Journal of Cleaner Production, Elsevier (In Press).

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"A Numerical Analysis of the Arching Mechanism in Pastefill throughout a Complete Mining Sequence"
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Contents

Statement of Access ii

Statement of Sources iii

Acknowledgements iv

Dedication v

Abstract vi

List of Publications viii

Table of Contents x

List of Figures xviii

List of Tables xxiii

List of Symbols xxv

1. INTRODUCTION 1
   - 1.1 General 1
   - 1.2 Problem Statement 4
   - 1.3 Relevance of the Research 4
   - 1.4 Thesis Overview 5

2. LITERATURE REVIEW 7
   - 2.1 General 7
     - 2.1.1 Mining Methods Used with Backfills 9
     - 2.1.2 Purpose of Minefill 9
       - Static Stability Requirements 10
       - Dynamic Stability Requirements 11
       - Drainage Requirements 12
     - 2.1.3 Minefill Types and Selection 11
   - 2.2 Hydraulic Fill 13
     - 2.2.1 Current Practices 14
     - 2.2.2 Geotechnical Considerations 15
       - Grain Size Distribution and Specific Gravity 15
       - Dry Density, Friction Angle, Porosity and Relative Density 16
       - Permeability 17

Compressibility and Consolidation 19

Liquefaction 21

2.3 Discussion of Failure Mechanisms in Underground Mine Barricades 22

2.4 In Situ Monitoring of Hydraulic Fill Stopes 28

2.5 Laboratory Modelling of Hydraulic Fill Stopes 30

2.6 Numerical Modelling of Hydraulic Fill Stopes 30

2.7 Objectives 34

3. HYDRAULIC FILL CHARACTERISATION 35

3.1 Introduction 35

3.2 Grain Shape 36

3.3 Grain Size Distribution and Specific Gravity 38

3.3.1 Sample Preparation 40

Preparation of Fill from Mine B 40

Preparation of Fill from Mines A, C, D, E and F 42

3.3.2 Grain Size Distribution 42

3.3.3 Specific Gravity 45

3.4 Permeability of Hydraulic Fills 46

3.4.1 Theoretical Developments 50

3.4.2 Sample Preparation 52

3.4.3 Constant Head Permeability Test 54

3.4.4 Falling Head Permeability Test 55

3.4.5 Hydraulic Fill Permeability Results 58

3.4.6 Discussion of Hydraulic Fill Permeability Results 60

3.5 Moisture Content, Maximum and Minimum Dry Densities, Relative Density and Void Ratio 62

3.6 Placement Property Tests 65

3.6.1 Test Methodology 69

3.6.2 Test Results 70

3.7 Direct Shear Tests 73

3.8 Oedometer Tests 76

3.9 Chapter Summary 76

4. PERMEABLE BARRICADE BRICKS 78

4.1 Introduction 78

4.1.1 Underground Barricade History 79

4.1.2 Barricade Construction 81

4.1.3 General Barricade Brick Properties 83

4.2 Porosity of Barricade Bricks 84

4.2.1 Testing Methodology 85

4.2.2 Test Results 86

4.3 Permeability of Barricade Bricks 87

4.3.1 Test Methodology 89

Brick Permeability Testing Apparatus 89

Specimen Preparation 91

Constant Head Permeability Test 93

Falling Head Permeability Test 94

Flow-Under-Pressure Tests 95

4.3.2 Permeability Results for Barricade Bricks 96

Constant and Falling Head Permeability Constant 97

Flow-Under-Pressure 98

Brick Permeability Summary 102

4.3.3 Composite Barricade Bricks 103

4.3.4 Barricade Brick Permeability Summary 106

4.4 Uniaxial Compression Tests 108

4.4.1 Sample Preparation 110

4.4.2 Test Methodology 113

4.4.3 Statistical Analysis on Strength and Stiffness of A2 Cores 113

Effects of Coring 114

Effects of Wetting 116

Strength and Stiffness Summary for A2 Cores 118

4.4.4 Probability Distribution Function for A2 Brick Core Strength and Stiffness 118

Unconfined Compressive Strength 120

Young’s Modulus 124

Summary 125

4.4.5 Effects of Sample Size and Shape 126

4.4.6 Uniaxial Compressive Strength Summary for Barricade Bricks 126
4.5 Chapter Summary 128

5. TWO-DIMENSIONAL MODELLING OF UNDERGROUND HYDRAULIC FILL STOPES 131

5.1 Introduction 131
5.1.1 FLAC 132
5.2 Verification Exercise: *FLAC* versus Isaacs and Carter (1983) 133
5.2.1 Problem Definition 133
5.2.2 Input Parameters 135
5.2.3 Modelling Approach 136
Program Design Methodology 136
Implicit versus Explicit Solution 141
5.2.4 Numerical Model Verification 141
5.3 Sensitivity Analysis 147
5.3.1 Sensitivity of Input Parameters 147
Permeability 148
Specific Gravity 151
Residual Moisture Content 152
5.3.2 Mesh Sensitivity 152
5.3.3 Sensitivity of Solution Time 158
5.3.4 Summary of Sensitivity Analysis for 2-dimensional *FLAC* Simulation 161
5.4 Two-Dimensional Filling and Drainage Analysis for Hydraulic Fill Stopes 162
5.4.1 Filling Schedule 162
5.4.2 Filling Rate 165
5.4.3 Geometry 166
Stope Dimensions 166
Multiple Drains 166
Drain Length 170
5.5 Chapter Summary 173

6. THREE-DIMENSIONAL MODELLING OF UNDERGROUND HYDRAULIC FILL STOPES 175
6.1 Introduction 175
6.1.1 Three-Dimensional Numerical Modelling in Underground Hydraulic Fill Stopes 175
6.1.2 *FLAC*^{3D} 176
6.2 Using Flow Nets to Determine Scaling Factors 177
6.2.1 Flow Nets in 2-Dimensional Stopes 179
6.2.2 Flow Nets in 3-Dimensional Stopes 180
6.3 Three-Dimensional Stope Filling Program 184
6.3.1 Problem Definition 185
6.3.2 Numerical Model Verification 187
6.4 Three-Dimensional Filling and Drainage Analysis for Hydraulic Fill Stopes 189
6.4.1 Permeability 189
6.4.2 Specific Gravity 197
6.4.3 Solids Content 200
6.4.4 Residual Water Content 204
6.4.5 Geometry 206
Flow Rate 208
Maximum Pore Water Pressure 214
6.5 Chapter Summary 223

7. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS 226
7.1 Summary 226
7.2 Conclusions 228
7.2.1 Hydraulic Fill Characterisation 228
7.2.2 Permeable Barricade Bricks 228
7.2.3 Two-Dimensional Modelling of Underground Hydraulic Fill Stopes 229
7.2.4 Three-Dimensional Modelling of Underground Hydraulic Fill Stopes 230
7.3 Recommendations for Future Research 231
7.3.1 Hydraulic Fill Characterisation 231

7.3.1 Hydraulic Fill Characterisation 231
7.3.2 Permeable Barricade Bricks 232
7.3.3 Two-Dimensional Modelling of Underground Hydraulic Fill Stopes 232
7.3.4 Three-Dimensional Modelling of Underground Hydraulic Fill Stopes 233

REFERENCES 234

APPENDICES

APPENDIX 1 246
FIG. A1.1 – Grain size distributions on hydraulic fill samples from mine A 247
FIG. A1.2 – Grain size distributions on hydraulic fill samples from mine B 248
FIG. A1.3 – Grain size distributions on hydraulic fill samples from mine C 249
FIG. A1.4 – Grain size distributions on hydraulic fill samples from mine D 250
FIG. A1.5 – Grain size distributions on hydraulic fill samples from mine E 251
FIG. A1.6 – Grain size distributions on hydraulic fill samples from mine F 252
TABLE A1.1 – Hydraulic fill permeability summary 253

APPENDIX 2 254
TABLE A2.1 – A1 brick dimensions and densities 255
TABLE A2.2 – A2 brick dimensions and densities 255
TABLE A2.3 – B brick dimensions and densities 256
TABLE A2.4 – Brick dimensions, porosity and specific gravity values 257
FIG. A2.1 – Schematic diagram of the brick permeameter 258
TABLE A2.5 – Constant head permeability test data for A1 and A2 bricks 259
TABLE A2.6 – Constant head permeability test data for B bricks 260
TABLE A2.7 – Falling head permeability test data for A1 and A2 bricks 261
TABLE A2.8 – Falling head permeability test data for B bricks 262
TABLE A2.9 – Flow-under-pressure permeability test data for A1 and A2 bricks 263
TABLE A2.10 – Flow-under-pressure permeability test data for B bricks 264
TABLE A2.11 – Unconfined compressive strength data for Mine D cores 265
TABLE A2.12 – Harr’s gamma function table 266
FIG. A2.2 – Pearson’s system (Harr, 1977) 267

FIG. A2.3 – Unconfined compressive strength frequency data for A2 barricade brick dry cores, with approximation by beta distribution 268
FIG. A2.4 – Unconfined compressive strength frequency data for A2 barricade brick 7 day wetted cores, with approximation by beta distribution 269
FIG. A2.5 – Unconfined compressive strength frequency data for A2 barricade Brick 90 day wetted cores, with approximation by beta distribution 270
FIG. A2.6 – Young's modulus frequency data for A2 barricade brick dry cores, with approximation by beta distribution 271
FIG. A2.7 – Young's modulus frequency data for A2 barricade brick 7 day wetted cores, with approximation by beta distribution 272
FIG. A2.8 – Young's modulus frequency data for A2 barricade brick 90 day wetted cores, with approximation by beta distribution 273

APPENDIX 3 274
TABLE A3.1 – Filling and drainage records from R454 stope at Mount Isa Mines Ltd. (Traves, 1988) 275
FIG. A3.1 – Plan view of R454 stope at Mount Isa Mines Ltd. (Traves, 1988) 277
FIG. A3.2 – Sections of R454 stope at Mount Isa Mines Ltd. (Traves, 1988) 278
PROGRAM A3.1 – Source listing *FISH* code for program used to monitor the real time taken to solve the 2-dimensional *FLAC* steady-state model to a convergence of sratio = 0.001 279
PROGRAM A3.2 – Source listing *FISH* and *FLAC* code for 2-dimensional stope filling program 281

APPENDIX 4 289
PROGRAM A4.1 – Source listing *FISH* and $FLAC^{3D}$ code 3-dimensional stope filling program 290
PROGRAM A4.2 – Source listing *FISH* and $FLAC^{3D}$ code 3-dimensional steady-state Case 1 program 302
TABLE A4.1 – Three-dimensional discharge and maximum pore pressure efficiencies for Cases 2, 3 and 4 relative to Case 1, at $X/D = 0.5$ and $D/B = 0.2$ 305

TABLE A4.2 – Three-dimensional discharge and maximum pore pressure efficiencies for Cases 2, 3 and 4 relative to Case 1, at *X/D* = 1 and *D/B* = 0.2 305

TABLE A4.3 – Three-dimensional discharge and maximum pore pressure efficiencies for Cases 2, 3 and 4 relative to Case 1, at *X/D* = 2 and *D/B* = 0.2 305

TABLE A4.4 – Three-dimensional discharge and maximum pore pressure efficiencies for Cases 2, 3 and 4 relative to Case 1, at *X/D* = 0.5 and *D/B* = 0.3 306

TABLE A4.5– Three-dimensional discharge and maximum pore pressure efficiencies for Cases 2, 3 and 4 relative to Case 1, at *X/D* = 1 and *D/B* = 0.3 306

TABLE A4.6– Three-dimensional discharge and maximum pore pressure efficiencies for Cases 2, 3 and 4 relative to Case 1, at *X/D* = 2 and *D/B* = 0.3 306

List of Figures

Figure	Details	Page
1.1	Idealized schematic of stope during excavation	2
1.2	Diagram of stope during filling	3
2.1	Three field permeameters (Herget and De Korompay, 1978)	18
2.2	Behaviour of minefill under increasing pore water pressure (www.ce.washington.edu/~liquefaction/html/main.html)	22
2.3	Test apparatus for observing the piping mechanism	23
2.4	Erosion tube initiating from void behind the barricade (reproduction of Figure 7, Bloss and chen, 1998)	25
3.1	Electromicrograph of hydraulic fill A2	37
3.2	Electromicrograph of hydraulic fills (a) C1 (b) C2 (c) C3 and (d) D6	37
3.3	Grain size distributions on all hydraulic fills	39
3.4	Malvern MasterSizer-X laser particle sizer	40
3.5	Rod Mill	41
3.6	Unmixed (a) and homogenous (b) samples in the large pan mixer	41
3.7	Creteangle multi-flow mixer	42
3.8	Generalised grain sixe distribution for Australian hydraulic fills	45
3.9	In situ permeability measurements on granular deposits in Mississippi River Valley, USA, as reported by Leonards (1962)	48
3.10	Various laboratory measured soil permeabilities (Lambe andWhitman, 1979)	49
3.11	Effect of consolidation pressure on permeability (Cedegren, 1967)	50
3.12	Schematic diagram of (a) constant head and (b) falling head test apparatus	52
3.13	Permeameter in test overflow box	53
3.14	Decant water at surface of permeameter	54
3.15	Top of permeameter (a) without sealant, (b) with sealant	55
3.16	Soil permeameter set-up (a) constant head (b) falling head	56
3.17	Sample disassemble procedure (a) removal of excess water and filter paper (b) removal of apparatus cylinder (c) dividing the sample (d)weighing the sample	57
3.18	JCU constant and falling head permeability apparatus in a mine	58
3.19	Fill constant head and falling head permeability values	59
3.20	Hazens's permeability - grain size relation for reconstituted laboratory samples	61
3.21	Dry density - specific gravity relation	63
3.22	Placement property data as relative density versus void ratio	65
3.23	Phase relationship for hydraulic fills	66
3.24	Porosity - water content space for displaying placement properties	68
3.25	Fill placement property variation with increased water	68
3.26	Typical placement property curve	69

3.27	Placement property curve for sample D6	71
3.28	Placement property curve for sample D6 as dry density versus water content	72
3.29	Friction angle versus relative density for sample D6	75
4.1	Photograph of in place porous brick barricade	79
4.2	Construction of a curved barricade	80
4.3	Photograph of in place porous brick barricade	80
4.4	Barricade failure mechanisms (a) theoretical (Duffield et al., 2003) (b) observed (Kuganathan, 2001)	82
4.5	Photograph of porous barricade brick and wall construction	83
4.6	Schematic diagram of brick porosity test	84
4.7	Brick suspended in water under scales in porosity test	85
4.8	Pressure testing cell	89
4.9	Pressure testing cell (a) sight glass on side of the pressure chamber (b) B base (c) top of confinement chamber	90
4.10	A1 porous bricks being sealed for testing	91
4.11	B brick completely sealed in base of pressure testing cell	92
4.12	Schematic representation of the constant head permeability test setup for the barricade bricks	93
4.13	Schematic representation of the falling head permeability test setup for the barricade bricks	95
4.14	Photograph of brick being tested for flow rate under pressure	96
4.15	Constant and falling head brick permeability comparison	98
4.16	Pressure versus flow plots for A1, A2 and B barricade bricks	99
4.17	Q/Q_{300} for A1, A2 and B barricade bricks	100
4.18	Permeability estimation from pressure-flow curves for A1 and A2 barricade bricks	101
4.19	Permeability estimation from pressure-flow curves for B barricade bricks	102
4.20	In situ barricade	104
4.21	Schematic diagram of composiste brick	105
4.22	Cored A2 bricks	108
4.23	Coring using the drill rig (a) coring of the sample (b) removal of cored sample	112
4.24	Sulphur capping to the ends of samples	113
4.25	Strength and stiffness comparison between dry core A and dry core B of A2 barricade bricks from Mine D	115
4.26	Strength and stiffness comparison between wet and dry barricade brick core samples	117
4.27	Unconfined compressive strength frequency data for A2 barricade brick dry cores, with approximation by beta distribution	123
4.28	Beta distributions for UCS core data	124
4.29	Young's modulus data for A2 barricade brick cores, with beta distributions	125

4.30 Young's modulus versus uniaxial compressive strength for A2 barricade brick cores 127
5.1 Two-dimensional verification simulation geometry 134
5.2 Two pore water pressure distribution assumptions for fill-barricade interface 138
5.3 Boundary condition cases for surfaces of hydraulic fill 138
5.4 Fill and water height comparison between Isaacs and Carter and *FLAC* for the verification simulation 142
5.5 Discharge rate comparison between Isaacs and Carter and *FLAC* for ther verification simulation 142
5.6 Discharge results for Isaacs and Carter and *FLAC* for 24 hour period between hours 601 and 624 143
5.7 One-dimensional approximation for flow analysis 145
5.8 Flow net at 600 hours 146
5.9 Rate of discharge variation with permeability during filling 149
5.10 Water height variation with permeability during filling 150
5.11 Discharge variation with permeability during filling 150
5.12 Model to determine sensitivity of stope drainage to mesh size 154
5.13 Multiple drain mesh analysis geometry 155
5.14 Mesh discretization arrangements 156
5.15 Maximum pore pressure and flow variation with mesh arrangement 157
5.16 Fill and water heights during filling for various filling schedules 163
5.17 Discharge comparison between simulations filled with fills of various specific gravity values 165
5.18 3-dimensional model arrangement for (a) 2 drains located on levels either 15 m, 30 m or 45 m apart, and (b) single drain arrangement 165
5.19 Cumulative discharge for various drain arrangements 168
5.20 Percentage of total discharge emitted by each drain during the filling and drainage of stope R454 at MIM 169
5.21 A 3-dimensional and an equivalent pseudo 2-dimensional arrangement 170
5.22 Variation in maximum pore pressure with drain length 171
5.23 Variation in discharge with drain length 172
5.24 Pore pressure contour plots in the bottom section of the 2-dimensional verification simulation with various drain lengths 173
6.1 Mixed discretization method used in *FLAC*^{3D} 177
6.2 One-dimensional flow 178
6.3 Scaling of a 2-dimensional stope and the flow nets 179
6.4 Three-dimensional flow net for 1-dimensional flow 181
6.5 Three-dimensional scaling 182
6.6 Three-dimensional modelling exercise to demonstrate stope scaling 183
6.7 Three-dimensional scaling of discharge 184
6.8 Verification geometry in (a) 2-dimensions, and (b) 3-dimensions 185

6.9 Scaled 3-dimensional verification stope geometry 186
6.10 Fill and water height comparison between Isaacs and Carter, *FLAC* and *FLAC*^{3D} for the verification simulation 188
6.11 Discharge rate comparison between Isaacs and Carter, *FLAC* and *FLAC*^{3D} for the verification simulation 188
6.12 One-dimensional stope flow simplification 190
6.13 Equipotential lines and fragments for a typical 2-dimensional stope 192
6.14 Two-dimensional stope 193
6.15 Minimum permeability requirement to prevent decant water for a 20 m square based stope with a 4 m x 4 m 4 m drain located centrally along the base of one of the stope walls 195
6.16 Variation of hydraulic gradient at the top of the stope height for 2-dimensional and 3-dimensional stopes 197
6.17 Fill and water height comparison between simulations filled with fills of various specific gravity values 198
6.18 Discharge comparison between simulations filled with fills of various specific gravity values 199
6.19 Fill and water height comparison between verification simulations filled at various solids contents 202
6.20 Discharge rate comparison between verification simulations filled at various solids contents 202
6.21 Maximum pore pressure comparison between verification simulations filled at various solids contents 203
6.22 *FLAC*^{3D} simulations of filling and draining a 25 m x 25 m x 150 m stope for various residual moisture content hydraulic fills 205
6.23 Plan view of four drain location cases analysed 206
6.24 Example Case 1 and Case 2 simulations for stope width to depth ratios of 1:1 and 2:1 respectively 207
6.25 Geometrical variables for 3-dimensional Case 1 stope 208
6.26 Three-dimensional total flow design chart for Case 1 210
6.27 Three-dimensional total flow design chart for Case 2 211
6.28 Three-dimensional total flow design chart for Case 3 212
6.29 Three-dimensional total flow design chart for Case 4 213
6.30 Maximum pore pressure locations shown on elevation view for 2-dimensional stopes 214
6.31 Maximum pore pressure locations shown on elevation view for 3-dimensional stopes 214
6.32 Three-dimensional maximum pore pressure design chart for Case 1 216
6.33 Three-dimensional maximum pore pressure design chart for Case 2 217
6.34 Three-dimensional maximum pore pressure design chart for Case 3 218

6.35 Three-dimensional maximum pore pressure design chart for Case 4 219

6.36 Pore pressure coefficient, β versus H_w/B for 2-dimensional and 3-dimensional modelling 220

6.37 Case 2, 3 and 4 discharge rates /Case 1 discharge rates for D/B = 0.2 221

6.38 Case 2, 3 and 4 discharge rates /Case 1 discharge rates for D/B = 0.3 222

6.39 Case 2, 3 and 4 u_{max}/Case 1 u_{max} for D/B = 0.2 222

6.40 Case 2, 3 and 4 u_{max}/Case 1 u_{max} for D/B = 0.3 223

List of Tables

Table	Description	Page
3.1	Arrival dates and conditions for hydraulic fills tested	36
3.2	Grain size distribution data for hydraulic fill samples	43
3.3	Hydraulic fill specific gravity values	46
3.4	Permeability and drainage characteristics of soils (Terzaghi et al., 1996)	47
3.5	Hazen's constant values reported by Lambe and Whitman (1979)	47
3.6	State of permeability test samples	53
3.7	Fill permeability summary	59
3.8	Relative densities of hydraulic fills	62
3.9	Placement property test data	73
3.10	Measured friction angle for hydraulic fill sample D6 with estimates based on empirical relations for granular soils	75
4.1	Brick dimensions, porosity and specific gravity values	87
4.2	Procedures used for the permeability tests on barricade bricks	88
4.3	Summary of brick permeability testing	88
4.4	Constant and falling head barricade brick permeability summary	97
4.5	Comparison of the theoretical and laboratory measured K_{eq}	106
4.6	Constant head, falling head and pressure-flow barricade brick permeability summary	107
4.7	Unconfined compressive strength test barricade brick samples	109
4.8	Dimensions and densities for A2 brick cores	111
4.9	Summary of UCS sample dimensions	113
4.10	UCS data for dry cores	122
4.11	Strength and stiffness summary for source A brick samples	126
4.12	Uniaxial compressive strength test summary for barricade bricks and brick cores	128
4.13	Strength, stiffness and E/UCS summary for common engineering materials	128
5.1	Input parameters for verification simulation	135
5.2	The Isaacs and Carter and *FLAC* model output summaries between hours 600 and 624	144
5.3	Water volume variation with fill specific gravity	152
5.4	Case 1 summary: Mesh size sensitivity	153
5.5	Case 2 summary: Mesh arrangement sensitivity	155
5.6	Relative runtime and output by different mesh arrangements	157
5.7	Relative runtime calculation rates for a specific problem solved by different computers	159
5.8	Case 1 summary: Mesh size sensitivity	159

5.9 Relative runtime for a steady-state stope problem solved by different computers 160

5.10 Variation in discharge and maximum pore pressure with drain length for the 2-dimensional verification stope 171

6.1 Results for 3-dimensional scaling exercise in *FLAC*^{3D} 183

6.2 Input parameters for scaled verification simulation 186

6.3 Two-dimensional hydraulic gradient variation with stope geometry 194

6.4 Three-dimensional hydraulic gradient variation with stope geometry 195

6.5 Water mass balance details for verification problem at hour 100 solved with specific gravities of 2.77, 3.50 and 4.33 200

6.6 Water balance details for verification problem at hours 100 and 545 solved with solids contents of 70%, 72% and 75% 203

6.7 Mass balance of water in two stopes 204

List of Symbols

A = cross-sectional area

a = air content

a_2 = cross-sectional area of the standpipe in the falling head test

C = Hazen's constant

C_c = coefficient of curvature

C_u = coefficient of uniformity

C_v = viscosity coefficient

D = constrained modulus

D_r = relative density

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 = void ratio

e_{min} = minimum void ratio

e_{max} = maximum void ratio

E = Young's modulus

G_s = Specific gravity

H, h = height

h_L = head loss

i = hydraulic gradient

k = permeability

k_e = effective permeability,

k_{eq} = equivalent permeability for a layered system

K_0 = horizontal pressure coefficient (assumed to be 0.5),

L = length

M_a = mass of air

M_s = mass of solids

M_t = total mass

M_w = mass of water

n = porosity

N_1 = corrected blow count number

Q = flow rate

S = saturation

S_v = grain surface per unit volume

S_x = standard deviation

t = the time taken for the water level to fall between the two electrodes

u = pore water pressure

V, V_t = total volume

V_a = volume of air

V_s = volume of solids

V_v = volume of voids

V_w =volume of water

w = water content

$\bar{x}$ = mean

α = shape parameter for Beta distribution

β = shape parameter for Beta distribution

β_1 = coefficient of skewness

β_2 = coefficient of kurtosis

ε_f = failure strain

Φ = friction angle

γ_w = unit weight of water

γ' = effective unit weight of fill

ν = Poisson’s ratio

ρ_d = dry density

ρ_w = density of water

σ_h = barricade pressure

σ_h' = effective horizontal pressure

σ_v' = effective vertical pressure