Appendix D.

Geomechanical Modelling Codes

Description:

The accompanying PDF provides a numerical modelling codes utilized for preliminary Jure Landslide modelling in this research. It is important to note that modelling in this research is strictly of a preliminary investigative nature due to a high degree of parameter uncertainty; numerous assumptions have been made due to an absence of borehole and piezometer data and limited information on hydrogeology, rock mass and joint parameters. Each numerical code is used not to precisely simulate the actual failure but as a tool to test research questions and to provide a background for potential future work that could be undertaken at the site.

FLAC3D: 3D Finite Difference Modelling Software Codes

Scenario 1: Homogeneous

```
model new

model restore "prefailureJureLandslidegeometry"

;Constitutive Model, Rock mass material and discontinuity properties based on Table 6.2.

;Bulk elastic modulus set to 3.1 GPa

;Shear Modulus is set to 1.9 GPA

;Mass Density is set to 2600 kg/m3

;Tensile Strength is set to 0.05 MPa

zone cmodel assign elastic

zone property bulk 3.1e9 shear 1.9e9 density 2600

;zone property cohesion 0.45 (MPa), friction 27°, tensile 0.05 MPa

;Initial Conditions (Background)

model gravity 9.81

zone initialize-stresses
```

```
;Boundary conditions and gravity are set:

Zone face apply velocity-y 0 range position-y -1605 -1604

Zone face apply velocity-x 0 range position-y -1605 -1604

Zone face apply velocity-x 0 range position-x 1377 1378

Zone face apply velocity-y 0 range position-x 1377 1378

Zone face apply velocity-y 0 range position-y 743 744

Zone face apply velocity-x 0 range position-y 743 744

Zone face apply velocity-x 0 range position-x -1117 -1116

Zone face apply velocity-y 0 range position-x -1117 -1116

Zone face apply velocity-z 0 range position-z -83 -82

Zone face apply velocity-x 0 range position-z -83 -82

Zone face apply velocity-y 0 range position-z -83 -82

;running as elastic to settle and then plastic to see failure.

;solve to initial equilibrium

model solve

model save "Background"

zone cmodel assign mohr-coulomb

zone property bulk 3.1e9 shear 1.9e9 density 2600

zone property cohesion 0.45 (MPa), friction 27°, tensile 0.05 MPa

model solve

model save "pre-failure-homo"
```

Scenario 2: Jointed

```
model new

model restore "prefailure_basalrearrelease"

;Separation of boundary faces

zone separate by-face new-side origin 0 0 0 group 'Basal' range group 'IF_Basal_Rupture'

zone separate by-face new-side origin 0 0 0 group 'Rear' range group 'IF_Rear_Release_Surface'

;Interface Creation

zone interface '1' create by-face range group 'IF_Basal_Rupture'

zone interface '2' create by-face range group 'IF_Rear_Release_Surface'

;large strain is set to see displacement

model largestrain on

;Constitutive Model and Properties

;Constitutive Model, Rock mass material and discontinuity properties based on Table 6.2.

;Bulk elastic modulus set to 3.1 GPa

;Shear Modulus is set to 1.9 GPA

;Mass Density is set to 2600 kg/m³

;Tensile Strength is set to 0.05 MPa

zone cmodel assign elastic

zone property bulk 3.1e9 shear 1.9e9 density 2600

;zone property cohesion 0.45 (MPa), friction 27°, tensile 0.05 MPa

;Initial Conditions

model gravity 9.81

zone initialize-stresses

;Boundary conditions and gravity are set:

Zone face apply velocity-y 0 range position-y -1986 1991

Zone face apply velocity-x 0 range position-y -1986 1991

Zone face apply velocity-x 0 range position-x -3791 -3790

Zone face apply velocity-y 0 range position-x -3791 -3790

Zone face apply velocity-y 0 range position-y 360 365

Zone face apply velocity-x 0 range position-y 360 365
```

```
Zone face apply velocity-x 0 range position-x -1292 -1297

Zone face apply velocity-y 0 range position-x -1292 -1297

Zone face apply velocity-z 0 range position-z -83 -82

Zone face apply velocity-x 0 range position-z -83 -82

Zone face apply velocity-y 0 range position-z -83 -82
```

;running as elastic to settle and then plastic to see failure. Attempt 4: Pre failure homo with joints

;solve to initial equilibrium

```
zone interface '1' node property stiffness-shear 0.1 (GPa/m), stiffness-normal 2 (GPa/m), friction 20 cohesion 0.015 (MPa)

zone interface '2' node property stiffness-shear 0.1 (GPa/m), stiffness-normal 2 (GPa/m), friction 20 cohesion 0.015 (MPa)

model solve

model save "JUREPREFAILURESURFACE_prebasalrear"

zone cmodel assign mohr-coulomb
```

;Bulk elastic modulus set to 3.1 GPa

;Shear Modulus is set to 1.9 GPA

;Mass Density is set to 2600 kg/m^3

;Tensile Strength is set to 0.05 MPa

;zone property cohesion 0.2 (MPa), friction 25º, tensile 0.03 MPa

;Boundary conditions and gravity are set:

```
Zone face apply velocity-y 0 range position-y -1986 1991

Zone face apply velocity-x 0 range position-y -1986 1991

Zone face apply velocity-x 0 range position-x -3791 -3790

Zone face apply velocity-y 0 range position-x -3791 -3790

Zone face apply velocity-y 0 range position-y 360 365

Zone face apply velocity-x 0 range position-y 360 365

Zone face apply velocity-x 0 range position-x -1292 -1297

Zone face apply velocity-y 0 range position-x -1292 -1297

Zone face apply velocity-z 0 range position-z -83 -82

Zone face apply velocity-x 0 range position-z -83 -82

Zone face apply velocity-y 0 range position-z -83 -82
```

```
**RESET DISPLACEMENT

model solve

model save "prebasalrear-plastic
```

UDEC: 2D Distinct Element Software Codes

Scenario 1: Homogeneous

config

round 2.443

edge 4.886

block -600,325 -600,1.785E3 -353.226,1.7E3 -100,1.62E3 118.83,1.572E3 277.272,1.553E3 376.297,1.492E3 693.179,1.193E3 871.425,1.065E3 1.01E3,925.372 1.307E3,820.304 1.624E3,775.181 1.843E3,775.181 1.843E3,325

;crack (-600,925.372) (1.010E3,925.372) join

;crack (1.010E3,925.372) (1.010E3,325) join

gen quad 50

gen edge 50

group zone 'User:rock:phyllite'

zone model mohr density 2.6E3 bulk 3.1 (GPa), shear 1.9 (GPa), friction 27º, cohesion 0.45 (MPa), tension 0.05 (MPa), dilation 0 range group 'User:rock'

boundary xvelocity 0 range -621.4761,-585.2544 296.2508,1.795E3

boundary xvelocity 0 range 1.838E3,1.882E3 294.3444,807.1674

boundary xvelocity 0 range -663.417,1.868E3 305.7828,342.0045

boundary yvelocity 0 range -631.0081,1.861E3 294.3444,345.8173

set gravity=0.0 -9.81

Scenario 1: Jointed

block -600,325 -600,1.785E3 -353.226,1.7E3 -100,1.62E3 118.83,1.572E3 277.272,1.553E3 376.297,1.492E3 693.179,1.193E3 871.425,1.065E3 1.01E3,925.372 1.307E3,820.304 1.624E3,775.181 1.843E3,775.181 1.843E3,325

crack (871.425,1.065E3) (-600,1.725E3)

crack (85.0787,1.611E3) (289.9325,1.236E3)

gen edge 50.0

group zone 'User:rock'

zone model mohr density 2.6E3 bulk 3.33333E9 shear 2E9 friction 27 cohesion 4.5E5 range group 'User:rock'

group joint 'User:ID219'

joint model area jks 0.1 (GPa/m), jkn 2 (GPa/m), jfriction 20º, jcohesion 0.015 (MPa), range group 'User:ID219'

; new contact default

set jcondf joint model area jks 0.1 (GPa/m), jfriction=20, jcohesion=0.015 (MPa)

boundary xvelocity 0 range -626.1985,-583.3853 299.6531,1.81E3

boundary xvelocity 0 range 1.833E3,1.863E3 302.7112,795.0628

boundary yvelocity 0 range -623.1404,1.86E3 299.6531,339.4082

set gravity=0.0 -10.0

;solve

3DEC: 3D Distinct Element Software Codes

new

Call PreFailureJureVolume.3ddat

 ;Mesh created from Remote Sensing 3d point cloud in RHINO/Griddle

save JUREGeometryHOMO.3dsav

;Will run model to equilibrium first with higher background joint/rock mass properties to avoid detachment and then run model with damaged (reduced) parameters

;;;ADDED IN 2 LATERAL RELEASE SURFACE JOINTS (NORTH AND SOUTH)

;;;ADDED in REAR RELEASE SURFACE AND BASAL RUPTURE SURFACE

;assigned elastic prop

;Bulk elastic modulus set to 3.1 GPa

;Shear modulus set to 1.9 GPa

```
;Mass Density is set to 2600 kg/m3

;Tensile strength set to 0.05 (MPa)

;;;;;;;;;;;;;;Manually add in 4 discontinuities (BASAL, REAR, and LATERAL RELEASE SURFACES) in
geospatial locations


join

set atol 0.0001

jset dip 25 dd 138 origin 1158 1327 1299 id 101 ;Basal Rupture

jset dip 77 dd 144 origin 889 1771 1332 id 102 ;Rear Release

jset dip 75 dd 240 origin 1703 1325 888 id 103 ;North Lateral

jset dip 75 dd 052 origin 976 850 910 id 104 ;South lateral

;join

Hide range plane below dip 75 dd 052 origin 976 850 910  ;South lateral OK

Hide range plane below dip dip 77 dd 144 origin 889 1771 1332  ;Rear Release

Hide range plane above dip 75 dd 240 origin 1703 1325 888  ;North Lateral

Hide range plane below dip 25 dd 138 origin 1158 1327 1299 ; basal

Hide range plane below dip 80 dd 324 origin 1800 780 750

group block JureFailure

show

hide range group JureFailure

;join

group block Stable

show

gen edge 200

save 3a_ZonedLateral.3dsav

;rock mass properties adapted from back analysis

;;when running plastic--> cohesion 0.2 MPa friction 25 tension 0.03 MPa

prop mat 1 bulk 2.9 (GPa) shear 1.5 (GPa) density 2600 (kg/m³)

change mat 1


;joint properties shear stiffness 0.01 (GPa/m), Normal stiffness 1 (GPa/m), cohesion 0.002 (MPa),
Friction angle 15, Tensile 0
```

```
change jmat 1 jcons 7

;gravity set to -9.81

gravity 0 0 -9.81

;Boundary Conditions set

boundary yvel 0 range y 2340 2349

boundary xvel 0 range y 2340 2349

boundary xvel 0 range x -5 5

boundary yvel 0 range x -5 5

boundary yvel 0 range y -5 5

boundary xvel 0 range y -5 5

boundary xvel 0 range x 2490 2497

boundary yvel 0 range x 2490 2497

boundary zvel 0 range z -5 5

boundary xvel 0 range z -5 5

boundary yvel 0 range z -5 5

;solve to initial equilibrium elastic

damp auto

set atol 0.01

solve

save JUREElasticEquilibriumJOINTED

Restore JUREElasticEquilibriumJOINTED

;;;Model set for plastic

reset disp

;;Rock mass prop for failure plastic

prop mat 1 bulk 3.1e9 shear 1.88e9 density 2600 bcohesion 4e6 bfriction 27 btension 1e6

change mat 1 cons 1

damp local

;Joint property change for area contact elastic/plastic with Coulomb slip failure  (THIS IS 1st
attempt with high parameters joints)

prop jmat 1 jkn 100e6 jks 10e6 jfric 23 res_fric 16 jcoh 1e6 res_coh 0 jten 0.2e6 res_tens 0

change jmat 1 jcons 1 ;range id 101
```

```
solve

save 4c_jurejointedlateral_plasticHIGH

reset disp

;;Reduced Joint Properties for Basal and Rear

;joint properties shear stiffness 0.01 (GPa/m), Normal stiffness 1 (GPa/m), cohesion 0.002 (MPa),
Friction angle 15, Tensile 0

res_tens 0

change jmat 2 jcons 1

solve

save  4d_JUREJOINTED_FINAL

;;FAILURE of unstable rock mass
```