Appendix G:

UDEC Code

;UDEC V6 Code to generate 15m tall by 10 m wide pillar with steel platen.

;DFN realization is adjusted by changing random seed in "set random"

```
new

set random 1003
round 0.3e-2
;set edge 0.05

block -8,-11.5 -8,11.5 8,11.5 8,-11.5
;
crack (-8,-7.5) (-6,-7.5)
crack (-6,-7.5) (-6,-9.5)
crack (-6,-9.5) (6,-9.5)
crack (6,-9.5) (6,-7.5)
crack (6,-7.5) (8,-7.5)
crack (-8,7.5) (-6,7.5)
crack (-6,7.5) (-6,9.5)
crack (-6,9.5) (6,9.5)
crack (6,9.5) (6,7.5)
crack (6,7.5) (8,7.5)
crack (-6,-7.5) (-5,-7.5)
crack (6,-7.5) (5,-7.5)
```

```
crack (-6,7.5) (-5,7.5)
crack (6,7.5) (5,7.5)
crack (-5,7.5) (-5,-7.5)
crack (5,7.5) (5,-7.5)
;
delete range -8,-5 -7.5,7.5
delete range 5,8 -7.5,7.5
;
jregion id 1 -6.0,-9.5 -6.0,9.5 6.0,9.5 6.0,-9.5
table 1 -8,-11.5 8,-11.5 8,-7.5 6,-7.5 6,-9.5 -6,-9.5 -6,-7.5 -8,-7.5 -8,-11.5
table 2 -8,11.5 -8,7.5 -6,7.5 -6,9.5 6,9.5 6,7.5 8,7.5 8,11.5 -8,11.5
;
vor edge 0.45 iterations 50 trigon round 0.003 range jregion 1
 jdelete


jset angle 0,5 trace 3.79,2.5 gap 0.8,0.1 spacing 0.8,0.2 id 1 range jregion 1
jset angle 90,10 trace 2.6,1.4 gap 0.8,0.1 spacing 0.8,0.2 id 2 range jregion 1

sav block.sav

gen edge 0.4 range jreg 1
gen edge 0.4 range inside table 1
gen edge 0.4 range inside table 2

sav zone.sav
```

```
rest zone.sav

def set_param
  ;rock properties
  b_den=2700
  b_e=41.0e9
  b_v=0.25
  b_k=b_e/(3*(1-2*b_v))
  b_g=b_e/(2*(1+b_v))
  ;
  ;steel platten properties
  s_den=7600
  s_e=200.0e9
  s_v=0.25
  s_k=s_e/(3*(1-2*s_v))
  s_g=s_e/(2*(1+s_v))
  ;
  ;flaws properties
  ks_kn_v=0.40
  f_fri=18.0
  f_coh=13.0e6
  f_ten=5.0e6
  f_kn=984e9
  f_ks=f_kn*ks_kn_v
  f_rcoh=0
```

```
 f_rtens=0


 ;
 ;joint properties
 s_fri=45.0
 s_coh=250e3
 s_ten=0.0
 s_kn=f_kn
 s_ks=f_ks
 s_rcoh=0

 ;steel contact properties
 ks_kn_v=0.40
 p_fri=18.0
 p_coh=13.0e6
 p_ten=5.0e6
 p_kn=5000e9
 p_ks=f_kn*ks_kn_v



 ;
 width_sam=10.0
 width_cap=16.0
 ;
end
set_param
```

```
prop mat 1 dens=b_den bulk=b_k shear=b_g

prop mat 2 dens=s_den bulk=s_k shear=s_g


change mat 2 rang inside table 1

change mat 2 range inside table 2


;

prop jmat 1 jkn=f_kn jks=f_ks jfric=f_fri jcoh=f_coh jten=f_ten jrescoh=f_rcoh
jrtens=f_rtens

prop jmat 2 jkn=s_kn jks=s_ks jfric=s_fri jcoh=s_coh jten=s_ten jrescoh=s_rcoh

prop jmat 3 jkn=p_kn jks=p_ks jfric=p_fri jcoh=p_coh jten=p_ten


change jmat 2 range id 1

change jmat 2 range id 2

change jmat 3 range angle -0.01 0.01, y -9.6,-9.4

change jmat 3 range angle -0.01 0.01, y 9.4,9.6

change jmat 3 range angle 89.99 90.01, x -6.1,-5.9

change jmat 3 range angle 89.99 90.01, x 5.9,6.1

sav model.sav


;;;-----------------------------------------

rest model.sav

;

def set_test_para

  ;
```

```
  ;triaxial
  ;sig3_cel=-0.0e6
  ;sig3_cap=sig3_cel*width_sam/width_cap
  Load_displacement=0.004*10*0.667
  disp_value=0.015
  fnam='Dis04-'
  each=20000
  ncyc=7
end
set_test_para
cal doPillar_stepload_stiffreducev3.dat

;doPillar_stepload_stiffreducev3.dat
set grav 0 -9.81
damp local



;; boundary conditions-------------------------
;triaxial
;bound stress=(0,0,sig3_cap) range (-5.5,5.5) (7.4,7.6)
;

bound xvel=0.0  range (-8,8) (11.4,11.6)
bound xvel=0.0  range (-8,8) (-11.6,-11.4)
bound yvel=0.0  range (-8,8) (-11.6,-11.4)
cyc 2000
```

```
;bound stress=(sig3_cel,0,0) range (-2.05,-1.95) (-5.05,5.05)
;bound stress=(sig3_cel,0,0) range (1.95,2.05) (-5.05,5.05)
;cyc 2000


def set_apply_vel
  ;Load_displacement=0.002*10
  app_v=-Load_displacement/(tdel*200000)
end
set_apply_vel

bound yvel app_v range (-8,8) (11.4,11.6)


reset disp
reset hist
cal track-syy.fis
;
hist unbal n=200

hist ydisp 0,7.5
hist P_syy_left
hist P_syy_core
hist P_syy_right
```

hist	syy	-4.86	0
hist	syy	-4.62	0
hist	syy	-4.38	0
hist	syy	-4.14	0
hist	syy	-3.9	0
hist	syy	-3.66	0
hist	syy	-3.42	0
hist	syy	-3.18	0
hist	syy	-2.94	0
hist	syy	-2.7	0
hist	syy	-2.28	0
hist	syy	-1.76	0
hist	syy	-1.24	0
hist	syy	-0.72	0
hist	syy	-0.2	0
hist	syy	0.32	0
hist	syy	0.84	0
hist	syy	1.36	0
hist	syy	1.88	0
hist	syy	2.4	0
hist	syy	2.74	0
hist	syy	2.98	0
hist	syy	3.22	0
hist	syy	3.46	0

```
hist      syy      3.7      0
hist      syy      3.94     0
hist      syy      4.18     0
hist      syy      4.42     0
hist      syy      4.66     0
hist      syy      4.9      0


;run
set ov 0.05
cal deactivation_disp.fis
cal Stiffnessreduction-Xdisp4.fis
;

cyc 60000
sav initialload.sav

cal detail_soften_dopillarV3.dat

;detail_soften_dopillarV3.dat

reset disp
reset hist

rest initialload.sav
```

cal Stiffnessreduction-Xdisp4.fis

cal deactivation_disp.fis

cyc each

stiffness_reduction3

bound yvel 0 range (-8,8) (11.4,11.6)

sav step1_detail_1of2.sav

cyc each

stiffness_reduction3

bound yvel app_v range (-8,8) (11.4,11.6)

sav step1_detail_2of2.sav

_deactivation

sav step1_deletion.sav

cyc each

stiffness_reduction3

bound yvel 0 range (-8,8) (11.4,11.6)

sav step2_detail_1of4.sav

cyc each

stiffness_reduction3

sav step2_detail_2of4.sav

cyc each

stiffness_reduction3

sav step2_detail_3of4.sav

cyc each

stiffness_reduction3

bound yvel app_v range (-8,8) (11.4,11.6)

sav step2_detail_4of4.sav

_deactivation

cyc each

stiffness_reduction3

bound yvel 0 range (-8,8) (11.4,11.6)

sav step3_detail_1of4.sav

cyc each

stiffness_reduction3

sav step3_detail_2of4.sav

cyc each

stiffness_reduction3

sav step3_detail_3of4.sav

cyc each

stiffness_reduction3

bound yvel app_v range (-8,8) (11.4,11.6)

sav step3_detail_4of4.sav

_deactivation

cyc each

stiffness_reduction3

bound yvel 0 range (-8,8) (11.4,11.6)

sav step4_detail_1of4.sav

cyc each

stiffness_reduction3

sav step4_detail_2of4.sav

cyc each

stiffness_reduction3

sav step4_detail_3of4.sav

cyc each

stiffness_reduction3

bound yvel app_v range (-8,8) (11.4,11.6)

sav step4_detail_4of4.sav

_deactivation

cyc each

stiffness_reduction3

bound yvel 0 range (-8,8) (11.4,11.6)

sav step5_detail_1of4.sav

cyc each

stiffness_reduction3

sav step5_detail_2of4.sav

cyc each

stiffness_reduction3

sav step5_detail_3of4.sav

cyc each

stiffness_reduction3

bound yvel app_v range (-8,8) (11.4,11.6)

sav step5_detail_4of4.sav

_deactivation

sav step5_end.sav

;Stiffnessreduction-Xdisp4.dat

prop jmat 11 jkn=98.4e10 jks=19.7e10 jfric=s_fri jcoh=0 jten=0 jrescoh=s_rcoh jrfric=25 jrtens=0 ;disp > 0.002

```
prop jmat 12 jkn=98.4e10 jks=39.4e9 jfric=s_fri jcoh=0 jten=0 jrescoh=s_rcoh jrfric=25
jrtens=0  ;disp > 0.01

prop jmat 13 jkn=98.4e10 jks=19.7e9 jfric=s_fri jcoh=0 jten=0 jrescoh=s_rcoh jrfric=25
jrtens=0  ;disp > 0.025


def stiffness_reduction3
  whilestepping
  ic =contact_head
  loop while ic # 0


    ib1=c_b1(ic)
    if ib1 # 0
      ig=b_gp(ib1)
      x_disp=0
      max_xdisp1=0
      loop while ig # 0
        x_disp =abs(gp_xdis(ig))
        if max_xdisp1 < x_disp then
          max_xdisp1 = x_disp
        endif
        ig=gp_next(ig)
      endloop
    endif



    ib2=c_b2(ic)
    if ib2 # 0
```

```
  ig=b_gp(ib2)
  x_disp=0
  max_xdisp2=0
  loop while ig # 0
    x_disp =abs(gp_xdis(ig))
    if max_xdisp2 < x_disp then
      max_xdisp2 = x_disp
    endif
    ig=gp_next(ig)
  endloop
endif

max_xdisp=max_xdisp1
if max_xdisp < max_xdisp2
  max_xdisp=max_xdisp2
endif

;mn=c_mat(ic)

if max_xdisp > 0.002;
  c_mat(ic) = 11
endif
if max_xdisp > 0.01;
  c_mat(ic) = 12
endif
if max_xdisp > 0.025;
```

```
      c_mat(ic) = 13
    endif
    ic=c_next(ic)
  endloop
end
```

;deactivation_disp.dat

```
;; pillar deactivation function; deactivation by displacement > 0.03m; written by FGao_Golder
prop mat 20 density 2.7 bulk 5.6E7 shear 3.36E7
prop jmat 20 jkn=f_kn jks=f_ks jfric=f_fri jcoh=f_coh jten=f_ten


Def _deactivation

  ib=block_head
  loop while ib # 0
    ig=b_gp(ib)
    x_disp=0
    max_xdisp=0
    loop while ig # 0
      x_disp =abs(gp_xdis(ig))
      if max_xdisp < x_disp then
        max_xdisp = x_disp
      endif
      ig=gp_next(ig)
```

```
    endloop
    ;if max_disp >= disp_value then    ;disp criterion
    if max_xdisp >= disp_value then    ;xdisp criterion
      if b_area(ib) < 5
        b_mat(ib) = 20
      endif
    endif
    ib=b_next(ib)
  endloop

 command
   delete mat 20
 endcommand
end
_deactivation
```

;**track-syy.dat**

```
;set log off
;cal block.fin
def set_point
  ;left 2.4 m

    zone_num_left=0

    zone_num_core=0
```

```
  zone_num_right=0


loop nn(1,10)
  xx=-5.1+0.24*nn
  yy=0
  i_b=b_near(xx,yy)
  if i_b # 0 then
    b_extra(i_b) = 1
    i_zon=b_zone(i_b)
    loop while i_zon # 0
      zone_num_left=zone_num_left+1
      i_zon=z_next(i_zon)
    endloop
  endif
endloop
;core 5.2
loop nn(1,10)
  xx=-2.8+0.52*nn
  yy=0
  i_b=b_near(xx,yy)
  if i_b # 0 then
    b_extra(i_b) = 2
    i_zon=b_zone(i_b)
    loop while i_zon # 0
      zone_num_core=zone_num_core+1
```

```
      i_zon=z_next(i_zon)
    endloop
  endif
 endloop

 ;right 2.4 m
 loop nn(1,10)
  xx=5.1-0.24*nn
  yy=0
  i_b=b_near(xx,yy)
  if i_b # 0 then
    b_extra(i_b) = 3
    i_zon=b_zone(i_b)
    loop while i_zon # 0
      zone_num_right=zone_num_right+1
      i_zon=z_next(i_zon)
    endloop
  endif
 endloop

end
set_point


def track_principal
 whilestepping
```

```
;stepNN=stepNN + 1
;if stepNN= 100 then
  ;stepNN = 0
  syy_sum_left=0

  syy_sum_core=0

  syy_sum_right=0



  i_b = block_head

  loop while i_b # 0
  if b_extra(i_b) = 1 then
    i_zon=b_zone(i_b)
    loop while i_zon # 0
      syy_sum_left = syy_sum_left-z_syy(i_zon)
      i_zon=z_next(i_zon)
    endloop
  endif
  if b_extra(i_b) = 2 then
    i_zon=b_zone(i_b)
    loop while i_zon # 0
      syy_sum_core = syy_sum_core-z_syy(i_zon)
      i_zon=z_next(i_zon)
    endloop
```

```
    endif
    if b_extra(i_b) = 3 then
      i_zon=b_zone(i_b)
      loop while i_zon # 0
        syy_sum_right = syy_sum_right-z_syy(i_zon)
        i_zon=z_next(i_zon)
      endloop
    endif
    i_b = b_next(i_b)
  endloop
  P_syy_left=syy_sum_left/zone_num_left
  P_syy_core=syy_sum_core/zone_num_core
  P_syy_right=syy_sum_right/zone_num_right
  ;endif
end
```