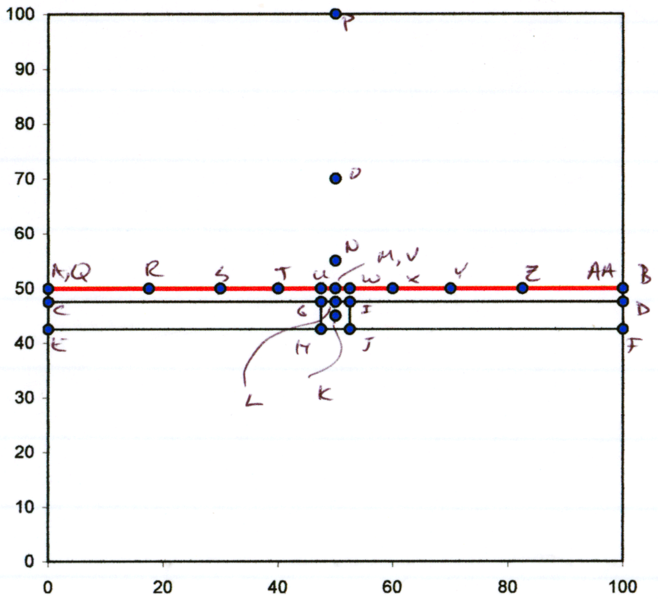
Rotation of Coordinate System

	Original			Rotated	
Point	x	y		x*	y*
A	0.000	50.000	A	0.000	37.534
B	100.000	50.000	B	100.000	62.466
C	0.000	47.500	C	0.000	34.957
D	100.000	47.500	D	100.000	59.890
E	0.000	42.500	E	0.000	29.804
F	100.000	42.500	F	100.000	54.737
G	47.500	47.500	G	48.179	46.969
H	47.500	42.500	H	49.389	42.118
I	52.500	47.500	I	53.031	48.179
J	52.500	42.500	J	54.240	43.328
K	50.000	45.000	K	51.210	45.149
L	50.000	47.500	L	50.605	47.574
M	50.000	50.000	M	50.000	50.000
N	50.000	55.000	N	48.790	54.851
O	50.000	70.000	O	45.162	69.406
P	50.000	100.000	P	37.534	100.000
Q	0.000	50.000	Q	0.000	37.534
R	17.500	50.000	R	18.465	42.138
S	30.000	50.000	S	30.594	45.162
T	40.000	50.000	T	40.297	47.581
U	47.500	50.000	U	47.574	49.395
V	50.000	50.000	V	50.000	50.000
W	52.500	50.000	W	52.426	50.605
X	60.000	50.000	X	59.703	52.419
Y	70.000	50.000	Y	69.406	54.838
Z	82.500	50.000	Z	81.535	57.862
AA	100.000	50.000	AA	100.000	62.466

Line	x	y		x*	y*
A-B	0.000	50.000		0.000	37.534
	100.000	50.000		100.000	62.466
C-D	0.000	47.500		0.000	34.957
	100.000	47.500		100.000	59.890
E-F	0.000	42.500		0.000	29.804
	100.000	42.500		100.000	54.737
G-H	47.500	47.500		48.179	46.969
	47.500	42.500		49.389	42.118
I-J	52.500	47.500		53.031	48.179
	52.500	42.500		54.240	43.328

Rotation angle (°) 14.0



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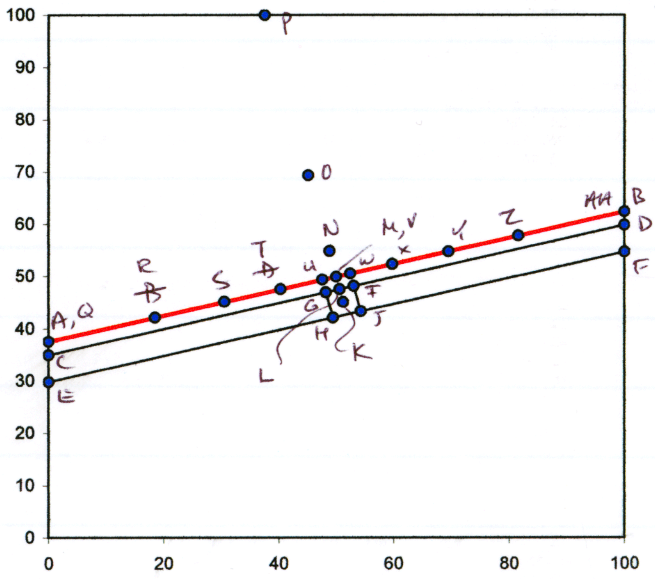

Rotated coordinates calculated using ROTATE.XLS - used for FLAC cases 7.7, 7.8, 7.9, 7.10.

```
; Case 7.8 - FLAC 4.0 input file (Sep 20, 2004; RSR)
;
; Inclined transgressing joint in a heated infinite rock
mass.  Joint
; properties selected to allow slippage.  Heat source 5x5 m
centered
; at x=51.210, y=45.149. Joint angle 14° from horizontal.
Power is
; 1500 W/m (60 w/cu.m. x 25 sq.m).  Typical Yucca Mountain
properties used.
;
config thermal extra 10
call dispmag.fis
;
; Geometry
;
;Points
;
;A, 0.000, 37.534
;B, 100.000, 62.466
;C, 0.000, 34.957
;D, 100.000, 59.890
;E, 0.000, 29.804
;F, 100.000, 54.737
;G, 48.179, 46.969
;H, 49.389, 42.118
;I, 53.031, 48.179
;J, 54.240, 43.328
;K, 51.210, 45.149
;L, 50.605, 47.574
;M, 50.000, 50.000
;N, 48.790, 54.851
;O, 45.162, 69.406
;P, 37.534, 100.000
;Q, 0.000, 37.534
;R, 18.465, 42.138
;S, 30.594, 45.162
;T, 40.297, 47.581
;U, 47.574, 49.395
;V, 50.000, 50.000
;W, 52.426, 50.605
;X, 59.703, 52.419
;Y, 69.406, 54.838
;Z, 81.535, 57.862
;AA, 100.000, 62.466
;
grid 50 29
model elastic th_isotropic
mod null j=16
gen 0.000,34.957 0.000,37.534 100.000,62.466 100.000,59.890
i=1,51 j=14,16 ; C A B D
gen 0.000,29.804 0.000,34.957 48.179,46.969 49.389,42.118
i=1,25 j=10,14 ; E C G H
gen 54.240,43.328 53.031,48.179  100.000,59.890
100.000,54.737 i=27,51 j=10,14 ; J I D F
gen 0.0,37.534 0.0,100.0 100.0,100.0 100.0,62.466 i=1,51
j=17,30 ; Upper block
int 1 aside from 1,16 to 51,16 bside from 1,17 to 51,17
gen 49.389,42.118  48.179,46.969  53.031,48.179
54.240,43.328 i=25,27 j=10,14 ; H G I J
mark i=25,27 j=10,14
gen 0.0,0.0 0.0,29.804 100.0,54.737 100.0,0.0 i=1,51 j=1,10
gen 0.000,29.804 0.000,34.957 48.179,46.969 49.389,42.118
i=1,25 j=10,14 ; E C G H
gen 54.240,43.328 53.031,48.179  100.000,59.890
100.000,54.737 i=27,51 j=10,14 ; J I D F
gen 49.389,42.118  48.179,46.969  53.031,48.179
54.240,43.328 i=25,27 j=10,14 ; H G I J
mark j=10,14
gen adjust
unmark
mark i=25,27 j=10,14
ini x=48.790 y=54.851  i=25 j=19 ; N
ini x=45.162 y=69.406  i=24 j=22 ; O
ini x=37.534 y=100.000 i=20 j=30 ; P
;
; Material properties
;
prop de=2210.0 b=19.2e9 s=13.6e9
prop thexp=10.0e-6 cond=2.13 spec=990.0
int 1 kn=5.0e4 ks=5.0e4
;int 1 c=1.0e20 f=0.0 t=1.0e20 di=0 ; no slip
;
int 1 c=100.0e3 f=41.0 t=40.0e3 di=0 ; slip
;
; Initial conditions
;
ini temp 25.0
ini syy -8.1e6 var 0 2.2e6 i=1,51 j=1,30
ini sxx -2.1546e6 var 0 0.5852e6 i=1,51 j=1,30
ini sxy 0 i=1,51 var 0.0 0.0 j=1,30
ini szz -2.1546e6 var 0 0.5852e6 i=1,51 j=1,30
;
; Boundary conditions
;
;apply yvel 0.0 j=1
;apply yvel 0.0 j=30
;apply xvel 0.0 i=1 j=1,16
;apply xvel 0.0 i=1 j=17,30
;apply xvel 0.0 i=51 j=1,16
;apply xvel 0.0 i=51 j=17,30
;
fix y j=1
fix y j=30
fix x i=1 j=1,16
fix x i=1 j=17,30
fix x i=51 j=1,16
fix x i=51 j=17,30
;
; Apply heat source
;
interior source 60 i=25,26 j=10,13
;
set mech on therm off
step 2000
ini xd 0
ini yd 0
ini xv 0
ini yv 0
;
; Time and force history
;
hist unbalanced ;1
hist thtime ; 2
;
; Thermal histories
;
hist temp i=26 j=12 ;3
hist temp i=26 j=14 ;4
hist temp i=26 j=16 ;5
hist temp i=25 j=19 ;6
hist temp i=24 j=22 ;7
hist temp i=20 j=30 ;8
;
; Mechanical histories
;
hist ydisp i=26 j=12 ;9
hist ydisp i=26 j=14 ;10
hist ydisp i=26 j=16 ;11
hist ydisp i=25 j=19 ;12
hist ydisp i=24 j=22 ;13
hist ydisp i=20 j=30 ;14
;
hist xdisp i=26 j=12 ;15
hist xdisp i=26 j=14 ;16
hist xdisp i=26 j=16 ;17
hist xdisp i=25 j=19 ;18
hist xdisp i=24 j=22 ;19
hist xdisp i=20 j=30 ;20
;
; Thermal mechanical analysis
;
set mech off therm on
set thdt 1e4
solve age 20000000
set mech on therm off
step 2000
set mech off therm on
solve age 40000000
set mech on therm off
step 2000
set mech off therm on
solve age 60000000
set mech on therm off
step 2000
set mech off therm on
solve age 80000000
set mech on therm off
step 2000
set mech off therm on
solve age 100000000
set mech on therm off
step 2000
set mech off therm on
solve age 120000000
set mech on therm off
step 2000
set mech off therm on
solve age 150000000
set mech on therm off
step 2000
set mech off therm on
solve age 200000000
set mech on therm off
step 2000
set mech off therm on
solve age 250000000
set mech on therm off
step 2000
set mech off therm on
```

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FLAC file
f78input.txt
(pg 1 of 2)

```
solve age 315400000
set mech on therm off
step 2000
save
disp_mag
save f78final.sav
;
set plot emf color
title
Case 7.8 Inclined Transgressing Joint (FLAC, Slip Allowed)
;
set out f78grid.emf
plot gri bou iw
copy
;
; Joint condition plots
;
set out f78jnd.emf
plot if 1 ndisp
copy
;
set out f78jsd.emf
plot if 1 sdisp
copy
;
set out f78jss.emf
plot if 1 ss
copy
;
set out f78jns.emf
plot if 1 ns
copy
;
set out f78jrnd.emf
plot if 1 closure
copy
;
set out f78jrsd.emf
plot if 1 ride
copy
;
; Contour plots
;
set out f78temp.emf
plot temp fill temp iw bou iw
copy
;
set out f78disp.emf
plot ex_1 fill alias 'Displacement' ex_1 iw disp iw bou iw
copy
;
set out f78xd.emf
plot xd fill xd iw bou iw
copy
;
set out f78yd.emf
plot yd fill yd iw bou iw
copy
;
set out f78sig1.emf
plot sig1 fill sig1 iw bou iw
copy
;
set out f78sig2.emf
plot sig2 fill sig2 iw bou iw
copy
;
set out f78sdif.emf
plot sdiff fill sdiff iw bou iw
copy
;
set out f78thist.emf
plo hist 3 4 5 6 7 8 vs 2
copy
;
set out f78ydhist.emf
plo hist 9 10 11 12 13 14 vs 2
copy
;
set out f78xdhist.emf
plo hist 15 16 17 18 19 20 vs 2
copy
;
set out f78unbal.emf
plo hist 1
copy
;
set hisfile f78temp.his
his write 3 4 5 6 7 8 vs 2 begin 1 skip 10
;
set hisfile f78yd.his
his write 9 10 11 12 13 14 vs 2 begin 1 skip 10
;
set hisfile f78xd.his
his write 15 16 17 18 19 20 vs 2 begin 1 skip 10
```

```
;
def xxx
  nn=561
end
xxx
def table_fill
  array f78(11,nn)
;
; Bottom of interface
;
  thvalr=thvald*pi/180.0
  pnt=int_pnt
  xnot=x(1,16)
  ynot=y(1,16)
  loop while pnt # 0
    pa = imem(pnt+$kicapt)
    loop while pa # 0
      ival=imem(pa+$kidi)
      jval=imem(pa+$kidj)
      xval=fmem(pa+$kidx)
      yval=fmem(pa+$kidy)
      lval=sqrt(((xval-xnot)*(xval-xnot))+((yval-ynot)*(yval-
ynot)))
      dxvalb=xdisp(ival,16)
      dyvalb=ydisp(ival,16)
      dtvalb=sqrt((dxvalb*dxvalb)+(dyvalb*dyvalb))
      thetav=atan2(dyvalb,dxvalb)
      dsvalb=dtvalb*cos(thetav-thvalr)
      dnvalb=dtvalb*sin(thetav-thvalr)
;
; Top of interface
;
      dxvalt=xdisp(ival,17)
      dyvalt=ydisp(ival,17)
      dtvalt=sqrt((dxvalt*dxvalt)+(dyvalt*dyvalt))
      thetav=atan2(dyvalt,dxvalt)
      dsvalt=dtvalt*cos(thetav-thvalr)
      dnvalt=dtvalt*sin(thetav-thvalr)
;
; Interface
;
      dclos=fmem(pa+$kidand)
      dride=fmem(pa+$kidasd)
      tempvalb=temp(ival,16)
      tempvalt=temp(ival,17)
;
; Create table entries
;
      table(1,ival)=yval
      table(2,ival)=xval
      table(3,ival)=lval
      table(4,ival)=dsvalb
      table(5,ival)=dnvalb
      table(6,ival)=dsvalt
      table(7,ival)=dnvalt
      table(8,ival)=dclos
      table(9,ival)=dride
      table(10,ival)=tempvalb
      table(11,ival)=tempvalt
;
; Array entries
;
      f78(1,ival)=string(yval)
      f78(2,ival)=string(xval)
      f78(3,ival)=string(lval)
      f78(4,ival)=string(dsvalb)
      f78(5,ival)=string(dnvalb)
      f78(6,ival)=string(dsvalt)
      f78(7,ival)=string(dnvalt)
      f78(8,ival)=string(dclos)
      f78(9,ival)=string(dride)
      f78(10,ival)=string(tempvalb)
      f78(11,ival)=string(tempvalt)
      pa=imem(pa)
    endLoop
    pnt=imem(pnt)
  endloop
  status=open('f78data.out',1,1)
  status=write(f78,561)
end
;
set thvald=14.0
;
cal int.fin
table_fill
;
set log f78slip.out
pr if 1
set log f78sr.out
pr sratio j=16,17
ret
```

FLAC file
f78input.txt
(pg 2 of 2)

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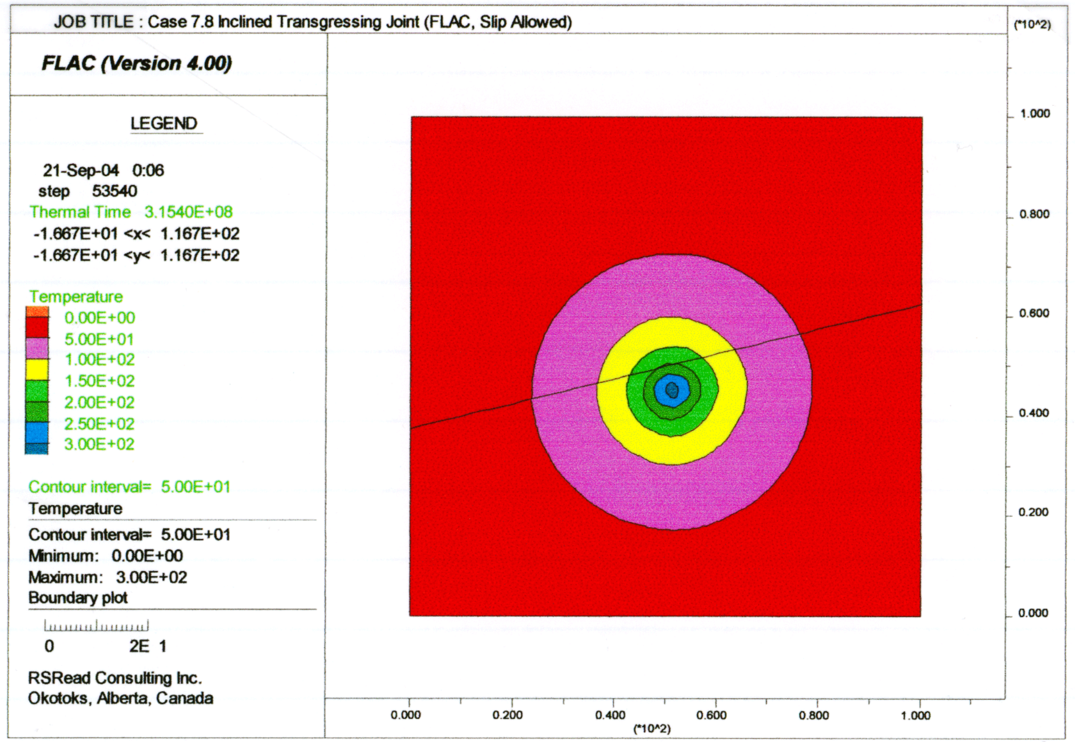

File f78temp.emf Temperature contours for Case 7.8

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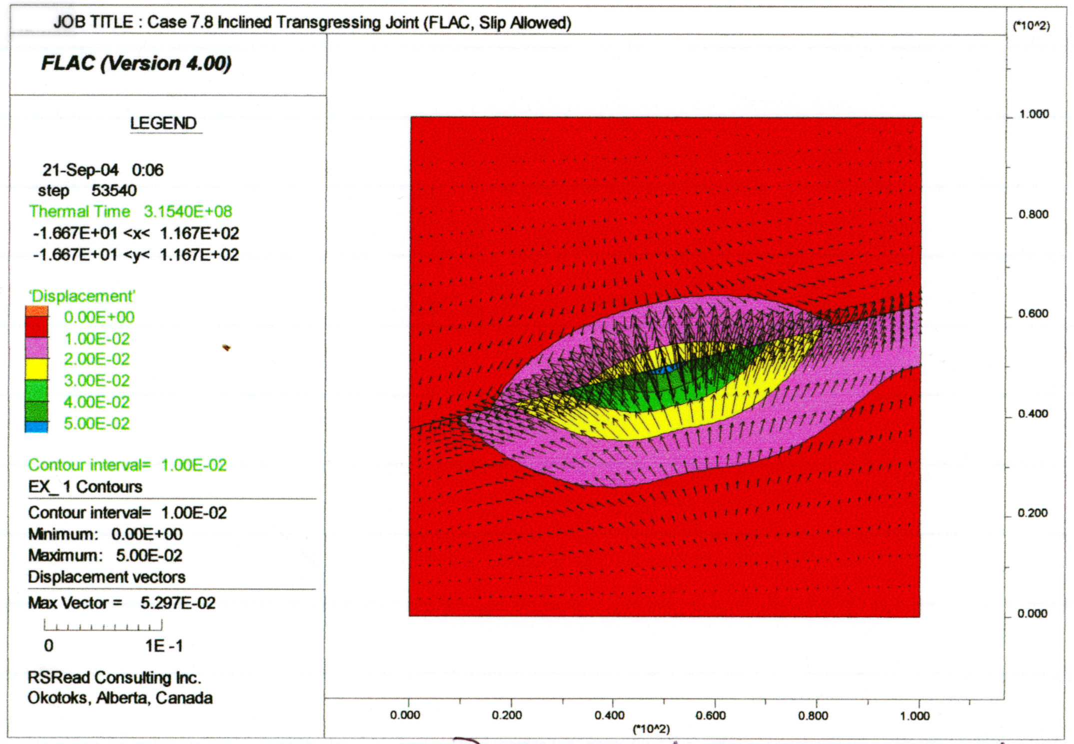

File f78disp.emf Displacement contours and vectors for Case 7.8

Sep 21/04

```
; Case 7.9 - FLAC 4.0 input file (Sep 20, 2004; RSR)
;
; Inclined transgressing joint in a heated infinite rock
mass.  Joint
; properties selected to allow slippage.  Heat source 5x5 m
centered
; at x=51.210, y=45.149. Joint angle 14° from horizontal.
Power is
; 1500 W/m (60 w/cu.m. x 25 sq.m).  Typical Yucca Mountain
properties used.
;
; Friction angle reduced to 20°
;
config thermal extra 10
call dispmag.fis
;
; Geometry
;
;Points
;
;A, 0.000, 37.534
;B, 100.000, 62.466
;C, 0.000, 34.957
;D, 100.000, 59.890
;E, 0.000, 29.804
;F, 100.000, 54.737
;G, 48.179, 46.969
;H, 49.389, 42.118
;I, 53.031, 48.179
;J, 54.240, 43.328
;K, 51.210, 45.149
;L, 50.605, 47.574
;M, 50.000, 50.000
;N, 48.790, 54.851
;O, 45.162, 69.406
;P, 37.534, 100.000
;Q, 0.000, 37.534
;R, 18.465, 42.138
;S, 30.594, 45.162
;T, 40.297, 47.581
;U, 47.574, 49.395
;V, 50.000, 50.000
;W, 52.426, 50.605
;X, 59.703, 52.419
;Y, 69.406, 54.838
;Z, 81.535, 57.862
;AA, 100.000, 62.466
;
grid 50 29
model elastic th_isotropic
mod null j=16
gen 0.000,34.957 0.000,37.534 100.000,62.466 100.000,59.890
i=1,51 j=14,16 ; C A B D
gen 0.000,29.804 0.000,34.957 48.179,46.969 49.389,42.118
i=1,25 j=10,14 ; E C G H
gen 54.240,43.328 53.031,48.179  100.000,59.890
100.000,54.737 i=27,51 j=10,14 ; J I D F
gen 0.0,37.534 0.0,100.0 100.0,100.0 100.0,62.466 i=1,51
j=17,30 ; Upper block
int 1 aside from 1,16 to 51,16 bside from 1,17 to 51,17
gen 49.389,42.118  48.179,46.969  53.031,48.179
54.240,43.328 i=25,27 j=10,14 ; H G I J
mark i=25,27 j=10,14
gen 0.0,0.0 0.0,29.804 100.0,54.737 100.0,0.0 i=1,51 j=1,10
gen 0.000,29.804 0.000,34.957 48.179,46.969 49.389,42.118
i=1,25 j=10,14 ; E C G H
gen 54.240,43.328 53.031,48.179  100.000,59.890
100.000,54.737 i=27,51 j=10,14 ; J I D F
gen 49.389,42.118  48.179,46.969  53.031,48.179
54.240,43.328 i=25,27 j=10,14 ; H G I J
mark j=10,14
gen adjust
unmark
mark i=25,27 j=10,14
ini x=48.790 y=54.851  i=25 j=19 ; N
ini x=45.162 y=69.406  i=24 j=22 ; O
ini x=37.534 y=100.000 i=20 j=30 ; P
;
; Material properties
;
prop de=2210.0 b=19.2e9 s=13.6e9
prop thexp=10.0e-6 cond=2.13 spec=990.0
int 1 kn=5.0e4 ks=5.0e4
;int 1 c=1.0e20 f=0.0 t=1.0e20 di=0 ; no slip
;
int 1 c=100.0e3 f=41.0 t=40.0e3 di=0 ; slip
;
; Initial conditions
;
ini temp 25.0
ini syy -8.1e6 var 0 2.2e6 i=1,51 j=1,30
ini sxx -2.1546e6 var 0 0.5852e6 i=1,51 j=1,30
ini sxy 0 i=1,51 var 0.0 0.0 j=1,30
ini szz -2.1546e6 var 0 0.5852e6 i=1,51 j=1,30
;
```

Error
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```
; Boundary conditions
;
;apply yvel 0.0 j=1
;apply yvel 0.0 j=30
;apply xvel 0.0 i=1 j=1,16
;apply xvel 0.0 i=1 j=17,30
;apply xvel 0.0 i=51 j=1,16
;apply xvel 0.0 i=51 j=17,30
;
fix y j=1
fix y j=30
fix x i=1 j=1,16
fix x i=1 j=17,30
fix x i=51 j=1,16
fix x i=51 j=17,30
;
; Apply heat source
;
interior source 60 i=25,26 j=10,13
;
set mech on therm off
step 2000
ini xd 0
ini yd 0
ini xv 0
ini yv 0
;
; Time and force history
;
hist unbalanced ;1
hist thtime ; 2
;
; Thermal histories
;
hist temp i=26 j=12 ;3
hist temp i=26 j=14 ;4
hist temp i=26 j=16 ;5
hist temp i=25 j=19 ;6
hist temp i=24 j=22 ;7
hist temp i=20 j=30 ;8
;
; Mechanical histories
;
hist ydisp i=26 j=12 ;9
hist ydisp i=26 j=14 ;10
hist ydisp i=26 j=16 ;11
hist ydisp i=25 j=19 ;12
hist ydisp i=24 j=22 ;13
hist ydisp i=20 j=30 ;14
;
hist xdisp i=26 j=12 ;15
hist xdisp i=26 j=14 ;16
hist xdisp i=26 j=16 ;17
hist xdisp i=25 j=19 ;18
hist xdisp i=24 j=22 ;19
hist xdisp i=20 j=30 ;20
;
; Thermal mechanical analysis
;
set mech off therm on
set thdt 1e4
solve age 20000000
set mech on therm off
step 2000
set mech off therm on
solve age 40000000
set mech on therm off
step 2000
set mech off therm on
solve age 60000000
set mech on therm off
step 2000
set mech off therm on
solve age 80000000
set mech on therm off
step 2000
set mech off therm on
solve age 100000000
set mech on therm off
step 2000
set mech off therm on
solve age 120000000
set mech on therm off
step 2000
set mech off therm on
solve age 150000000
set mech on therm off
step 2000
set mech off therm on
solve age 200000000
set mech on therm off
step 2000
set mech off therm on
solve age 250000000
set mech on therm off
```

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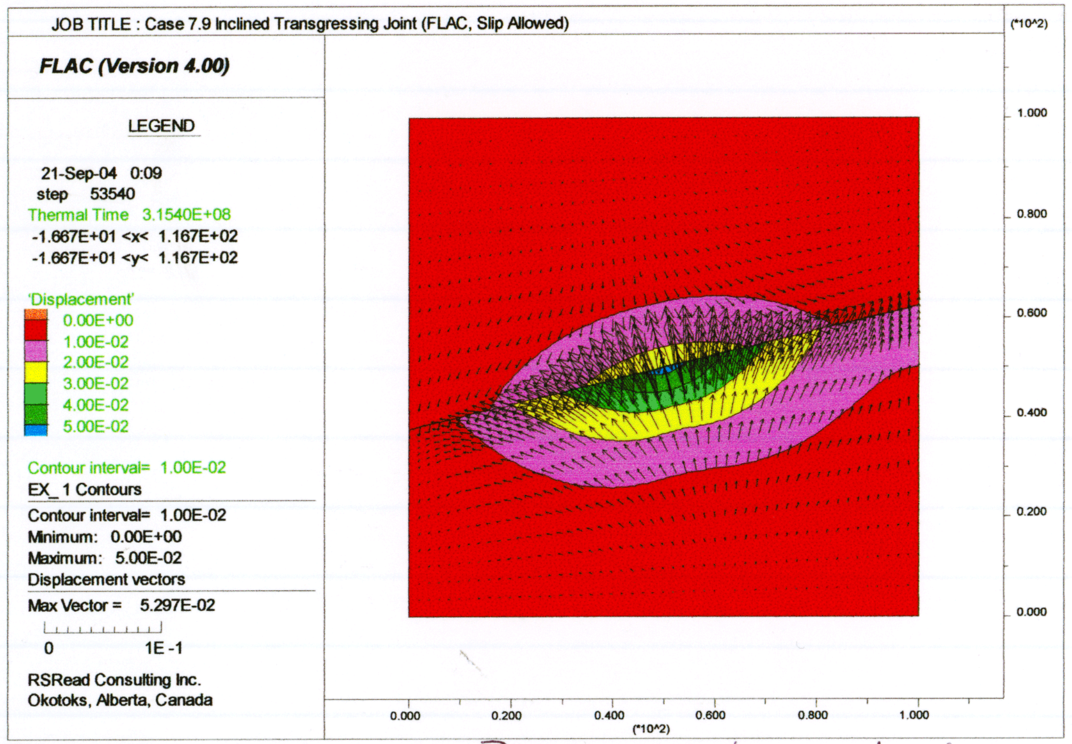
Flac file
f79input.txt
(pg 1 of 2)

```
step 2000
set mech off therm on
solve age 315400000
set mech on therm off
step 2000
save
disp_mag
save f79final.sav
;
set plot emf color
title
Case 7.9 Inclined Transgressing Joint (FLAC, Slip Allowed)
;
set out f79grid.emf
plot gri bou iw
copy
;
; Joint condition plots
;
set out f79jnd.emf
plot if 1 ndisp
copy
;
set out f79jsd.emf
plot if 1 sdisp
copy
;
set out f79jss.emf
plot if 1 ss
copy
;
set out f79jns.emf
plot if 1 ns
copy
;
set out f79jrnd.emf
plot if 1 closure
copy
;
set out f79jrsd.emf
plot if 1 ride
copy
;
; Contour plots
;
set out f79temp.emf
plot temp fill temp iw bou iw
copy
;
set out f79disp.emf
plot ex_1 fill alias 'Displacement' ex_1 iw disp iw bou iw
copy
;
set out f79xd.emf
plot xd fill xd iw bou iw
copy
;
set out f79yd.emf
plot yd fill yd iw bou iw
copy
;
set out f79sig1.emf
plot sig1 fill sig1 iw bou iw
copy
;
set out f79sig2.emf
plot sig2 fill sig2 iw bou iw
copy
;
set out f79sdif.emf
plot sdiff fill sdiff iw bou iw
copy
;
set out f79thist.emf
plo hist 3 4 5 6 7 8 vs 2
copy
;
set out f79ydhist.emf
plo hist 9 10 11 12 13 14 vs 2
copy
;
set out f79xdhist.emf
plo hist 15 16 17 18 19 20 vs 2
copy
;
set out f79unbal.emf
plo hist 1
copy
;
set hisfile f79temp.his
his write 3 4 5 6 7 8 vs 2 begin 1 skip 10
;
set hisfile f79yd.his
his write 9 10 11 12 13 14 vs 2 begin 1 skip 10
;
```

```
set hisfile f79xd.his
his write 15 16 17 18 19 20 vs 2 begin 1 skip 10
;
def xxx
  nn=561
end
xxx
def table_fill
  array f79(11,nn)
;
; Bottom of interface
;
  thvalr=thvald*pi/180.0
  pnt=int_pnt
  xnot=x(1,16)
  ynot=y(1,16)
  loop while pnt # 0
    pa = imem(pnt+$kicapt)
    loop while pa # 0
      ival=imem(pa+$kidi)
      jval=imem(pa+$kidj)
      xval=fmem(pa+$kidx)
      yval=fmem(pa+$kidy)
      lval=sqrt(((xval-xnot)*(xval-xnot))+((yval-ynot)*(yval-
ynot)))
      dxvalb=xdisp(ival,16)
      dyvalb=ydisp(ival,16)
      dtvalb=sqrt((dxvalb*dxvalb)+(dyvalb*dyvalb))
      thetav=atan2(dyvalb,dxvalb)
      dsvalb=dtvalb*cos(thetav-thvalr)
      dnvalb=dtvalb*sin(thetav-thvalr)
;
; Top of interface
;
      dxvalt=xdisp(ival,17)
      dyvalt=ydisp(ival,17)
      dtvalt=sqrt((dxvalt*dxvalt)+(dyvalt*dyvalt))
      thetav=atan2(dyvalt,dxvalt)
      dsvalt=dtvalt*cos(thetav-thvalr)
      dnvalt=dtvalt*sin(thetav-thvalr)
;
; Interface
;
      dclos=fmem(pa+$kidand)
      dride=fmem(pa+$kidasd)
      tempvalb=temp(ival,16)
      tempvalt=temp(ival,17)
;
; Create table entries
;
      table(1,ival)=yval
      table(2,ival)=xval
      table(3,ival)=lval
      table(4,ival)=dsvalb
      table(5,ival)=dnvalb
      table(6,ival)=dsvalt
      table(7,ival)=dnvalt
      table(8,ival)=dclos
      table(9,ival)=dride
      table(10,ival)=tempvalb
      table(11,ival)=tempvalt
;
; Array entries
;
      f79(1,ival)=string(yval)
      f79(2,ival)=string(xval)
      f79(3,ival)=string(lval)
      f79(4,ival)=string(dsvalb)
      f79(5,ival)=string(dnvalb)
      f79(6,ival)=string(dsvalt)
      f79(7,ival)=string(dnvalt)
      f79(8,ival)=string(dclos)
      f79(9,ival)=string(dride)
      f79(10,ival)=string(tempvalb)
      f79(11,ival)=string(tempvalt)
      pa=imem(pa)
    endLoop
    pnt=imem(pnt)
  endloop
  status=open('f79data.out',1,1)
  status=write(f79,561)
end
;
set thvald=14.0
;
cal int.fin
table_fill
;
set log f79slip.out
pr if 1
set log f79sr.out
pr sratio j=16,17
ret
```

Sep 21/04

Flac file
f79 input.txt
(pg 2 of 2)



JOB TITLE : Case 7.9 Inclined Transgressing Joint (FLAC, Slip Allowed)

FLAC (Version 4.00)

LEGEND

21-Sep-04 0:09
step 53540
Thermal Time 3.1540E+08
-1.667E+01 <x< 1.167E+02
-1.667E+01 <y< 1.167E+02

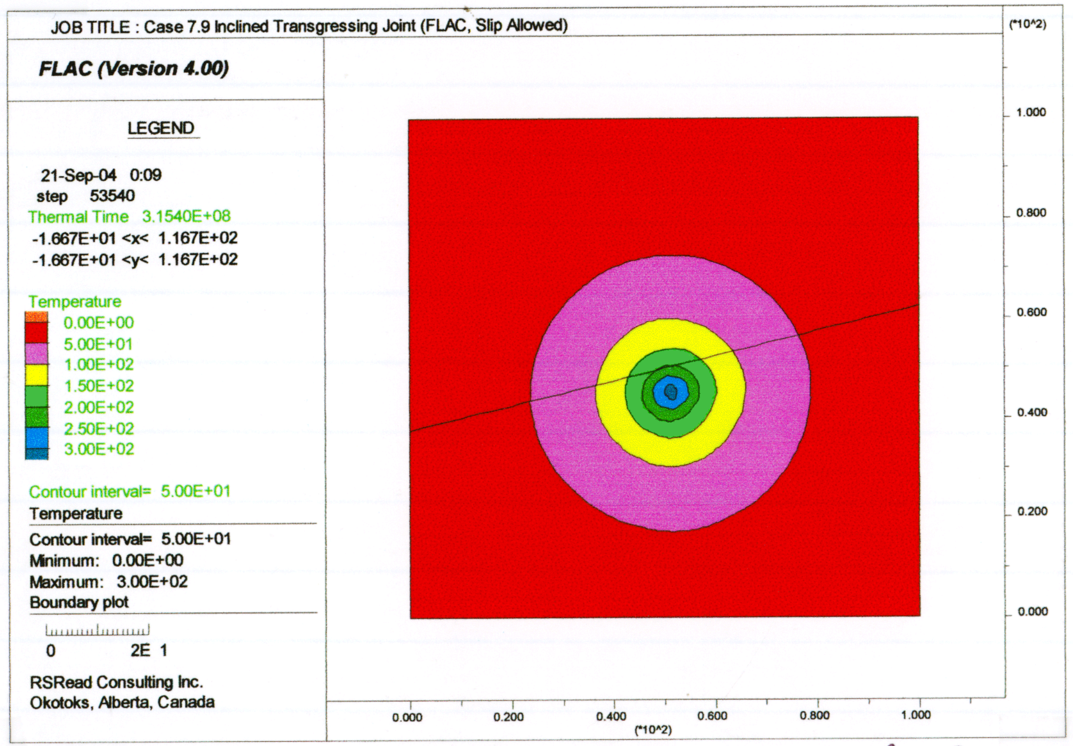
'Displacement'
0.00E+00
1.00E-02
2.00E-02
3.00E-02
4.00E-02
5.00E-02

Contour interval= 1.00E-02
EX_1 Contours
Contour interval= 1.00E-02
Minimum: 0.00E+00
Maximum: 5.00E-02
Displacement vectors
Max Vector = 5.297E-02

RSRead Consulting Inc.
Okotoks, Alberta, Canada

File f79disp.emf Displacement contours and vectors for Case 7.9 (Friction = 41°)

Sep21/04



JOB TITLE : Case 7.9 Inclined Transgressing Joint (FLAC, Slip Allowed)

FLAC (Version 4.00)

LEGEND

21-Sep-04 0:09
step 53540
Thermal Time 3.1540E+08
-1.667E+01 <x< 1.167E+02
-1.667E+01 <y< 1.167E+02

Temperature
0.00E+00
5.00E+01
1.00E+02
1.50E+02
2.00E+02
2.50E+02
3.00E+02

Contour interval= 5.00E+01
Temperature
Contour interval= 5.00E+01
Minimum: 0.00E+00
Maximum: 3.00E+02
Boundary plot

RSRead Consulting Inc.
Okotoks, Alberta, Canada

File f79temp.emf Temperature contours for Case 7.9 - (friction = 41°)

Sep21/04

```
; Case 7.10 - FLAC 4.0 input file (Sep 20, 2004; RSR)
;
; Inclined transgressing joint in a heated infinite rock
mass.  Joint
; properties selected to allow slippage.  Heat source 5x5 m
centered
; at x=51.210, y=45.149. Joint angle 14° from horizontal.
Power is
; 1500 W/m (60 w/cu.m. x 25 sq.m).  Typical Yucca Mountain
properties used.
;
; Friction angle reduced to 20°.  Stresses rotated 90°
;
config thermal extra 10
call dispmag.fis
;
; Geometry
;
;Points
;
;A, 0.000, 37.534
;B, 100.000, 62.466
;C, 0.000, 34.957
;D, 100.000, 59.890
;E, 0.000, 29.804
;F, 100.000, 54.737
;G, 48.179, 46.969
;H, 49.389, 42.118
;I, 53.031, 48.179
;J, 54.240, 43.328
;K, 51.210, 45.149
;L, 50.605, 47.574
;M, 50.000, 50.000
;N, 48.790, 54.851
;O, 45.162, 69.406
;P, 37.534, 100.000
;Q, 0.000, 37.534
;R, 18.465, 42.138
;S, 30.594, 45.162
;T, 40.297, 47.581
;U, 47.574, 49.395
;V, 50.000, 50.000
;W, 52.426, 50.605
;X, 59.703, 52.419
;Y, 69.406, 54.838
;Z, 81.535, 57.862
;AA, 100.000, 62.466
;
grid 50 29
model elastic th_isotropic
mod null j=16
gen 0.000,34.957 0.000,37.534 100.000,62.466 100.000,59.890
i=1,51 j=14,16 ; C A B D
gen 0.000,29.804 0.000,34.957 48.179,46.969 49.389,42.118
i=1,25 j=10,14 ; E C G H
gen 54.240,43.328 53.031,48.179  100.000,59.890
100.000,54.737 i=27,51 j=10,14 ; J I D F
gen 0.0,37.534 0.0,100.0 100.0,100.0 100.0,62.466 i=1,51
j=17,30 ; Upper block
int 1 aside from 1,16 to 51,16 bside from 1,17 to 51,17
gen 49.389,42.118  48.179,46.969  53.031,48.179
54.240,43.328 i=25,27 j=10,14 ; H G I J
mark i=25,27 j=10,14
gen 0.0,0.0 0.0,29.804 100.0,54.737 100.0,0.0 i=1,51 j=1,10
gen 0.000,29.804 0.000,34.957 48.179,46.969 49.389,42.118
i=1,25 j=10,14 ; E C G H
gen 54.240,43.328 53.031,48.179  100.000,59.890
100.000,54.737 i=27,51 j=10,14 ; J I D F
gen 49.389,42.118  48.179,46.969  53.031,48.179
54.240,43.328 i=25,27 j=10,14 ; H G I J
mark j=10,14
gen adjust
unmark
mark i=25,27 j=10,14
ini x=48.790 y=54.851  i=25 j=19 ; N
ini x=45.162 y=69.406  i=24 j=22 ; O
ini x=37.534 y=100.000 i=20 j=30 ; P
;
; Material properties
;
prop de=2210.0 b=19.2e9 s=13.6e9
prop thexp=10.0e-6 cond=2.13 spec=990.0
int 1 kn=5.0e4 ks=5.0e4
;int 1 c=1.0e20 f=0.0 t=1.0e20 di=0 ; no slip
;
int 1 c=100.0e3 f=41.0 t=40.0e3 di=0 ; slip
;
; Initial conditions
;
ini temp 25.0
ini sxx -8.1e6 var 2.2e6 0 i=1,51 j=1,30
ini syy -2.1546e6 var 0.5852e6 0 i=1,51 j=1,30
ini sxy 0 i=1,51 var 0.0 0.0 j=1,30
ini szz -2.1546e6 var 0.5852e6 0 i=1,51 j=1,30
;
```

Error Sep 21/04.

```
; Boundary conditions
;
;apply yvel 0.0 j=1
;apply yvel 0.0 j=30
;apply xvel 0.0 i=1 j=1,16
;apply xvel 0.0 i=1 j=17,30
;apply xvel 0.0 i=51 j=1,16
;apply xvel 0.0 i=51 j=17,30
;
fix y j=1
fix y j=30
fix x i=1 j=1,16
fix x i=1 j=17,30
fix x i=51 j=1,16
fix x i=51 j=17,30
;
; Apply heat source
;
interior source 60 i=25,26 j=10,13
;
set mech on therm off
step 2000
ini xd 0
ini yd 0
ini xv 0
ini yv 0
;
; Time and force history
;
hist unbalanced ;1
hist thtime ; 2
;
; Thermal histories
;
hist temp i=26 j=12 ;3
hist temp i=26 j=14 ;4
hist temp i=26 j=16 ;5
hist temp i=25 j=19 ;6
hist temp i=24 j=22 ;7
hist temp i=20 j=30 ;8
;
; Mechanical histories
;
hist ydisp i=26 j=12 ;9
hist ydisp i=26 j=14 ;10
hist ydisp i=26 j=16 ;11
hist ydisp i=25 j=19 ;12
hist ydisp i=24 j=22 ;13
hist ydisp i=20 j=30 ;14
;
hist xdisp i=26 j=12 ;15
hist xdisp i=26 j=14 ;16
hist xdisp i=26 j=16 ;17
hist xdisp i=25 j=19 ;18
hist xdisp i=24 j=22 ;19
hist xdisp i=20 j=30 ;20
;
; Thermal mechanical analysis
;
set mech off therm on
set thdt 1e4
solve age 20000000
set mech on therm off
step 2000
set mech off therm on
solve age 40000000
set mech on therm off
step 2000
set mech off therm on
solve age 60000000
set mech on therm off
step 2000
set mech off therm on
solve age 80000000
set mech on therm off
step 2000
set mech off therm on
solve age 100000000
set mech on therm off
step 2000
set mech off therm on
solve age 120000000
set mech on therm off
step 2000
set mech off therm on
solve age 150000000
set mech on therm off
step 2000
set mech off therm on
solve age 200000000
set mech on therm off
step 2000
set mech off therm on
solve age 250000000
set mech on therm off
```

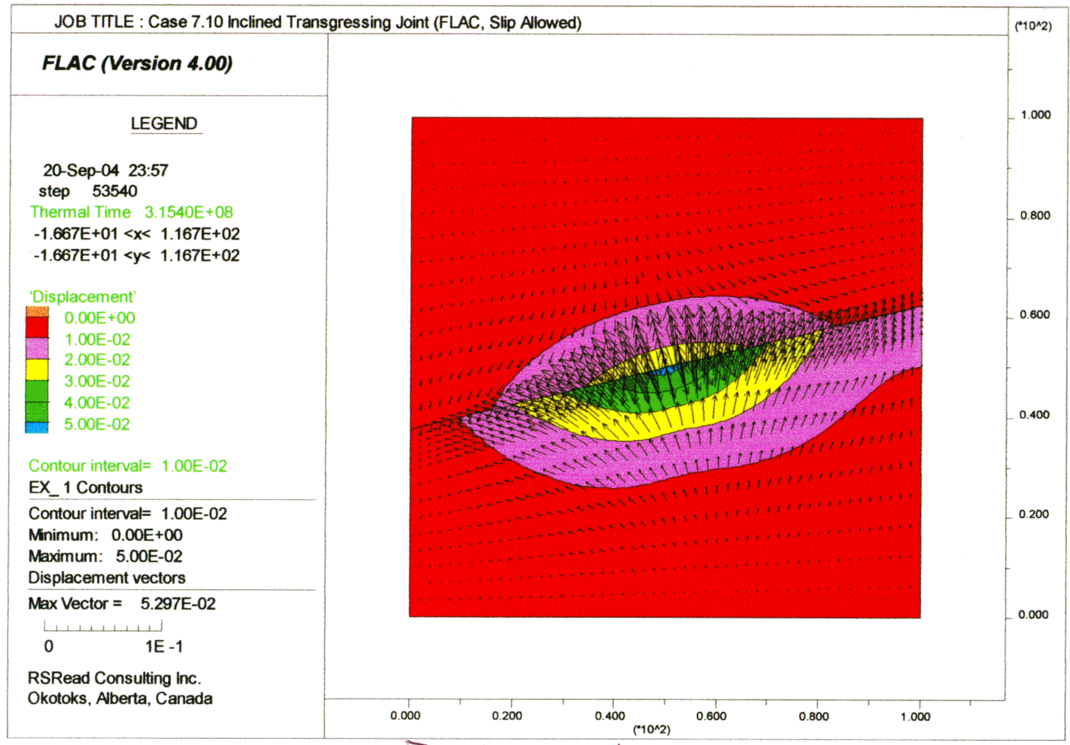
Sep21/04

FLAC file
f710input.txt
(pg 1 of 2)

```
step 2000
set mech off therm on
solve age 315400000
set mech on therm off
step 2000
save
disp_mag
save f710final.sav
;
set plot emf color
title
Case 7.10 Inclined Transgressing Joint (FLAC, Slip Allowed)
;
set out f710grid.emf
plot gri bou iw
copy
;
; Joint condition plots
;
set out f710jnd.emf
plot if 1 ndisp
copy
;
set out f710jsd.emf
plot if 1 sdisp
copy
;
set out f710jss.emf
plot if 1 ss
copy
;
set out f710jns.emf
plot if 1 ns
copy
;
set out f710jrnd.emf
plot if 1 closure
copy
;
set out f710jrsd.emf
plot if 1 ride
copy
;
; Contour plots
;
set out f710temp.emf
plot temp fill temp iw bou iw
copy
;
set out f710disp.emf
plot ex_1 fill alias 'Displacement' ex_1 iw disp iw bou iw
copy
;
set out f710xd.emf
plot xd fill xd iw bou iw
copy
;
set out f710yd.emf
plot yd fill yd iw bou iw
copy
;
set out f710sig1.emf
plot sig1 fill sig1 iw bou iw
copy
;
set out f710sig2.emf
plot sig2 fill sig2 iw bou iw
copy
;
set out f710sdif.emf
plot sdiff fill sdiff iw bou iw
copy
;
set out f710thist.emf
plo hist 3 4 5 6 7 8 vs 2
copy
;
set out f710ydhist.emf
plo hist 9 10 11 12 13 14 vs 2
copy
;
set out f710xdhist.emf
plo hist 15 16 17 18 19 20 vs 2
copy
;
set out f710unbal.emf
plo hist 1
copy
;
set hisfile f710temp.his
his write 3 4 5 6 7 8 vs 2 begin 1 skip 10
;
set hisfile f710yd.his
his write 9 10 11 12 13 14 vs 2 begin 1 skip 10
;
set hisfile f710xd.his
his write 15 16 17 18 19 20 vs 2 begin 1 skip 10
;
def xxx
  nn=561
end
xxx
def table_fill
  array f710(11,nn)
;
; Bottom of interface
;
  thvalr=thvald*pi/180.0
  pnt=int_pnt
  xnot=x(1,16)
  ynot=y(1,16)
  loop while pnt # 0
    pa = imem(pnt+$kicapt)
    loop while pa # 0
      ival=imem(pa+$kidi)
      jval=imem(pa+$kidj)
      xval=fmem(pa+$kidx)
      yval=fmem(pa+$kidy)
      lval=sqrt(((xval-xnot)*(xval-xnot))+((yval-ynot)*(yval-
ynot)))
      dxvalb=xdisp(ival,16)
      dyvalb=ydisp(ival,16)
      dtvalb=sqrt((dxvalb*dxvalb)+(dyvalb*dyvalb))
      thetav=atan2(dyvalb,dxvalb)
      dsvalb=dtvalb*cos(thetav-thvalr)
      dnvalb=dtvalb*sin(thetav-thvalr)
;
; Top of interface
;
      dxvalt=xdisp(ival,17)
      dyvalt=ydisp(ival,17)
      dtvalt=sqrt((dxvalt*dxvalt)+(dyvalt*dyvalt))
      thetav=atan2(dyvalt,dxvalt)
      dsvalt=dtvalt*cos(thetav-thvalr)
      dnvalt=dtvalt*sin(thetav-thvalr)
;
; Interface
;
      dclos=fmem(pa+$kidand)
      dride=fmem(pa+$kidasd)
      tempvalb=temp(ival,16)
      tempvalt=temp(ival,17)
;
; Create table entries
;
      table(1,ival)=yval
      table(2,ival)=xval
      table(3,ival)=lval
      table(4,ival)=dsvalb
      table(5,ival)=dnvalb
      table(6,ival)=dsvalt
      table(7,ival)=dnvalt
      table(8,ival)=dclos
      table(9,ival)=dride
      table(10,ival)=tempvalb
      table(11,ival)=tempvalt
;
; Array entries
;
      f710(1,ival)=string(yval)
      f710(2,ival)=string(xval)
      f710(3,ival)=string(lval)
      f710(4,ival)=string(dsvalb)
      f710(5,ival)=string(dnvalb)
      f710(6,ival)=string(dsvalt)
      f710(7,ival)=string(dnvalt)
      f710(8,ival)=string(dclos)
      f710(9,ival)=string(dride)
      f710(10,ival)=string(tempvalb)
      f710(11,ival)=string(tempvalt)
      pa=imem(pa)
    endLoop
    pnt=imem(pnt)
  endloop
  status=open('f710data.out',1,1)
  status=write(f710,561)
end
;
set thvald=14.0
;
cal int.fin
table_fill
;
set log f710slip.out
pr if 1
set log f710sr.out
pr sratio j=16,17
ret
```

FLAC file
f710 input.txt
(pg 2of2)

R
Sep21/04



File f710input.txt Displacement contours and vectors for case 7.10
(Friction = 41°)

R
Sep 21/04.

Noted that input files for Cases 7.9 and 7.10 contained wrong friction angle (41°) instead of lowered value (20°).

FLAC Cases 7.9 and 7.10 re-run with friction angle = 20° on joint. No change in slip condition.

Case 7.11 run with friction angle of 10° → no slip using same boundary conditions as Case 7.10.

Rate of change in mechanical loading may differ from UDEC as different time stepping / calculation scheme used. Plots stored in f79plots.xls, f710plots.xls and ~~Plots~~ f711plots.xls. under /Case 7/FLAC/.

R Sep21/04

Generate output from UDEC to match that from FLAC.

Will require re-running UDEC cases using JM5.

Reviewing plots, joint stiffness too low in Cases 7.8, 7.9 and 7.10, 7.11. Increase by 1e6 for Cases 7.12 and 7.13. Case 7.12 is for an inclined joint of Yucca Mtn properties, oriented @ 14° from horizontal. Normal and shear stiffness = $5e^{10}$ Pa/m

Summary of FLAC Cases.

Case 7.1	Horizontal joint, zero initial stress, no slip
7.2	Same as above with slightly reduced joint stiffness and weak joint properties ($c = 100$ kPa, $\phi = 20°$, $\sigma_T = 1$ MPa)
7.3	Same as Case 7.1 but with inclined joint ($\theta = 26.56°$), reduced stiffness
7.4.	Inclined joint ($\theta = 26.56°$), stiffness high, joint properties as per 7.2.
7.5	Not run due to small source power.
7.6	Not run due to small source power
7.7	Inclined joint ($\theta = 14°$), high stiffness ($5e^{11}$ Pa/m), no slip, source 1.5 kw/m, typical Yucca Mtn Properties used.
7.8	Inclined joint ($\theta = 14°$), low stiffness ($5e^{4}$ Pa/m), Yucca Mtn properties for blocks and joints ($c = 100e^{3}$ Pa, $\sigma_T = 40e^{3}$ Pa, $\phi = 41°$), in situ stresses
7.9	As for 7.8 but with friction angle reduced ($\phi = 20°$)
7.10	As for 7.9 but with stresses rotated 90° to simulate subvertical joint.
7.11	As for 7.10 but with $\phi = 10°$
7.12	As for 7.10 but with joint stiffness high ($5e^{10}$ Pa/m)
7.13	As for ~~7.8~~ 7.9 but with joint stiffness high ($5e^{10}$ Pa/m)

RSR Sep 21/04

```
; Case 7.11 - FLAC 4.0 input file (Sep 21, 2004; RSR)
;
; Inclined transgressing joint in a heated infinite rock
mass.  Joint
; properties selected to allow slippage.  Heat source 5x5 m
centered
; at x=51.210, y=45.149. Joint angle 14° from horizontal.
Power is
; 1500 W/m (60 w/cu.m. x 25 sq.m).  Typical Yucca Mountain
properties used.
;
; Friction angle reduced to 10°.  Stresses rotated 90°
;
config thermal extra 10
call dispmag.fis
;
; Geometry
;
;Points
;
;A, 0.000, 37.534
;B, 100.000, 62.466
;C, 0.000, 34.957
;D, 100.000, 59.890
;E, 0.000, 29.804
;F, 100.000, 54.737
;G, 48.179, 46.969
;H, 49.389, 42.118
;I, 53.031, 48.179
;J, 54.240, 43.328
;K, 51.210, 45.149
;L, 50.605, 47.574
;M, 50.000, 50.000
;N, 48.790, 54.851
;O, 45.162, 69.406
;P, 37.534, 100.000
;Q, 0.000, 37.534
;R, 18.465, 42.138
;S, 30.594, 45.162
;T, 40.297, 47.581
;U, 47.574, 49.395
;V, 50.000, 50.000
;W, 52.426, 50.605
;X, 59.703, 52.419
;Y, 69.406, 54.838
;Z, 81.535, 57.862
;AA, 100.000, 62.466
;
grid 50 29
model elastic th_isotropic
mod null j=16
gen 0.000,34.957 0.000,37.534 100.000,62.466 100.000,59.890
i=1,51 j=14,16 ; C A B D
gen 0.000,29.804 0.000,34.957 48.179,46.969 49.389,42.118
i=1,25 j=10,14 ; E C G H
gen 54.240,43.328 53.031,48.179  100.000,59.890
100.000,54.737 i=27,51 j=10,14 ; J I D F
gen 0.0,37.534 0.0,100.0 100.0,100.0 100.0,62.466 i=1,51
j=17,30 ; Upper block
int 1 aside from 1,16 to 51,16 bside from 1,17 to 51,17
gen 49.389,42.118  48.179,46.969  53.031,48.179
54.240,43.328 i=25,27 j=10,14 ; H G I J
mark i=25,27 j=10,14
gen 0.0,0.0 0.0,29.804 100.0,54.737 100.0,0.0 i=1,51 j=1,10
gen 0.000,29.804 0.000,34.957 48.179,46.969 49.389,42.118
i=1,25 j=10,14 ; E C G H
gen 54.240,43.328 53.031,48.179  100.000,59.890
100.000,54.737 i=27,51 j=10,14 ; J I D F
gen 49.389,42.118  48.179,46.969  53.031,48.179
54.240,43.328 i=25,27 j=10,14 ; H G I J
mark j=10,14
gen adjust
unmark
mark i=25,27 j=10,14
ini x=48.790 y=54.851  i=25 j=19 ; N
ini x=45.162 y=69.406  i=24 j=22 ; O
ini x=37.534 y=100.000 i=20 j=30 ; P
;
; Material properties
;
prop de=2210.0 b=19.2e9 s=13.6e9
prop thexp=10.0e-6 cond=2.13 spec=990.0
int 1 kn=5.0e4 ks=5.0e4
;int 1 c=1.0e20 f=0.0 t=1.0e20 di=0 ; no slip
;
int 1 c=100.0e3 f=10.0 t=40.0e3 di=0 ; slip
;
; Initial conditions
;
ini temp 25.0
ini sxx -8.1e6 var 2.2e6 0 i=1,51 j=1,30
ini syy -2.1546e6 var 0.5852e6 0 i=1,51 j=1,30
ini sxy 0 i=1,51 var 0.0 0.0 j=1,30
ini szz -2.1546e6 var 0.5852e6 0 i=1,51 j=1,30
;
; Boundary conditions
;
;apply yvel 0.0 j=1
;apply yvel 0.0 j=30
;apply xvel 0.0 i=1 j=1,16
;apply xvel 0.0 i=1 j=17,30
;apply xvel 0.0 i=51 j=1,16
;apply xvel 0.0 i=51 j=17,30
;
fix y j=1
fix y j=30
fix x i=1 j=1,16
fix x i=1 j=17,30
fix x i=51 j=1,16
fix x i=51 j=17,30
;
; Apply heat source
;
interior source 60 i=25,26 j=10,13
;
set mech on therm off
step 2000
ini xd 0
ini yd 0
ini xv 0
ini yv 0
;
; Time and force history
;
hist unbalanced ;1
hist thtime ; 2
;
; Thermal histories
;
hist temp i=26 j=12 ;3
hist temp i=26 j=14 ;4
hist temp i=26 j=16 ;5
hist temp i=25 j=19 ;6
hist temp i=24 j=22 ;7
hist temp i=20 j=30 ;8
;
; Mechanical histories
;
hist ydisp i=26 j=12 ;9
hist ydisp i=26 j=14 ;10
hist ydisp i=26 j=16 ;11
hist ydisp i=25 j=19 ;12
hist ydisp i=24 j=22 ;13
hist ydisp i=20 j=30 ;14
;
hist xdisp i=26 j=12 ;15
hist xdisp i=26 j=14 ;16
hist xdisp i=26 j=16 ;17
hist xdisp i=25 j=19 ;18
hist xdisp i=24 j=22 ;19
hist xdisp i=20 j=30 ;20
;
; Thermal mechanical analysis
;
set mech off therm on
set thdt 1e4
solve age 20000000
set mech on therm off
step 2000
set mech off therm on
solve age 40000000
set mech on therm off
step 2000
set mech off therm on
solve age 60000000
set mech on therm off
step 2000
set mech off therm on
solve age 80000000
set mech on therm off
step 2000
set mech off therm on
solve age 100000000
set mech on therm off
step 2000
set mech off therm on
solve age 120000000
set mech on therm off
step 2000
set mech off therm on
solve age 150000000
set mech on therm off
step 2000
set mech off therm on
solve age 200000000
set mech on therm off
step 2000
set mech off therm on
solve age 250000000
set mech on therm off
```

R Sep 21/04

Flac file
f711input.txt
(pg 1 of 2)

```
step 2000
set mech off therm on
solve age 315400000
set mech on therm off
step 2000
save
disp_mag
save f711final.sav
;
set plot emf color
title
Case 7.11 Inclined Transgressing Joint (FLAC, Slip Allowed)
;
set out f711grid.emf
plot gri bou iw
copy
;
; Joint condition plots
;
set out f711jnd.emf
plot if 1 ndisp
copy
;
set out f711jsd.emf
plot if 1 sdisp
copy
;
set out f711jss.emf
plot if 1 ss
copy
;
set out f711jns.emf
plot if 1 ns
copy
;
set out f711jrnd.emf
plot if 1 closure
copy
;
set out f711jrsd.emf
plot if 1 ride
copy
;
; Contour plots
;
set out f711temp.emf
plot temp fill temp iw bou iw
copy
;
set out f711disp.emf
plot ex_1 fill alias 'Displacement' ex_1 iw disp iw bou iw
copy
;
set out f711xd.emf
plot xd fill xd iw bou iw
copy
;
set out f711yd.emf
plot yd fill yd iw bou iw
copy
;
set out f711sig1.emf
plot sig1 fill sig1 iw bou iw
copy
;
set out f711sig2.emf
plot sig2 fill sig2 iw bou iw
copy
;
set out f711sdif.emf
plot sdiff fill sdiff iw bou iw
copy
;
set out f711thist.emf
plo hist 3 4 5 6 7 8 vs 2
copy
;
set out f711ydhist.emf
plo hist 9 10 11 12 13 14 vs 2
copy
;
set out f711xdhist.emf
plo hist 15 16 17 18 19 20 vs 2
copy
;
set out f711unbal.emf
plo hist 1
copy
;
set hisfile f711temp.his
his write 3 4 5 6 7 8 vs 2 begin 1 skip 10
;
set hisfile f711yd.his
his write 9 10 11 12 13 14 vs 2 begin 1 skip 10
;
```

```
set hisfile f711xd.his
his write 15 16 17 18 19 20 vs 2 begin 1 skip 10
;
def xxx
  nn=561
end
xxx
def table_fill
  array f711(11,nn)
;
; Bottom of interface
;
  thvalr=thvald*pi/180.0
  pnt=int_pnt
  xnot=x(1,16)
  ynot=y(1,16)
  loop while pnt # 0
    pa = imem(pnt+$kicapt)
    loop while pa # 0
      ival=imem(pa+$kidi)
      jval=imem(pa+$kidj)
      xval=fmem(pa+$kidx)
      yval=fmem(pa+$kidy)
      lval=sqrt(((xval-xnot)*(xval-xnot))+((yval-ynot)*(yval-
ynot)))
      dxvalb=xdisp(ival,16)
      dyvalb=ydisp(ival,16)
      dtvalb=sqrt((dxvalb*dxvalb)+(dyvalb*dyvalb))
      thetav=atan2(dyvalb,dxvalb)
      dsvalb=dtvalb*cos(thetav-thvalr)
      dnvalb=dtvalb*sin(thetav-thvalr)
;
; Top of interface
;
      dxvalt=xdisp(ival,17)
      dyvalt=ydisp(ival,17)
      dtvalt=sqrt((dxvalt*dxvalt)+(dyvalt*dyvalt))
      thetav=atan2(dyvalt,dxvalt)
      dsvalt=dtvalt*cos(thetav-thvalr)
      dnvalt=dtvalt*sin(thetav-thvalr)
;
; Interface
;
      dclos=fmem(pa+$kidand)
      dride=fmem(pa+$kidasd)
      tempvalb=temp(ival,16)
      tempvalt=temp(ival,17)
;
; Create table entries
;
      table(1,ival)=yval
      table(2,ival)=xval
      table(3,ival)=lval
      table(4,ival)=dsvalb
      table(5,ival)=dnvalb
      table(6,ival)=dsvalt
      table(7,ival)=dnvalt
      table(8,ival)=dclos
      table(9,ival)=dride
      table(10,ival)=tempvalb
      table(11,ival)=tempvalt
;
; Array entries
;
      f711(1,ival)=string(yval)
      f711(2,ival)=string(xval)
      f711(3,ival)=string(lval)
      f711(4,ival)=string(dsvalb)
      f711(5,ival)=string(dnvalb)
      f711(6,ival)=string(dsvalt)
      f711(7,ival)=string(dnvalt)
      f711(8,ival)=string(dclos)
      f711(9,ival)=string(dride)
      f711(10,ival)=string(tempvalb)
      f711(11,ival)=string(tempvalt)
      pa=imem(pa)
    endLoop
    pnt=imem(pnt)
  endloop
  status=open('f711data.out',1,1)
  status=write(f711,561)
end
;
set thvald=14.0
;
cal int.fin
table_fill
;
set log f711slip.out
pr if 1
set log f711sr.out
pr sratio j=16,17
ret
```

Sep21/02

FLAC file
f711input.txt
(pg 2 of 2)

```
; Case 7.12 - FLAC 4.0 input file (Sep 21, 2004; RSR)
;
; Inclined transgressing joint in a heated infinite rock
mass.  Joint
; properties selected to allow slippage.  Heat source 5x5 m
centered
; at x=51.210, y=45.149. Joint angle 14° from horizontal.
Power is
; 1500 W/m (60 w/cu.m. x 25 sq.m).  Typical Yucca Mountain
properties used.
;
; Friction angle reduced to 20°.  Stresses rotated 90°.
; Increase joint stiffness by 1e6.
;
config thermal extra 10
call dispmag.fis
;
; Geometry
;
;Points
;
;A, 0.000, 37.534
;B, 100.000, 62.466
;C, 0.000, 34.957
;D, 100.000, 59.890
;E, 0.000, 29.804
;F, 100.000, 54.737
;G, 48.179, 46.969
;H, 49.389, 42.118
;I, 53.031, 48.179
;J, 54.240, 43.328
;K, 51.210, 45.149
;L, 50.605, 47.574
;M, 50.000, 50.000
;N, 48.790, 54.851
;O, 45.162, 69.406
;P, 37.534, 100.000
;Q, 0.000, 37.534
;R, 18.465, 42.138
;S, 30.594, 45.162
;T, 40.297, 47.581
;U, 47.574, 49.395
;V, 50.000, 50.000
;W, 52.426, 50.605
;X, 59.703, 52.419
;Y, 69.406, 54.838
;Z, 81.535, 57.862
;AA, 100.000, 62.466
;
grid 50 29
model elastic th_isotropic
mod null j=16
gen 0.000,34.957 0.000,37.534 100.000,62.466 100.000,59.890
i=1,51 j=14,16 ; C A B D
gen 0.000,29.804 0.000,34.957 48.179,46.969 49.389,42.118
i=1,25 j=10,14 ; E C G H
gen 54.240,43.328 53.031,48.179  100.000,59.890
100.000,54.737 i=27,51 j=10,14 ; J I D F
gen 0.0,37.534 0.0,100.0 100.0,100.0 100.0,62.466 i=1,51
j=17,30 ; Upper block
int 1 aside from 1,16 to 51,16 bside from 1,17 to 51,17
gen 49.389,42.118  48.179,46.969  53.031,48.179
54.240,43.328 i=25,27 j=10,14 ; H G I J
mark i=25,27 j=10,14
gen 0.0,0.0 0.0,29.804 100.0,54.737 100.0,0.0 i=1,51 j=1,10
gen 0.000,29.804 0.000,34.957 48.179,46.969 49.389,42.118
i=1,25 j=10,14 ; E C G H
gen 54.240,43.328 53.031,48.179  100.000,59.890
100.000,54.737 i=27,51 j=10,14 ; J I D F
gen 49.389,42.118  48.179,46.969  53.031,48.179
54.240,43.328 i=25,27 j=10,14 ; H G I J
mark j=10,14
gen adjust
unmark
mark i=25,27 j=10,14
ini x=48.790 y=54.851  i=25 j=19 ; N
ini x=45.162 y=69.406  i=24 j=22 ; O
ini x=37.534 y=100.000 i=20 j=30 ; P
;
; Material properties
;
prop de=2210.0 b=19.2e9 s=13.6e9
prop thexp=10.0e-6 cond=2.13 spec=990.0
int 1 kn=5.0e10 ks=5.0e10
;int 1 c=1.0e20 f=0.0 t=1.0e20 di=0 ; no slip
;
int 1 c=100.0e3 f=20.0 t=40.0e3 di=0 ; slip
;
; Initial conditions
;
ini temp 25.0
ini sxx -8.1e6 var 2.2e6 0 i=1,51 j=1,30
ini syy -2.1546e6 var 0.5852e6 0 i=1,51 j=1,30
ini sxy 0 i=1,51 var 0.0 0.0 j=1,30
ini szz -2.1546e6 var 0.5852e6 0 i=1,51 j=1,30
```

```
;
; Boundary conditions
;
;apply yvel 0.0 j=1
;apply yvel 0.0 j=30
;apply xvel 0.0 i=1 j=1,16
;apply xvel 0.0 i=1 j=17,30
;apply xvel 0.0 i=51 j=1,16
;apply xvel 0.0 i=51 j=17,30
;
fix y j=1
fix y j=30
fix x i=1 j=1,16
fix x i=1 j=17,30
fix x i=51 j=1,16
fix x i=51 j=17,30
;
; Apply heat source
;
interior source 60 i=25,26 j=10,13
;
set mech on therm off
step 2000
ini xd 0
ini yd 0
ini xv 0
ini yv 0
;
; Time and force history
;
hist unbalanced ;1
hist thtime ; 2
;
; Thermal histories
;
hist temp i=26 j=12 ;3
hist temp i=26 j=14 ;4
hist temp i=26 j=16 ;5
hist temp i=25 j=19 ;6
hist temp i=24 j=22 ;7
hist temp i=20 j=30 ;8
;
; Mechanical histories
;
hist ydisp i=26 j=12 ;9
hist ydisp i=26 j=14 ;10
hist ydisp i=26 j=16 ;11
hist ydisp i=25 j=19 ;12
hist ydisp i=24 j=22 ;13
hist ydisp i=20 j=30 ;14
;
hist xdisp i=26 j=12 ;15
hist xdisp i=26 j=14 ;16
hist xdisp i=26 j=16 ;17
hist xdisp i=25 j=19 ;18
hist xdisp i=24 j=22 ;19
hist xdisp i=20 j=30 ;20
;
; Thermal mechanical analysis
;
set mech off therm on
set thdt 1e4
solve age 20000000
set mech on therm off
step 2000
set mech off therm on
solve age 40000000
set mech on therm off
step 2000
set mech off therm on
solve age 60000000
set mech on therm off
step 2000
set mech off therm on
solve age 80000000
set mech on therm off
step 2000
set mech off therm on
solve age 100000000
set mech on therm off
step 2000
set mech off therm on
solve age 120000000
set mech on therm off
step 2000
set mech off therm on
solve age 150000000
set mech on therm off
step 2000
set mech off therm on
solve age 200000000
set mech on therm off
step 2000
set mech off therm on
solve age 250000000
```

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FLAC file
f712input.txt
(pg 1 of 2)

```
set mech on therm off
step 2000
set mech off therm on
solve age 315400000
set mech on therm off
step 2000
save
disp_mag
save f712final.sav
;
set plot emf color
title
Case 7.12 Inclined Transgressing Joint (FLAC, Slip Allowed)
;
set out f712grid.emf
plot gri bou iw
copy
;
; Joint condition plots
;
set out f712jnd.emf
plot if 1 ndisp
copy
;
set out f712jsd.emf
plot if 1 sdisp
copy
;
set out f712jss.emf
plot if 1 ss
copy
;
set out f712jns.emf
plot if 1 ns
copy
;
set out f712jrnd.emf
plot if 1 closure
copy
;
set out f712jrsd.emf
plot if 1 ride
copy
;
; Contour plots
;
set out f712temp.emf
plot temp fill temp iw bou iw
copy
;
set out f712disp.emf
plot ex_1 fill alias 'Displacement' ex_1 iw disp iw bou iw
copy
;
set out f712xd.emf
plot xd fill xd iw bou iw
copy
;
set out f712yd.emf
plot yd fill yd iw bou iw
copy
;
set out f712sig1.emf
plot sig1 fill sig1 iw bou iw
copy
;
set out f712sig2.emf
plot sig2 fill sig2 iw bou iw
copy
;
set out f712sdif.emf
plot sdiff fill sdiff iw bou iw
copy
;
set out f712thist.emf
plo hist 3 4 5 6 7 8 vs 2
copy
;
set out f712ydhist.emf
plo hist 9 10 11 12 13 14 vs 2
copy
;
set out f712xdhist.emf
plo hist 15 16 17 18 19 20 vs 2
copy
;
set out f712unbal.emf
plo hist 1
copy
;
set hisfile f712temp.his
his write 3 4 5 6 7 8 vs 2 begin 1 skip 10
;
set hisfile f712yd.his
his write 9 10 11 12 13 14 vs 2 begin 1 skip 10
```

```
;
set hisfile f712xd.his
his write 15 16 17 18 19 20 vs 2 begin 1 skip 10
;
def xxx
  nn=561
end
xxx
def table_fill
  array f712(11,nn)
;
; Bottom of interface
;
  thvalr=thvald*pi/180.0
  pnt=int_pnt
  xnot=x(1,16)
  ynot=y(1,16)
  loop while pnt # 0
    pa = imem(pnt+$kicapt)
    loop while pa # 0
      ival=imem(pa+$kidi)
      jval=imem(pa+$kidj)
      xval=fmem(pa+$kidx)
      yval=fmem(pa+$kidy)
      lval=sqrt(((xval-xnot)*(xval-xnot))+((yval-ynot)*(yval-
ynot)))
      dxvalb=xdisp(ival,16)
      dyvalb=ydisp(ival,16)
      dtvalb=sqrt((dxvalb*dxvalb)+(dyvalb*dyvalb))
      thetav=atan2(dyvalb,dxvalb)
      dsvalb=dtvalb*cos(thetav-thvalr)
      dnvalb=dtvalb*sin(thetav-thvalr)
;
; Top of interface
;
      dxvalt=xdisp(ival,17)
      dyvalt=ydisp(ival,17)
      dtvalt=sqrt((dxvalt*dxvalt)+(dyvalt*dyvalt))
      thetav=atan2(dyvalt,dxvalt)
      dsvalt=dtvalt*cos(thetav-thvalr)
      dnvalt=dtvalt*sin(thetav-thvalr)
;
; Interface
;
      dclos=fmem(pa+$kidand)
      dride=fmem(pa+$kidasd)
      tempvalb=temp(ival,16)
      tempvalt=temp(ival,17)
;
; Create table entries
;
      table(1,ival)=yval
      table(2,ival)=xval
      table(3,ival)=lval
      table(4,ival)=dsvalb
      table(5,ival)=dnvalb
      table(6,ival)=dsvalt
      table(7,ival)=dnvalt
      table(8,ival)=dclos
      table(9,ival)=dride
      table(10,ival)=tempvalb
      table(11,ival)=tempvalt
;
; Array entries
;
      f712(1,ival)=string(yval)
      f712(2,ival)=string(xval)
      f712(3,ival)=string(lval)
      f712(4,ival)=string(dsvalb)
      f712(5,ival)=string(dnvalb)
      f712(6,ival)=string(dsvalt)
      f712(7,ival)=string(dnvalt)
      f712(8,ival)=string(dclos)
      f712(9,ival)=string(dride)
      f712(10,ival)=string(tempvalb)
      f712(11,ival)=string(tempvalt)
      pa=imem(pa)
    endLoop
    pnt=imem(pnt)
  endloop
  status=open('f712data.out',1,1)
  status=write(f712,561)
end
;
set thvald=14.0
;
cal int.fin
table_fill
;
set log f712slip.out
pr if 1
set log f712sr.out
pr sratio j=16,17
ret
```

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FLAC file
f712input.txt
(pg 2 of 2)

```
; Case 7.13 - FLAC 4.0 input file (Sep 21, 2004; RSR)
;
; Inclined transgressing joint in a heated infinite rock
mass.  Joint
; properties selected to allow slippage.  Heat source 5x5 m
centered
; at x=51.210, y=45.149. Joint angle 14° from horizontal.
Power is
; 1500 W/m (60 w/cu.m. x 25 sq.m).  Typical Yucca Mountain
properties used.
;
; Friction angle reduced to 20°. Increase joint stiffness by
1e6.
;
config thermal extra 10
call dispmag.fis
;
; Geometry
;
;Points
;
;A, 0.000, 37.534
;B, 100.000, 62.466
;C, 0.000, 34.957
;D, 100.000, 59.890
;E, 0.000, 29.804
;F, 100.000, 54.737
;G, 48.179, 46.969
;H, 49.389, 42.118
;I, 53.031, 48.179
;J, 54.240, 43.328
;K, 51.210, 45.149
;L, 50.605, 47.574
;M, 50.000, 50.000
;N, 48.790, 54.851
;O, 45.162, 69.406
;P, 37.534, 100.000
;Q, 0.000, 37.534
;R, 18.465, 42.138
;S, 30.594, 45.162
;T, 40.297, 47.581
;U, 47.574, 49.395
;V, 50.000, 50.000
;W, 52.426, 50.605
;X, 59.703, 52.419
;Y, 69.406, 54.838
;Z, 81.535, 57.862
;AA, 100.000, 62.466
;
grid 50 29
model elastic th_isotropic
mod null j=16
gen 0.000,34.957 0.000,37.534 100.000,62.466 100.000,59.890
i=1,51 j=14,16 ; C A B D
gen 0.000,29.804 0.000,34.957 48.179,46.969 49.389,42.118
i=1,25 j=10,14 ; E C G H
gen 54.240,43.328 53.031,48.179  100.000,59.890
100.000,54.737 i=27,51 j=10,14 ; J I D F
gen 0.0,37.534 0.0,100.0 100.0,100.0 100.0,62.466 i=1,51
j=17,30 ; Upper block
int 1 aside from 1,16 to 51,16 bside from 1,17 to 51,17
gen 49.389,42.118  48.179,46.969  53.031,48.179
54.240,43.328 i=25,27 j=10,14 ; H G I J
mark i=25,27 j=10,14
gen 0.0,0.0 0.0,29.804 100.0,54.737 100.0,0.0 i=1,51 j=1,10
gen 0.000,29.804 0.000,34.957 48.179,46.969 49.389,42.118
i=1,25 j=10,14 ; E C G H
gen 54.240,43.328 53.031,48.179  100.000,59.890
100.000,54.737 i=27,51 j=10,14 ; J I D F
gen 49.389,42.118  48.179,46.969  53.031,48.179
54.240,43.328 i=25,27 j=10,14 ; H G I J
mark j=10,14
gen adjust
unmark
mark i=25,27 j=10,14
ini x=48.790 y=54.851  i=25 j=19 ; N
ini x=45.162 y=69.406  i=24 j=22 ; O
ini x=37.534 y=100.000 i=20 j=30 ; P
;
; Material properties
;
prop de=2210.0 b=19.2e9 s=13.6e9
prop thexp=10.0e-6 cond=2.13 spec=990.0
int 1 kn=5.0e10 ks=5.0e10
;int 1 c=1.0e20 f=0.0 t=1.0e20 di=0 ; no slip
;
int 1 c=100.0e3 f=20.0 t=40.0e3 di=0 ; slip
;
; Initial conditions
;
ini temp 25.0
ini syy -8.1e6 var 0.0 2.2e6 i=1,51 j=1,30
ini sxx -2.1546e6 var 0.0 0.5852e6 i=1,51 j=1,30
ini sxy 0 i=1,51 var 0.0 0.0 j=1,30
ini szz -2.1546e6 var 0.0 0.5852e6 i=1,51 j=1,30
```

```
;
; Boundary conditions
;
;apply yvel 0.0 j=1
;apply yvel 0.0 j=30
;apply xvel 0.0 i=1 j=1,16
;apply xvel 0.0 i=1 j=17,30
;apply xvel 0.0 i=51 j=1,16
;apply xvel 0.0 i=51 j=17,30
;
fix y j=1
fix y j=30
fix x i=1 j=1,16
fix x i=1 j=17,30
fix x i=51 j=1,16
fix x i=51 j=17,30
;
; Apply heat source
;
interior source 60 i=25,26 j=10,13
;
set mech on therm off
step 2000
ini xd 0
ini yd 0
ini xv 0
ini yv 0
;
; Time and force history
;
hist unbalanced ;1
hist thtime ; 2
;
; Thermal histories
;
hist temp i=26 j=12 ;3
hist temp i=26 j=14 ;4
hist temp i=26 j=16 ;5
hist temp i=25 j=19 ;6
hist temp i=24 j=22 ;7
hist temp i=20 j=30 ;8
;
; Mechanical histories
;
hist ydisp i=26 j=12 ;9
hist ydisp i=26 j=14 ;10
hist ydisp i=26 j=16 ;11
hist ydisp i=25 j=19 ;12
hist ydisp i=24 j=22 ;13
hist ydisp i=20 j=30 ;14
;
hist xdisp i=26 j=12 ;15
hist xdisp i=26 j=14 ;16
hist xdisp i=26 j=16 ;17
hist xdisp i=25 j=19 ;18
hist xdisp i=24 j=22 ;19
hist xdisp i=20 j=30 ;20
;
; Thermal mechanical analysis
;
set mech off therm on
set thdt 1e4
solve age 20000000
set mech on therm off
step 2000
set mech off therm on
solve age 40000000
set mech on therm off
step 2000
set mech off therm on
solve age 60000000
set mech on therm off
step 2000
set mech off therm on
solve age 80000000
set mech on therm off
step 2000
set mech off therm on
solve age 100000000
set mech on therm off
step 2000
set mech off therm on
solve age 120000000
set mech on therm off
step 2000
set mech off therm on
solve age 150000000
set mech on therm off
step 2000
set mech off therm on
solve age 200000000
set mech on therm off
step 2000
set mech off therm on
solve age 250000000
```

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FLAC
File f713input.txt
(pg 1 of 2)

```
set mech on therm off
step 2000
set mech off therm on
solve age 315400000
set mech on therm off
step 2000
save
disp_mag
save f713final.sav
;
set plot emf color
title
Case 7.13 Inclined Transgressing Joint (FLAC, Slip Allowed)
;
set out f713grid.emf
plot gri bou iw
copy
;
; Joint condition plots
;
set out f713jnd.emf
plot if 1 ndisp
copy
;
set out f713jsd.emf
plot if 1 sdisp
copy
;
set out f713jss.emf
plot if 1 ss
copy
;
set out f713jns.emf
plot if 1 ns
copy
;
set out f713jrnd.emf
plot if 1 closure
copy
;
set out f713jrsd.emf
plot if 1 ride
copy
;
; Contour plots
;
set out f713temp.emf
plot temp fill temp iw bou iw
copy
;
set out f713disp.emf
plot ex_1 fill alias 'Displacement' ex_1 iw disp iw bou iw
copy
;
set out f713xd.emf
plot xd fill xd iw bou iw
copy
;
set out f713yd.emf
plot yd fill yd iw bou iw
copy
;
set out f713sig1.emf
plot sig1 fill sig1 iw bou iw
copy
;
set out f713sig2.emf
plot sig2 fill sig2 iw bou iw
copy
;
set out f713sdif.emf
plot sdiff fill sdiff iw bou iw
copy
;
set out f713thist.emf
plo hist 3 4 5 6 7 8 vs 2
copy
;
set out f713ydhist.emf
plo hist 9 10 11 12 13 14 vs 2
copy
;
set out f713xdhist.emf
plo hist 15 16 17 18 19 20 vs 2
copy
;
set out f713unbal.emf
plo hist 1
copy
;
set hisfile f713temp.his
his write 3 4 5 6 7 8 vs 2 begin 1 skip 10
;
set hisfile f713yd.his
his write 9 10 11 12 13 14 vs 2 begin 1 skip 10
;
set hisfile f713xd.his
his write 15 16 17 18 19 20 vs 2 begin 1 skip 10
;
def xxx
  nn=561
end
xxx
def table_fill
  array f713(11,nn)
;
; Bottom of interface
;
  thvalr=thvald*pi/180.0
  pnt=int_pnt
  xnot=x(1,16)
  ynot=y(1,16)
  loop while pnt # 0
    pa = imem(pnt+$kicapt)
    loop while pa # 0
      ival=imem(pa+$kidi)
      jval=imem(pa+$kidj)
      xval=fmem(pa+$kidx)
      yval=fmem(pa+$kidy)
      lval=sqrt(((xval-xnot)*(xval-xnot))+((yval-ynot)*(yval-
ynot)))
      dxvalb=xdisp(ival,16)
      dyvalb=ydisp(ival,16)
      dtvalb=sqrt((dxvalb*dxvalb)+(dyvalb*dyvalb))
      thetav=atan2(dyvalb,dxvalb)
      dsvalb=dtvalb*cos(thetav-thvalr)
      dnvalb=dtvalb*sin(thetav-thvalr)
;
; Top of interface
;
      dxvalt=xdisp(ival,17)
      dyvalt=ydisp(ival,17)
      dtvalt=sqrt((dxvalt*dxvalt)+(dyvalt*dyvalt))
      thetav=atan2(dyvalt,dxvalt)
      dsvalt=dtvalt*cos(thetav-thvalr)
      dnvalt=dtvalt*sin(thetav-thvalr)
;
; Interface
;
      dclos=fmem(pa+$kidand)
      dride=fmem(pa+$kidasd)
      tempvalb=temp(ival,16)
      tempvalt=temp(ival,17)
;
; Create table entries
;
      table(1,ival)=yval
      table(2,ival)=xval
      table(3,ival)=lval
      table(4,ival)=dsvalb
      table(5,ival)=dnvalb
      table(6,ival)=dsvalt
      table(7,ival)=dnvalt
      table(8,ival)=dclos
      table(9,ival)=dride
      table(10,ival)=tempvalb
      table(11,ival)=tempvalt
;
; Array entries
;
      f713(1,ival)=string(yval)
      f713(2,ival)=string(xval)
      f713(3,ival)=string(lval)
      f713(4,ival)=string(dsvalb)
      f713(5,ival)=string(dnvalb)
      f713(6,ival)=string(dsvalt)
      f713(7,ival)=string(dnvalt)
      f713(8,ival)=string(dclos)
      f713(9,ival)=string(dride)
      f713(10,ival)=string(tempvalb)
      f713(11,ival)=string(tempvalt)
      pa=imem(pa)
    endLoop
    pnt=imem(pnt)
  endloop
  status=open('f713data.out',1,1)
  status=write(f713,561)
end
;
set thvald=14.0
;
cal int.fin
table_fill
;
set log f713slip.out
pr if 1
set log f713sr.out
pr sratio j=16,17
ret
```

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FLAC file
f713 input.txt
(pg 2 of 2)

Summary of Observations from FLAC cases run to date.

Cases 7.1 and 7.2 have initial stresses of zero. Hence they represent generic cases of a joint of any orientation close to a heat source. In Case 7.2, slip occurs on all but 5 contacts. This is reflected in the plot of relative displacements along the interface. Joint opening occurs along most of the interface.

Case 7.3 and 7.4 are very similar to Case 7.1 and 7.2 as expected given that there is no initial stress in the model, and the source power is the same (2000 W/m).

Case 7.7 and 7.8 have significantly different interface responses from previous cases given that non-zero initial stresses are specified. Heating results in closure along the entire joint. and a uniform shear profile that does not indicate slip. The reduction in joint normal and shear stiffness results in less localization of displacement. and increases displacement by almost 3 orders of magnitude. Case 7.9 is identical to 7.8 despite a lower friction angle (20°) → no slip occurs so strength is not a controlling factor. Case 7.13 uses higher stiffness values than 7.8 and 7.9, resulting in slip along part of the interface resulting from tensile bond breakage.

Case 10 and 11 represent rotated stress cases to simulate a subvertical fracture in a typical Yucca Mtn. stress field. The difference in friction angles (20° vs 10°, respectively) between these cases has no effect on displacement response because strength does not control the response (ie no slip occurs). Case 7.12 uses a high stiffness value typical of Yucca Mtn interfaces and produces slip using a friction angle of 20°. Slip in this case results from tensile breakage of interface contact bonds. Only a portion of the interface experiences this exaggerated shear displacement.

Conclusions: Joint normal and shear stiffness control to a large extent the interface displacement response, and the stress accumulation at the interface that can lead to shear or tensile failure. Sept 21/04.

Case 7.3 (UDEC)

- modify file INCLINED1.TXT to produce slightly modified plots and tables for import into U73.XLS. Tables are stored as u73cdata.out and u73bdata.out. These output files are cut and pasted into U73.XLS to overwrite existing data in the template. All data files are stored in /Case7/UDEC/

File U73INPUT.TXT is shown on page 57. This is the UDEC input file for case 7.3. The properties are the same as those used in the FLAC analysis of this case. There are some differences in how the grid is developed in UDEC which leads to 51 contacts at the top of the interface and 56 contacts at the bottom. This is slightly more than the 51 contacts in FLAC.

```
; Case 7.3 - UDEC 3.1 input file (Sep 21, 2004; RSR)
;
; Base case with inclined transgressing joint in a heated
; infinite rock mass (slip disallowed on joint, no
; initial stresses, source 50 kW/m, theta=26.6 degrees).
;
config thermal
set mech on
;
; Geometry
;
rou 0.001
bl 0,0 0,100 100,100 100,0
crack 0 25 100 75 ; Main joint
crack 0 22.2049 100 72.2049 ; Top
crack 0 16.6147 100 66.6147 ; Bottom
crack 48.8819 46.6459 51.1180 42.1738 ; Left side
crack 53.3541 48.8820 55.5902 44.4098 ; Right side
;
gen quad 2.0
;
; Material properties
;
change jcons=5 range block 358 143
change jcons=5 range block 143 358
prop m=1 de=2210.0 k=19.0e9 g=13.0e9
prop m=1 thexp=15.0e-6 cond=20.0 spec=1000.0
prop jm=1 jkn=19.0e10 jks=13.0e10
prop jm=1 jcoh=1.0e20 jfric=0.0 jten=1.0e20 jd=0
prop jm=1 jrescoh=1.0e20 jrfric=0.0 jrten=1.0e20
;prop jm=2 jkn=19.0e10 jks=13.0e10
;prop jm=2 jcoh=100.0e3 jfric=20.0 jten=1.0e6 jd=0
;prop jm=2 jrescoh=100.0e3 jrfric=20.0 jrten=1.0e6
;change jmat=2 range block 358 143
;change jmat=2 range block 143 358
;
; Initial conditions
;
initemp 34.0 0 100 0 100
;ini sxx -8.1e6 grad 0.022e6 0
;ini syy -2.1546e6 grad 0.005852e6 0
;ini sxy 0.0
;ini szz -2.1546e6 grad 0.005852e6 0
;
; Boundary conditions
;
bound yvel 0.0 range (0,100) (-0.1, 0.1)
bound yvel 0.0 range (0,100) (99.1, 100.1)
bound xvel 0.0 range (-0.1, 0.1) (0,100)
bound xvel 0.0 range (99.1, 100.1) (0,100)
;
; Apply heat source
;
thapp source 50000 0 range 51.1180 53.3541 44.4098 46.6459
;
; Equilibrate model
;
set ovtol 0.5
;step 4000
;change jmat=2 range block 358 143
;change jmat=2 range block 143 358
ini xd 0
ini yd 0
ini nd 0
ini sd 0
ini xv 0
ini yv 0
ini bxv 0
ini byv 0
ini brv 0
;
; Thermal histories
;
thist temp 52.236, 45.528 ; 1
thist temp 51.342, 47.317 ; 2
thist temp 50,50 ;3
thist temp 45.528, 58.944 ; 4
thist temp 38.819, 72.361 ; 5
thist temp 27.639, 94.721 ; 6
;
; Mechanical histories
;
hist ydisp 52.236, 45.528 ; 1
hist ydisp 51.342, 47.317 ; 2
hist ydisp 50,50 ;3
hist ydisp 45.528, 58.944 ; 4
hist ydisp 38.819, 72.361 ; 5
hist ydisp 27.639, 94.721 ; 6
hist unbalanced ;7
hist ndis 50 50 ;8
hist sdis 50 50 ;9
;
; Thermal mechanical analysis
;
;
set nther 2500
set nmech 4000
damp auto
run age 1000000 temp 50
step 4000
;
cal dispmag.fis
disp_mag
save u73final.sav
;
set plot emf color
title
Case 7.3 Inclined Transgressing Joint (UDEC, No Slip Allowed)
;
; Geometry
;
set out u73grid.emf
set color iw
plo zone green blo iw
copy

; Joint condition plots
;
set out u73jndl.emf
set color iw
plot joint 0 50 100 50 ndisp 2
copy
;
set out u73jnsl.emf
set color iw
plot joint 0 50 100 50 nstr 2
copy
;
set out u73jsdl.emf
set color iw
plot joint 0 50 100 50 sdisp 2
copy
;
set out u73jssl.emf
set color iw
plot joint 0 50 100 50 sstr 2
copy
;
set out u73shear.emf
set color iw
plo blo iw shear red
copy
;
set out u73slip.emf
set color iw
plo blo iw slip red
copy
;
; Contour plots
;
set out u73temp.emf
set color iw
plot temp fill temp iw blo iw
copy
;
set out u73disp.emf
set color iw
plot gp_extra fill alias 'Displacement' gp_extra iw disp iw
blo iw
copy
;
set out u73xd.emf
set color iw
plot xd fill xd iw blo iw
copy
;
set out u73yd.emf
set color iw
plot yd fill yd iw blo iw
copy
;
set out u73sig1.emf
set color iw
plot sig1 fill sig1 iw blo iw
copy
;
set out u73sig2.emf
set color iw
plot sig2 fill sig2 iw blo iw
copy
;
set out u73sdif.emf
set color iw
plot sdiff fill sdiff iw blo iw
copy
;
set out u73thist.emf
set color iw
plo thist 1 2 3 4 5 6
copy
```

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UDEC file
u73input.txt
(Case 7.3,
pg 1 of 2)

```
;
set out u73ydhist.emf
set color iw
plo hist 1 2 3 4 5 6
copy
;
set out u73xdhist.emf
set color iw
plo hist 7 8 9 10 11 12
copy
;
set out u73unbal.emf
set color iw
plo hist 13
copy
;
set out u73jns.emf
set color iw
plo hist 14 15
copy
;
; Create output tables
;
def xxx
  nn=2000
end
xxx
def table_fill
  array u73c(13,nn)
  array u73b(9,nn)
  ic=contact_head
  ib=block_head
  ii=1
  thvalr=thvald*pi/180.0
  mval=tan(thvalr)
  bval=50.0-50.0*mval
;
; Contact information
;
  loop while ic # 0
    xval=c_x(ic)
    yval=c_y(ic)
    ycal=mval*xval+bval
    lval=sqrt(xval^2+(yval-bval)^2)
    blk1=c_b1(ic)
    blk2=c_b2(ic)
    clval=c_length(ic)
    dclos=c_ndis(ic)
    dride=c_sdis(ic)
    nfval=c_nforce(ic)
    sfval=c_sforce(ic)
    nsval=-nfval/clval
    ssval=-sfval/clval
    tyval=c_type(ic)
    slipc=fmem(ic+$kgam)
;
; Create table entries
;
   if abs(yval-ycal)<0.1 then
    table(1,ii)=yval
    table(2,ii)=xval
    table(3,ii)=lval
    table(4,ii)=blk1
    table(5,ii)=blk2
    table(6,ii)=nfval
    table(7,ii)=sfval
    table(8,ii)=dclos
    table(9,ii)=dride
    table(10,ii)=nsval
    table(11,ii)=ssval
    table(12,ii)=tyval
    table(13,ii)=slipc
;
; Array entries
;
    u73c(1,ii)=string(yval)
    u73c(2,ii)=string(xval)
    u73c(3,ii)=string(lval)
    u73c(4,ii)=string(blk1)
    u73c(5,ii)=string(blk2)
    u73c(6,ii)=string(nfval)
    u73c(7,ii)=string(sfval)
    u73c(8,ii)=string(dclos)
    u73c(9,ii)=string(dride)
    u73c(10,ii)=string(nsval)
    u73c(11,ii)=string(ssval)
    u73c(12,ii)=string(tyval)
    u73c(13,ii)=string(slipc)
    ii=ii+1
   end_if
   ic=c_next(ic)
  end_loop
  ii=1
;
; Gridpoints on joint
;
  loop while ib # 0
    cg=b_gp(ib)
    loop while cg # 0
      blkc=ib
      xval=gp_x(cg)
      yval=gp_y(cg)
      ycal=mval*xval+bval
      lval=sqrt(xval^2+(yval-bval)^2)
      dxval=gp_xdis(cg)
      dyval=gp_ydis(cg)
      dsval=dxval*cos(thvalr)-dyval*sin(thvalr)
      dnval=dxval*sin(thvalr)+dyval*cos(thvalr)
      gtemp=fmem(cg+$kgtemp)
;
; Create table entries
;
      if abs(yval-ycal)<0.1 then
        table(13,ii)=yval
        table(14,ii)=xval
        table(15,ii)=lval
        table(16,ii)=blkc
        table(17,ii)=dxval
        table(18,ii)=dyval
        table(19,ii)=dsval
        table(20,ii)=dnval
;
; Array entries
;
        u73b(1,ii)=string(yval)
        u73b(2,ii)=string(xval)
        u73b(3,ii)=string(lval)
        u73b(4,ii)=string(blkc)
        u73b(5,ii)=string(dxval)
        u73b(6,ii)=string(dyval)
        u73b(7,ii)=string(dsval)
        u73b(8,ii)=string(dnval)
        u73b(9,ii)=string(gtemp)
        ii=ii+1
      end_if
      cg=gp_next(cg)
    end_loop
    ib=b_next(ib)
  end_loop
  status=open('u73cdata.out',1,1)
  status=write(u73c,2000)
  status=close
  status=open('u73bdata.out',1,1)
  status=write(u73b,2000)
end
;
set thvald=26.565051
cal contact.fin
cal jmat.fin
table_fill
;
; Write thermal histories to files
;
thist write 1 u73t1.out
thist write 2 u73t2.out
thist write 3 u73t3.out
thist write 4 u73t4.out
thist write 5 u73t5.out
thist write 6 u73t6.out
;
ret
```

modified
this logic
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UDEC file
u73 INPUT.TXT
(pg 2 of 2)

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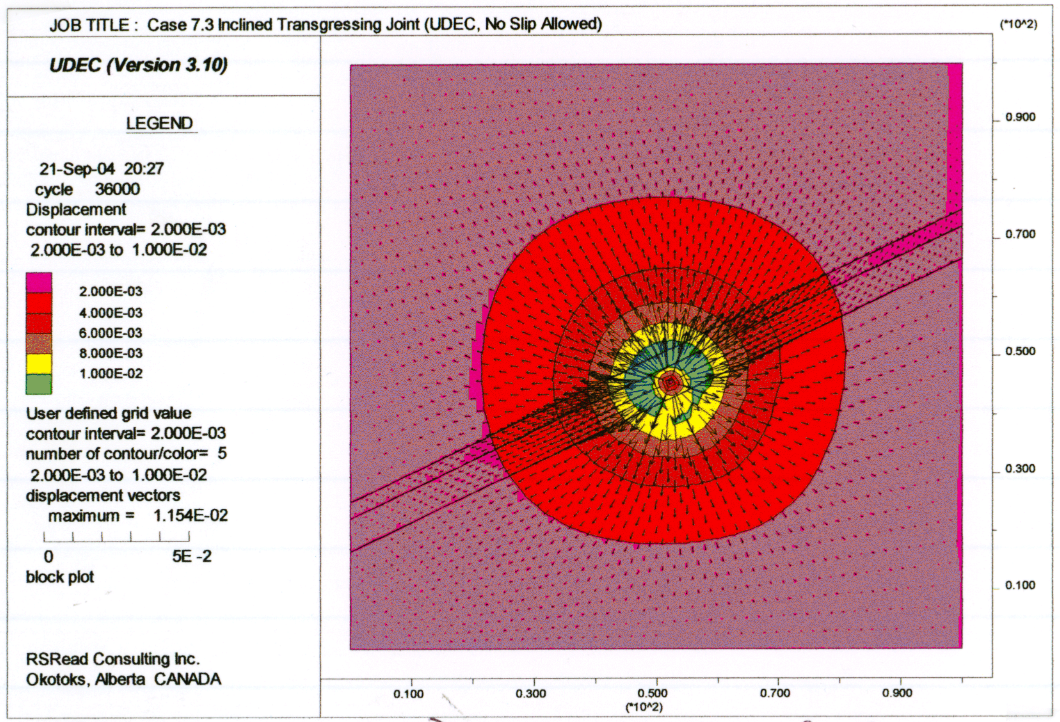
```
;
; Create output tables
;
def xxx
  nn=2000
end
xxx
def table_fill
  array u73c(13,nn)
  array u73b(9,nn)
  ic=contact_head
  ib=block_head
  ii=1
  thvalr=thvald*pi/180.0
  mval=tan(thvalr)
  bval=50.0-50.0*mval
;
; Contact information
;
  loop while ic # 0
    xval=c_x(ic)
    yval=c_y(ic)
    ycal=mval*xval+bval
    lval=sqrt(xval^2+(yval-bval)^2)
    blk1=c_b1(ic)
    blk2=c_b2(ic)
    clval=c_length(ic)
    dclos=c_ndis(ic)
    dride=c_sdis(ic)
    nfval=c_nforce(ic)
    sfval=c_sforce(ic)
    nsval=-nfval/clval
    ssval=-sfval/clval
    tyval=c_type(ic)
    slipc=fmem(ic+$kgam)
;
; Create table entries
;
   if abs(yval-ycal)<0.1 then
    table(1,ii)=yval
    table(2,ii)=xval
    table(3,ii)=lval
    table(4,ii)=blk1
    table(5,ii)=blk2
    table(6,ii)=nfval
    table(7,ii)=sfval
    table(8,ii)=dclos
    table(9,ii)=dride
    table(10,ii)=nsval
    table(11,ii)=ssval
    table(12,ii)=tyval
    table(13,ii)=slipc
;
; Array entries
;
    u73c(1,ii)=string(yval)
    u73c(2,ii)=string(xval)
    u73c(3,ii)=string(lval)
    u73c(4,ii)=string(blk1)
    u73c(5,ii)=string(blk2)
    u73c(6,ii)=string(nfval)
    u73c(7,ii)=string(sfval)
    u73c(8,ii)=string(dclos)
    u73c(9,ii)=string(dride)
    u73c(10,ii)=string(nsval)
    u73c(11,ii)=string(ssval)
    u73c(12,ii)=string(tyval)
    u73c(13,ii)=string(slipc)
    ii=ii+1
   end_if
   ic=c_next(ic)
  end_loop
  ii=1
;
; Gridpoints on joint
;
  loop while ib # 0
    cg=b_gp(ib)
    loop while cg # 0
      blkc=ib
      xval=gp_x(cg)
      yval=gp_y(cg)
      ycal=mval*xval+bval
      lval=sqrt(xval^2+(yval-bval)^2)
      dxval=gp_xdis(cg)
      dyval=gp_ydis(cg)
      thetav=atan2(dyval,dxval)
      dtvalb=sqrt((dxval*dxval)+(dyval*dyval))
      dsval=dtvalb*cos(thetav-thvalr)
      dnval=dtvalb*sin(thetav-thvalr)
;      dsval=dxval*cos(thvalr)-dyval*sin(thvalr)
;      dnval=dxval*sin(thvalr)+dyval*cos(thvalr)
      gtemp=fmem(cg+$kgtemp)
;
; Create table entries
;
      if abs(yval-ycal)<0.1 then
        table(13,ii)=yval
        table(14,ii)=xval
        table(15,ii)=lval
        table(16,ii)=blkc
        table(17,ii)=dxval
        table(18,ii)=dyval
        table(19,ii)=dsval
        table(20,ii)=dnval
;
; Array entries
;
        u73b(1,ii)=string(yval)
        u73b(2,ii)=string(xval)
        u73b(3,ii)=string(lval)
        u73b(4,ii)=string(blkc)
        u73b(5,ii)=string(dxval)
        u73b(6,ii)=string(dyval)
        u73b(7,ii)=string(dsval)
        u73b(8,ii)=string(dnval)
        u73b(9,ii)=string(gtemp)
        ii=ii+1
      end_if
      cg=gp_next(cg)
    end_loop
    ib=b_next(ib)
  end_loop
  status=open('u73cdata.out',1,1)
  status=write(u73c,2000)
  status=close
  status=open('u73bdata.out',1,1)
  status=write(u73b,2000)
end
```

Sep 21/04

Modified subroutine
to calculate values for
comparison with FLAC
→ modified U73INPUT.TXT
to incorporate this logic
sept. 21/04.



File u73disp.emf Displacement pattern for Case 7.3 using UDEC.

Sep 21/04.

Plots for Case 7.3 (UDEC) stored in /Case 7/UDEC/u73plots.doc.

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- ideas for calculating error
  a) Interpolate UDEC results to match FLAC grid
  b) Calculate $\Sigma \text{abs}(dy)$ along interface, and $\Sigma(y)^{abs}$.
  c) Average error = $\Sigma \text{abs}(d_y) / \Sigma_y^{(abs)}$
     → avoids problems with point specific error.
  d) Max error = $\Sigma \text{abs}(dy)_{max} / \Sigma \text{abs}(y_{max})$

- Developed interpolation algorithm/formula that translates UDEC results with >51 contacts into a 51 line file. Captured in EXCEL in u73.xls.

Case 7.3 Summary of Results (FLAC)

Parameter	Maximum		Minimum		Mean	Σ Absolute
	X	Value	X	Value	Value	Values
FLAC Shear displacement at bottom of interface (m)	56.00	7.05E-03	44.00	-6.96E-03	4.89E-05	1.36E-01
FLAC Shear displacement at top of interface (m)	56.00	6.86E-03	44.00	-6.78E-03	5.02E-05	1.34E-01
FLAC Normal displacement at bottom of interface (m)	50.00	1.13E-02	2.00	-9.56E-05	2.02E-03	1.03E-01
FLAC Normal displacement at top of interface (m)	50.00	1.10E-02	2.00	-9.88E-05	2.01E-03	1.03E-01
FLAC Relative normal displacement on interface (m)	60.00	3.81E-05	50.00	-2.70E-04	-1.05E-05	1.37E-03
FLAC Relative shear displacement on interface (m)	46.00	2.15E-04	54.00	-2.21E-04	1.26E-06	1.96E-03
FLAC Total displacement at bottom of interface (m)	50.00	1.13E-02	0.00	1.79E-04	3.60E-03	1.83E-01
FLAC Total displacement at top of interface (m)	50.00	1.10E-02	0.00	1.81E-04	3.55E-03	1.81E-01
FLAC Normal stress at bottom of interface (Pa)	60.00	7.24E+06	50.00	-5.13E+07	0.00E+00	2.60E+08
FLAC Normal stress at top of interface (Pa)	60.00	7.24E+06	50.00	-5.13E+07	0.00E+00	2.60E+08
FLAC Shear stress at bottom of interface (Pa)	46.00	2.80E+07	54.00	-2.87E+07	0.00E+00	2.55E+08
FLAC Shear stress at top of interface (Pa)	46.00	2.80E+07	54.00	-2.87E+07	0.00E+00	2.55E+08
FLAC Temperature at bottom of interface (°C)	50.00	118.14	0.00	34.00	40.95	2088.52
FLAC Temperature at top of interface (°C)	50.00	100.82	0.00	34.00	39.16	1997.40
Maximum temperature at source (°C)	50.00	425.24	-	-	-	
Number of Contacts	51					
Number of Contacts at Slip Condition	0					

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Case 7.3 Summary of Results (UDEC, Interpolated)

Parameter	Maximum		Minimum		Mean	Σ Absolute
	X	Value	X	Value	Value	Values
UDEC Shear displacement at bottom of interface (m)	56.00	6.96E-03	44.00	-6.99E-03	3.55E-05	1.37E-01
UDEC Shear displacement at top of interface (m)	56.00	7.17E-03	44.00	-7.20E-03	3.43E-05	1.39E-01
UDEC Normal displacement at bottom of interface (m)	50.00	1.09E-02	0.00	-1.74E-04	1.97E-03	1.01E-01
UDEC Normal displacement at top of interface (m)	50.00	1.14E-02	0.00	-1.73E-04	1.99E-03	1.02E-01
UDEC Relative normal displacement on interface (m)	58.00	5.51E-05	50.00	-4.94E-04	-1.33E-05	1.93E-03
UDEC Relative shear displacement on interface (m)	46.00	3.75E-04	54.00	-3.73E-04	1.41E-06	2.74E-03
UDEC Total displacement at bottom of interface (m)	50.00	1.11E-02	0.00	1.95E-04	3.58E-03	1.83E-01
UDEC Total displacement at top of interface (m)	50.00	1.14E-02	0.00	1.93E-04	3.62E-03	1.85E-01
UDEC Normal stress at bottom of interface (Pa)	58.00	1.05E+07	50.00	-9.38E+07	-2.51E+06	3.67E+08
UDEC Normal stress at top of interface (Pa)	60.00	5.40E+06	47.50	-1.59E+07	-9.67E+05	1.46E+08
UDEC Shear stress at bottom of interface (Pa)	46.00	4.87E+07	54.00	-4.85E+07	1.83E+05	3.56E+08
UDEC Shear stress at top of interface (Pa)	42.00	1.31E+07	58.00	-1.33E+07	1.95E+05	1.53E+08
UDEC Temperature at bottom of interface (°C)	50.00	1.06E+02	0.00	3.40E+01	3.99E+01	2033.09
UDEC Temperature at top of interface (°C)	50.00	1.12E+02	0.00	3.40E+01	4.00E+01	2042.17
Maximum temperature at source (°C)	50.00	419.20	-	-	-	-
Number of Contacts	51					
Number of Contacts at Slip Condition	0					

Case 7.3 Relative Error between UDEC and FLAC Results*

Parameter	Maximum		Minimum		Mean	Total
	ΔX	Error	ΔX	Error	Error	Error
Shear displacement at bottom of interface (m)	0.0	1%	0.0	0%	0%	1%
Shear displacement at top of interface (m)	0.0	4%	0.0	6%	0%	4%
Normal displacement at bottom of interface (m)	0.0	4%	-2.0	1%	1%	2%
Normal displacement at top of interface (m)	0.0	4%	-2.0	1%	0%	1%
Relative normal displacement on interface (m)	-2.0	7%	0.0	86%	1%	41%
Relative shear displacement on interface (m)	0.0	62%	0.0	59%	0%	40%
Total displacement at bottom of interface (m)	0.0	3%	0.0	0%	0%	0%
Total displacement at top of interface (m)	0.0	5%	0.0	0%	1%	2%
Normal stress at bottom of interface (Pa)	-2.0	6%	0.0	83%	5%	41%
Normal stress at top of interface (Pa)	0.0	4%	-2.5	69%	2%	44%
Shear stress at bottom of interface (Pa)	0.0	72%	0.0	69%	1%	40%
Shear stress at top of interface (Pa)	-4.0	52%	4.0	54%	1%	40%
Temperature at bottom of interface (°C)	0.0	15%	0.0	0%	1%	3%
Temperature at top of interface (°C)	0.0	15%	0.0	0%	1%	2%
Maximum temperature at source (°C)	0.0	-1%	-	-	-	
Number of Contacts	0%					
Number of Contacts at Slip Condition	0%					

Mean error = $(\text{Mean}_u - \text{Mean}_F)/\text{Max}_F$
Total error = $(\Sigma \text{Abs}(V_u) - \Sigma \text{Abs}(V_F)) / \Sigma \text{Abs}(V_F)$

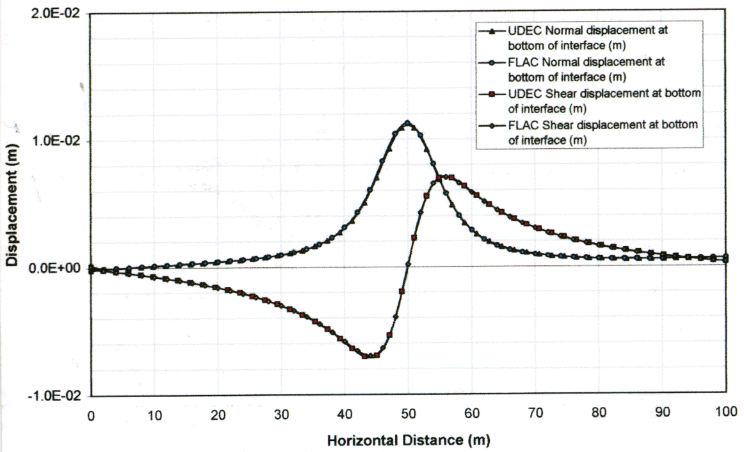
* Relative error calculated as difference between UDEC and FLAC values normalized to maximum deviation from mean along interface in either ~~total~~ displacement, stress, or temperature

RR Sep 22/04.

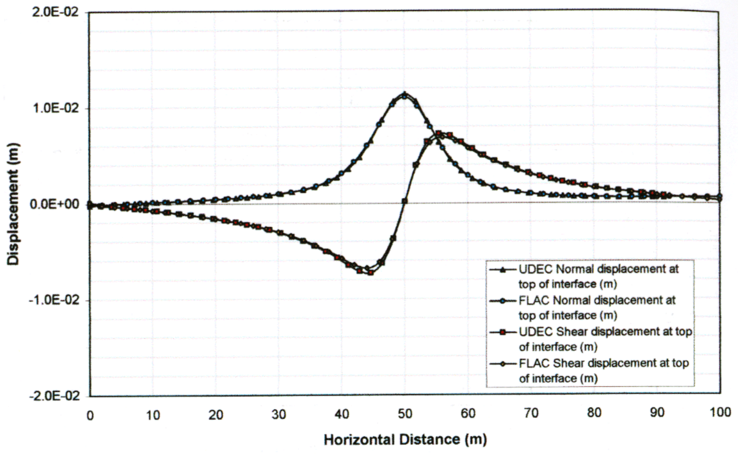
Output from comparison file C73.xls /Case 7/Comparison/.

Sep22/04

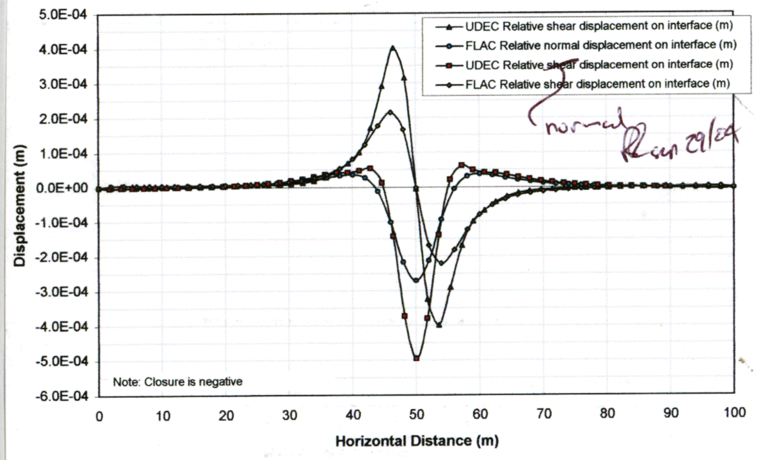
Case 7.3 - Comparison of Results for an Inclined Interface Subjected to a Volumetric Heat Source (No Slip Allowed)



Case 7.3 - Comparison of Results for an Inclined Interface Subjected to a Volumetric Heat Source (No Slip Allowed)

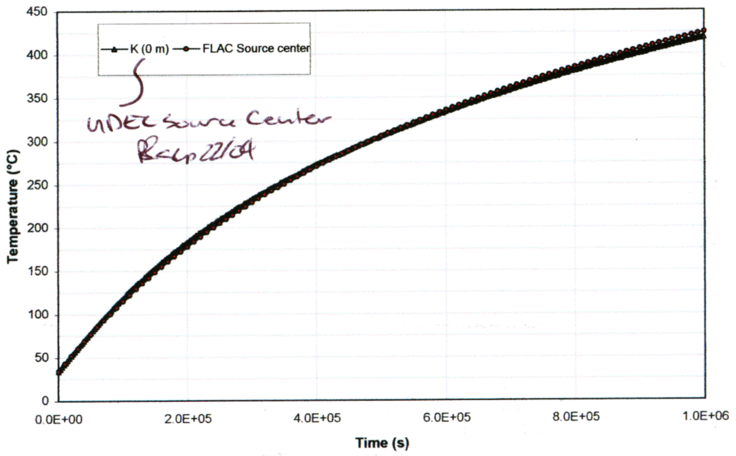


Case 7.3 - Comparison of Results for an Inclined Interface Subjected to a Volumetric Heat Source (No Slip Allowed)



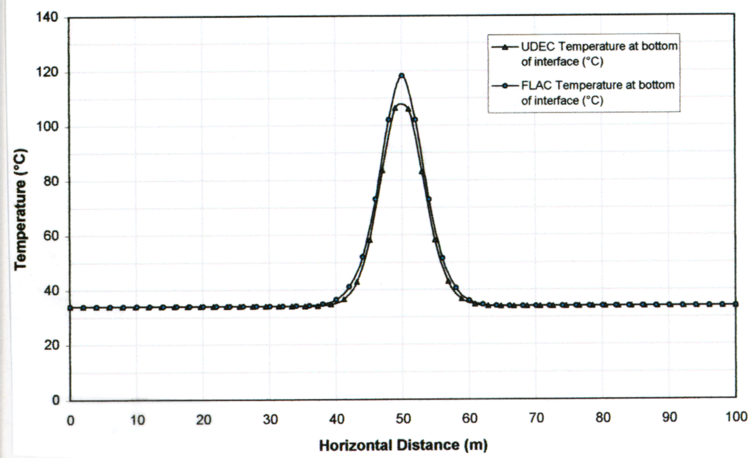
normal
Sep22/04

Case 7.3 - Comparison of Results for an Inclined Interface Subjected to a Volumetric Heat Source (No Slip Allowed)

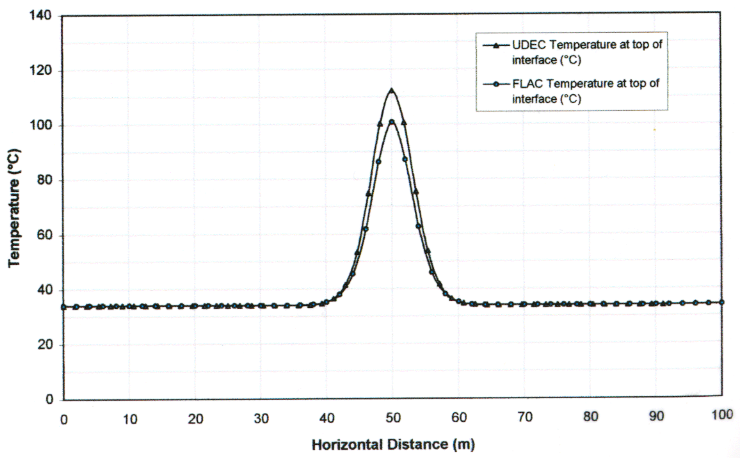


UDEC Source Center
Sep22/04

Case 7.3 - Comparison of Results for an Inclined Interface Subjected to a Volumetric Heat Source (No Slip Allowed)

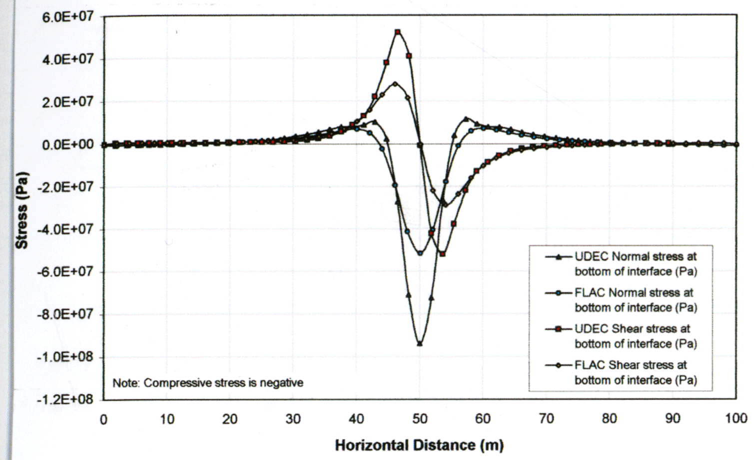


Case 7.3 - Comparison of Results for an Inclined Interface Subjected to a Volumetric Heat Source (No Slip Allowed)

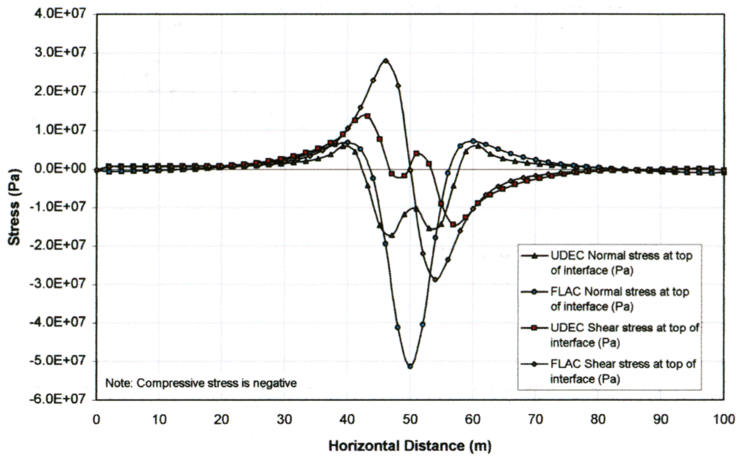


Sep22/04

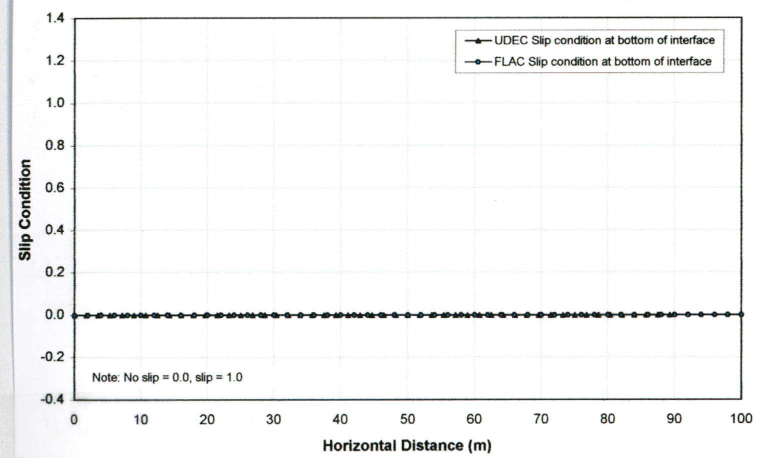
Case 7.3 - Comparison of Results for an Inclined Interface Subjected to a Volumetric Heat Source (No Slip Allowed)



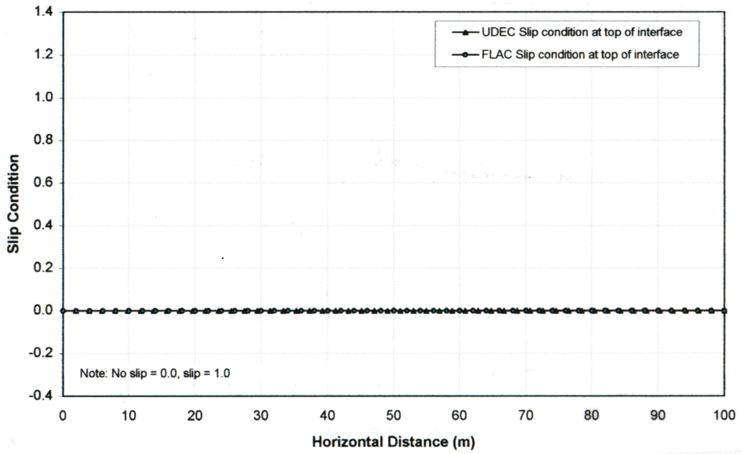
Case 7.3 - Comparison of Results for an Inclined Interface Subjected to a Volumetric Heat Source (No Slip Allowed)



Case 7.3 - Comparison of Results for an Inclined Interface Subjected to a Volumetric Heat Source (No Slip Allowed)



Case 7.3 - Comparison of Results for an Inclined Interface Subjected to a Volumetric Heat Source (No Slip Allowed)



Summary of Comparison for Case 7.3 - All responses along interface.

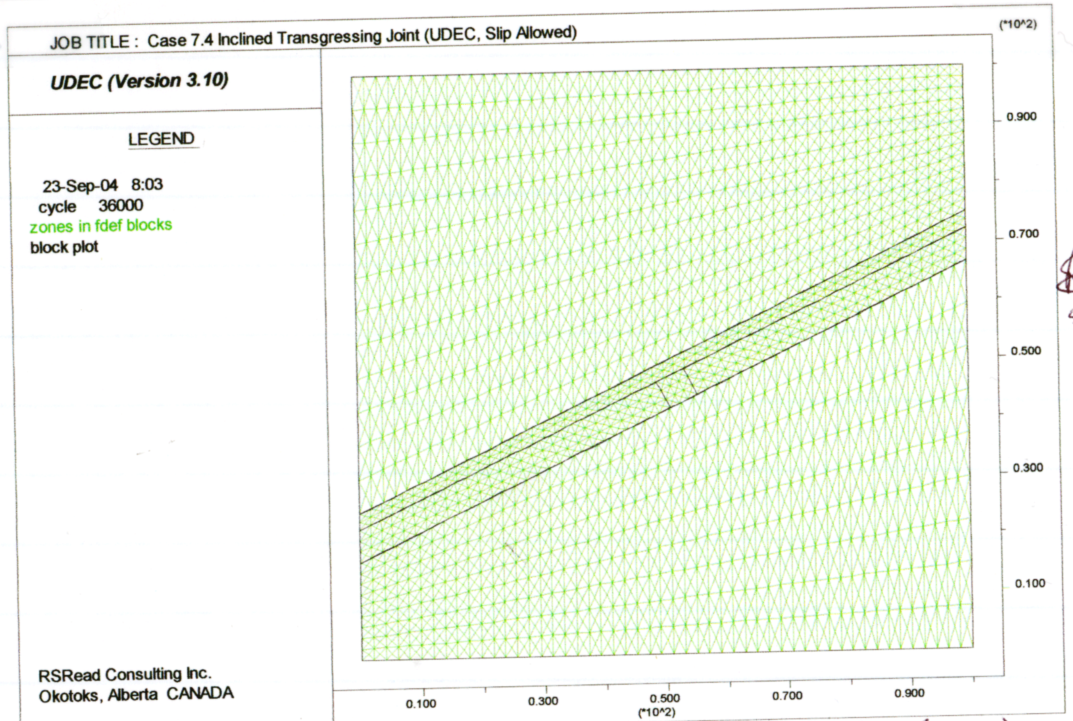
- Normal and shear displacement responses very similar between FLAC & UDEC.
- Relative normal and shear responses differ slightly but are very small values relative to total displacement. Top and bottom interfaces in UDEC behave differently, as witnessed by shear and normal stress response.
- Temperature responses are similar but FLAC is slightly cooler at top of interface, warmer at bottom.
- No slip in either model.

Data stored in U73.XLS. Plots in C73.XLS along with Tables.

Sep22/04

Sept. 23/04

- Case 7.4 (UDEC) run using input file u74input.txt. Plots stored in u74plots.doc under /Case 7/UDEC/.



JOB TITLE : Case 7.4 Inclined Transgressing Joint (UDEC, Slip Allowed)

UDEC (Version 3.10)

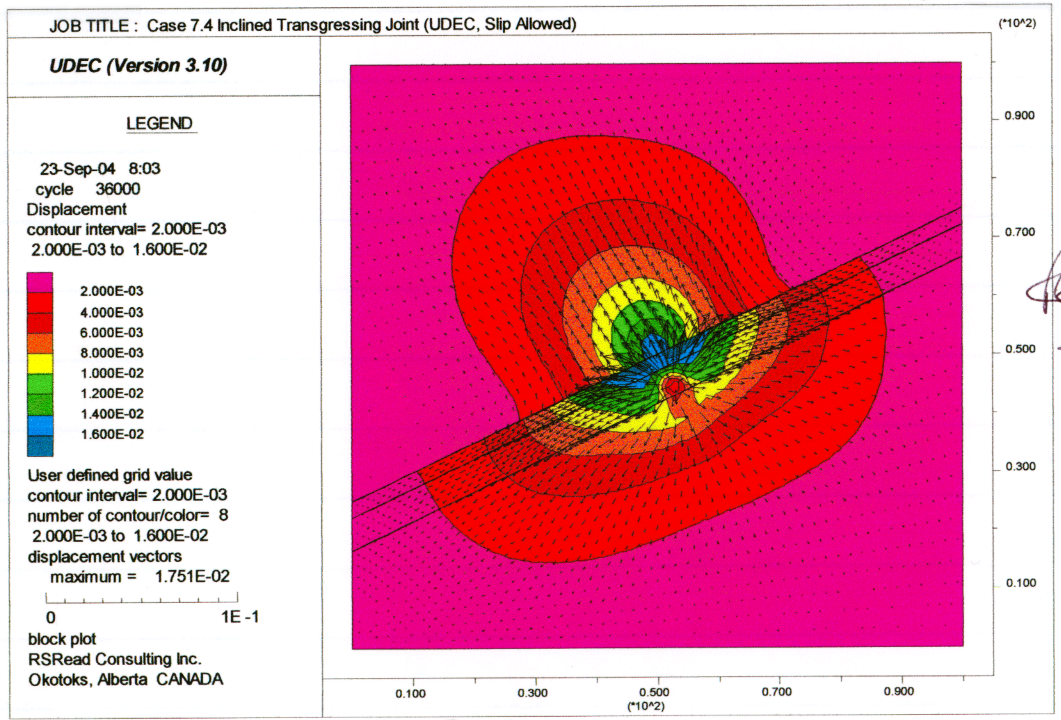
LEGEND

23-Sep-04 8:03
cycle 36000
zones in fdef blocks
block plot

RSRead Consulting Inc.
Okotoks, Alberta CANADA

Sep 23/04

File u74grid.emf Grid used for Cases 7.3 and 7.4 (UDEC)



JOB TITLE : Case 7.4 Inclined Transgressing Joint (UDEC, Slip Allowed)

UDEC (Version 3.10)

LEGEND

23-Sep-04 8:03
cycle 36000
Displacement
contour interval= 2.000E-03
2.000E-03 to 1.600E-02

2.000E-03
4.000E-03
6.000E-03
8.000E-03
1.000E-02
1.200E-02
1.400E-02
1.600E-02

User defined grid value
contour interval= 2.000E-03
number of contour/color= 8
2.000E-03 to 1.600E-02
displacement vectors
maximum = 1.751E-02
0 1E -1
block plot
RSRead Consulting Inc.
Okotoks, Alberta CANADA

Sep 23/04

File u74disp.emf Displacement contours and vectors for Case 7.4.

Sep 28/04

- some plots not registering properly - rerun cases 7.3 and 7.4 and save updated plot files to /Case 7/UDEC/ Input code for case 7.4 on pages 66-67.

Sep. 29/04

Imported all output from UDEC and FLAC Case 7.4 into EXCEL workbook C74.xls to create summary tables and comparative plots (see pages 68-70).

Case 7.4 Comparison Summary

- Comparison of FLAC and UDEC results shows that the FLAC model slips on only part of the interface, whereas the UDEZ model slips at all except 1 point. This results in more shear displacement in the lower block in UDEC, and less in the upper block, than in FLAC simulation. This pattern is reflected in the stress profile along the interface - shear stresses in the upper block are much lower in UDEC simulation than in FLAC simulation.

Temperature profiles are very similar but slightly higher in UDEC compared to FLAC.

Higher number of contacts in UDEC in lower block (56) compared to FLAC (51); same number on upper block. Mean error is within 14% (relative to maximum deviation from background).

```
; Case 7.4 - UDEC 3.1 input file (Sep 23, 2004; RSR)
;
; Base case with inclined transgressing joint in a heated
; infinite rock mass (slip allowed on joint, no
; initial stresses, source 50 kW/m, theta=26.6 degrees).
;
config thermal
set mech on
;
; Geometry
;
rou 0.001
bl 0,0 0,100 100,100 100,0
crack 0 25 100 75 ; Main joint
crack 0 22.2049 100 72.2049 ; Top
crack 0 16.6147 100 66.6147 ; Bottom
crack 48.8819 46.6459 51.1180 42.1738 ; Left side
crack 53.3541 48.8820 55.5902 44.4098 ; Right side
;
gen quad 2.0
;
; Material properties
;
change jcons=5 range block 358 143
change jcons=5 range block 143 358
prop m=1 de=2210.0 k=19.0e9 g=13.0e9
prop m=1 thexp=15.0e-6 cond=20.0 spec=1000.0
prop jm=1 jkn=19.0e11 jks=13.0e11
prop jm=1 jcoh=1.0e20 jfric=0.0 jten=1.0e20 jd=0
prop jm=1 jrescoh=1.0e20 jrfric=0.0 jrten=1.0e20
prop jm=2 jkn=19.0e11 jks=13.0e11
prop jm=2 jcoh=100.0e3 jfric=20.0 jten=1.0e6 jd=0
prop jm=2 jrescoh=100.0e3 jrfric=20.0 jrten=1.0e6
change jmat=2 range block 358 143
change jmat=2 range block 143 358
;
; Initial conditions
;
initemp 34.0 0 100 0 100
;ini sxx -8.1e6 grad 0.022e6 0
;ini syy -2.1546e6 grad 0.005852e6 0
;ini sxy 0.0
;ini szz -2.1546e6 grad 0.005852e6 0
;
; Boundary conditions
;
bound yvel 0.0 range (0,100) (-0.1, 0.1)
bound yvel 0.0 range (0,100) (99.1, 100.1)
bound xvel 0.0 range (-0.1, 0.1) (0,100)
bound xvel 0.0 range (99.1, 100.1) (0,100)
;
; Apply heat source
;
thapp source 50000 0 range 51.1180 53.3541 44.4098 46.6459
;
; Equilibrate model
;
set ovtol 0.5
;step 4000
;change jmat=2 range block 358 143
;change jmat=2 range block 143 358
ini xd 0
ini yd 0
ini nd 0
ini sd 0
ini xv 0
ini yv 0
ini bxv 0
ini byv 0
ini brv 0
;
; Thermal histories
;
thist temp 52.236, 45.528 ; 1
thist temp 51.342, 47.317 ; 2
thist temp 50,50 ;3
thist temp 45.528, 58.944 ; 4
thist temp 38.819, 72.361 ; 5
thist temp 27.639, 94.721 ; 6
;
; Mechanical histories
;
hist ydisp 52.236, 45.528 ; 1
hist ydisp 51.342, 47.317 ; 2
hist ydisp 50,50 ;3
hist ydisp 45.528, 58.944 ; 4
hist ydisp 38.819, 72.361 ; 5
hist ydisp 27.639, 94.721 ; 6
hist unbalanced ;7
hist ndis 50 50 ;8
hist sdis 50 50 ;9
;
; Thermal mechanical analysis
;
;
set nther 2500
set nmech 4000
damp auto
run age 1000000 temp 50
step 4000
;
cal dispmag.fis
disp_mag
save u74final.sav
;
set plot emf color
title
Case 7.4 Inclined Transgressing Joint (UDEC, Slip Allowed)
;
; Geometry
;
set out u74grid.emf
set color iw
plo zone green blo iw
copy

; Joint condition plots
;
set out u74jndl.emf
set color iw
plot joint 0 25 100 75 ndisp 2
copy
;
set out u74jnsl.emf
set color iw
plot joint 0 25 100 75 nstr 2
copy
;
set out u74jsdl.emf
set color iw
plot joint 0 25 100 75 sdisp 2
copy
;
set out u74jssl.emf
set color iw
plot joint 0 25 100 75 sstr 2
copy
;
set out u74shear.emf
set color iw
plo blo iw shear red
copy
;
set out u74slip.emf
set color iw
plo blo iw slip red
copy
;
; Contour plots
;
set out u74temp.emf
set color iw
plot temp fill temp iw blo iw
copy
;
set out u74disp.emf
set color iw
plot gp_extra fill alias 'Displacement' gp_extra iw disp iw
blo iw
copy
;
set out u74xd.emf
set color iw
plot xd fill xd iw blo iw
copy
;
set out u74yd.emf
set color iw
plot yd fill yd iw blo iw
copy
;
set out u74sig1.emf
set color iw
plot sig1 fill sig1 iw blo iw
copy
;
set out u74sig2.emf
set color iw
plot sig2 fill sig2 iw blo iw
copy
;
set out u74sdif.emf
set color iw
plot sdiff fill sdiff iw blo iw
copy
;
set out u74thist.emf
set color iw
plo thist 1 2 3 4 5 6
copy
```

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UDEC
input file
u74input.txt
(pg 1 of 2)

```
;
set out u74ydhist.emf
set color iw
plo hist 1 2 3 4 5 6
copy
;
;set out u74xdhist.emf
;set color iw
;plo hist 7 8 9 10 11 12
;copy
;
set out u74unbal.emf
set color iw
plo hist 7
copy
;
set out u74jns.emf
set color iw
plo hist 8 9
copy
;
; Create output tables
;
def xxx
  nn=2000
end
xxx
def table_fill
  array u74c(13,nn)
  array u74b(9,nn)
  ic=contact_head
  ib=block_head
  ii=1
  thvalr=thvald*pi/180.0
  mval=tan(thvalr)
  bval=50.0-50.0*mval
;
; Contact information
;
  loop while ic # 0
    xval=c_x(ic)
    yval=c_y(ic)
    ycal=mval*xval+bval
    lval=sqrt(xval^2+(yval-bval)^2)
    blk1=c_b1(ic)
    blk2=c_b2(ic)
    clval=c_length(ic)
    dclos=c_ndis(ic)
    dride=c_sdis(ic)
    nfval=c_nforce(ic)
    sfval=c_sforce(ic)
    nsval=-nfval/clval
    ssval=-sfval/clval
    tyval=c_type(ic)
    slipc=fmem(ic+$kgam)
;
; Create table entries
;
   if abs(yval-ycal)<0.1 then
    table(1,ii)=yval
    table(2,ii)=xval
    table(3,ii)=lval
    table(4,ii)=blk1
    table(5,ii)=blk2
    table(6,ii)=nfval
    table(7,ii)=sfval
    table(8,ii)=dclos
    table(9,ii)=dride
    table(10,ii)=nsval
    table(11,ii)=ssval
    table(12,ii)=tyval
    table(13,ii)=slipc
;
; Array entries
;
    u74c(1,ii)=string(yval)
    u74c(2,ii)=string(xval)
    u74c(3,ii)=string(lval)
    u74c(4,ii)=string(blk1)
    u74c(5,ii)=string(blk2)
    u74c(6,ii)=string(nfval)
    u74c(7,ii)=string(sfval)
    u74c(8,ii)=string(dclos)
    u74c(9,ii)=string(dride)
    u74c(10,ii)=string(nsval)
    u74c(11,ii)=string(ssval)
    u74c(12,ii)=string(tyval)
    u74c(13,ii)=string(slipc)
    ii=ii+1
   end_if
   ic=c_next(ic)
  end_loop
  ii=1
;
; Gridpoints on joint
;
  loop while ib # 0
    cg=b_gp(ib)
    loop while cg # 0
      blkc=ib
      xval=gp_x(cg)
      yval=gp_y(cg)
      ycal=mval*xval+bval
      lval=sqrt(xval^2+(yval-bval)^2)
      dxval=gp_xdis(cg)
      dyval=gp_ydis(cg)
      thetav=atan2(dyval,dxval)
      dtvalb=sqrt((dxval*dxval)+(dyval*dyval))
      dsval=dtvalb*cos(thetav-thvalr)
      dnval=dtvalb*sin(thetav-thvalr)
;      dsval=dxval*cos(thvalr)-dyval*sin(thvalr)
;      dnval=dxval*sin(thvalr)+dyval*cos(thvalr)
      gtemp=fmem(cg+$kgtemp)
;
; Create table entries
;
      if abs(yval-ycal)<0.1 then
        table(13,ii)=yval
        table(14,ii)=xval
        table(15,ii)=lval
        table(16,ii)=blkc
        table(17,ii)=dxval
        table(18,ii)=dyval
        table(19,ii)=dsval
        table(20,ii)=dnval
;
; Array entries
;
        u74b(1,ii)=string(yval)
        u74b(2,ii)=string(xval)
        u74b(3,ii)=string(lval)
        u74b(4,ii)=string(blkc)
        u74b(5,ii)=string(dxval)
        u74b(6,ii)=string(dyval)
        u74b(7,ii)=string(dsval)
        u74b(8,ii)=string(dnval)
        u74b(9,ii)=string(gtemp)
        ii=ii+1
      end_if
      cg=gp_next(cg)
    end_loop
    ib=b_next(ib)
  end_loop
  status=open('u74cdata.out',1,1)
  status=write(u74c,2000)
  status=close
  status=open('u74bdata.out',1,1)
  status=write(u74b,2000)
end
;
set thvald=26.565051
cal contact.fin
cal jmat.fin
table_fill
;
; Write thermal histories to files
;
thist write 1 u74t1.out
thist write 2 u74t2.out
thist write 3 u74t3.out
thist write 4 u74t4.out
thist write 5 u74t5.out
thist write 6 u74t6.out
;
ret
```

Sep 28/04

UDEC input file
u74input.txt
(pg 2 of 2).

SN673 Vol 1

Case 7.4 Summary of Results (FLAC)

Parameter	Maximum		Minimum		Mean	Σ Absolute
	X	Value	X	Value	Value	Values
FLAC Shear displacement at bottom of interface (m)	58.00	1.20E-02	42.00	-1.24E-02	-3.51E-04	2.23E-01
FLAC Shear displacement at top of interface (m)	54.00	6.37E-03	46.00	-6.37E-03	1.75E-04	5.18E-02
FLAC Normal displacement at bottom of interface (m)	50.00	1.26E-02	68.00	-1.92E-03	9.17E-04	1.13E-01
FLAC Normal displacement at top of interface (m)	50.00	1.26E-02	92.00	1.62E-04	3.65E-03	1.86E-01
FLAC Relative normal displacement on interface (m)	38.00	6.71E-03	50.00	-2.55E-05	2.75E-03	1.41E-01
FLAC Relative shear displacement on interface (m)	40.00	1.01E-02	58.00	-9.58E-03	5.39E-04	1.95E-01
FLAC Total displacement at bottom of interface (m)	44.00	1.36E-02	100.00	2.97E-04	5.37E-03	2.74E-01
FLAC Total displacement at top of interface (m)	50.00	1.26E-02	90.00	2.50E-04	3.85E-03	1.96E-01
FLAC Normal stress at bottom of interface (Pa)	92.00	7.66E+05	50.00	-4.85E+07	0.00E+00	1.49E+08
FLAC Normal stress at top of interface (Pa)	92.00	7.66E+05	50.00	-4.85E+07	0.00E+00	1.49E+08
FLAC Shear stress at bottom of interface (Pa)	46.00	5.65E+07	54.00	-5.65E+07	0.00E+00	1.65E+08
FLAC Shear stress at top of interface (Pa)	46.00	5.65E+07	54.00	-5.65E+07	0.00E+00	1.65E+08
FLAC Temperature at bottom of interface (°C)	50.00	118.00	0.00	34.00	40.95	2088.20
FLAC Temperature at top of interface (°C)	50.00	101.00	0.00	34.00	39.17	1997.70
Maximum temperature at source (°C)	50.00	425.24	-	-	-	
Number of Contacts		51		51		
Number of Contacts at Slip Condition		27		27		

Sep 29/04

Case 7.4 Summary of Results (UDEC, Interpolated)

Parameter	Maximum		Minimum		Mean	Σ Absolute
	X	Value	X	Value	Value	Values
UDEC Shear displacement at bottom of interface (m)	56.00	1.54E-02	44.00	-1.53E-02	-3.56E-04	2.88E-01
UDEC Shear displacement at top of interface (m)	32.00	1.09E-03	66.00	-1.25E-03	-2.06E-05	3.03E-02
UDEC Normal displacement at bottom of interface (m)	50.00	1.53E-02	68.00	-1.29E-03	1.42E-03	1.05E-01
UDEC Normal displacement at top of interface (m)	50.00	1.52E-02	0.00	-1.73E-04	3.12E-03	1.60E-01
UDEC Relative normal displacement on interface (m)	62.00	5.64E-03	50.00	-5.62E-05	1.69E-03	8.63E-02
UDEC Relative shear displacement on interface (m)	42.00	1.51E-02	56.00	-1.54E-02	3.39E-04	3.09E-01
UDEC Total displacement at bottom of interface (m)	54.00	1.75E-02	100.00	3.74E-04	6.51E-03	3.32E-01
UDEC Total displacement at top of interface (m)	50.00	1.52E-02	6.00	9.80E-05	3.30E-03	1.68E-01
UDEC Normal stress at bottom of interface (Pa)	0.00	1.40E+06	50.00	-1.07E+08	-4.75E+06	3.12E+08
UDEC Normal stress at top of interface (Pa)	0.00	2.05E+06	47.50	-1.17E+06	7.67E+05	4.41E+07
UDEC Shear stress at bottom of interface (Pa)	47.50	2.15E+07	52.50	-2.25E+07	-4.99E+04	6.60E+07
UDEC Shear stress at top of interface (Pa)	47.50	5.46E+05	90.00	-2.43E+05	5.51E+03	1.75E+06
UDEC Temperature at bottom of interface (°C)	50.00	1.12E+02	0.00	3.40E+01	4.01E+01	2042.58
UDEC Temperature at top of interface (°C)	50.00	1.06E+02	0.00	3.40E+01	3.99E+01	2032.74
Maximum temperature at source (°C)	50.00	419.20	-	-	-	-
Number of Contacts		56		51		
Number of Contacts at Slip Condition		55		50		

Case 7.4 Relative Error between UDEC and FLAC Results*

Parameter	Maximum		Minimum		Mean	Total
	ΔX	Error	ΔX	Error	Error	Error
Shear displacement at bottom of interface (m)	-2.0	28%	2.0	24%	0%	29%
Shear displacement at top of interface (m)	-22.0	43%	20.0	41%	2%	41%
Normal displacement at bottom of interface (m)	0.0	30%	0.0	7%	6%	7%
Normal displacement at top of interface (m)	0.0	29%	-92.0	4%	6%	14%
Relative normal displacement on interface (m)	24.0	11%	0.0	0%	11%	39%
Relative shear displacement on interface (m)	2.0	49%	-2.0	58%	2%	59%
Total displacement at bottom of interface (m)	10.0	47%	0.0	1%	14%	21%
Total displacement at top of interface (m)	0.0	32%	-84.0	2%	7%	14%
Normal stress at bottom of interface (Pa)	-92.0	1%	0.0	120%	10%	109%
Normal stress at top of interface (Pa)	-92.0	3%	-2.5	98%	2%	70%
Shear stress at bottom of interface (Pa)	1.5	62%	-1.5	60%	0%	60%
Shear stress at top of interface (Pa)	1.5	99%	36.0	100%	0%	99%
Temperature at bottom of interface (°C)	0.0	7%	0.0	0%	1%	2%
Temperature at top of interface (°C)	0.0	7%	0.0	0%	1%	2%
Maximum temperature at source (°C)	0.0	-1%	-	-	-	
Number of Contacts		10%		0%		
Number of Contacts at Slip Condition		55%		45%		

* Relative error calculated as difference between UDEC and FLAC values normalized to maximum deviation from mean along interface in either total displacement, stress, or temperature

From file C74.xls
/Case7/UDEC/

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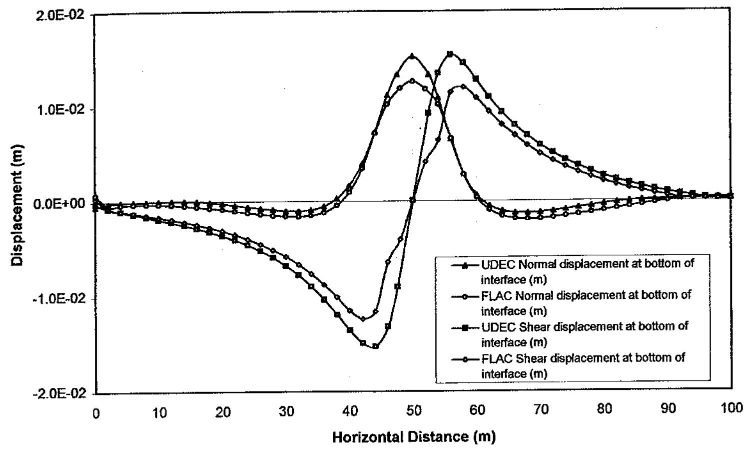
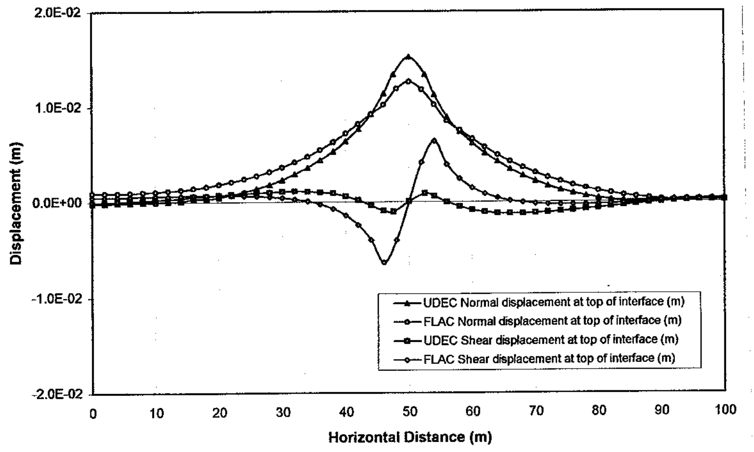
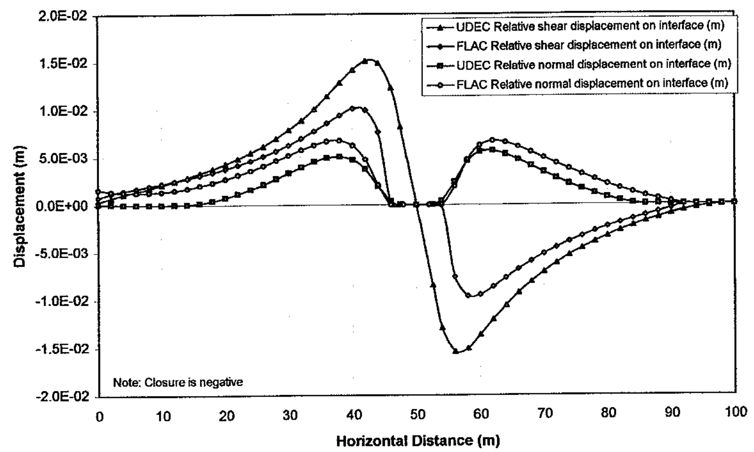
Case 7.4 - Comparison of Results for an Inclined Interface Subjected to a Volumetric Heat Source (Slip Allowed)



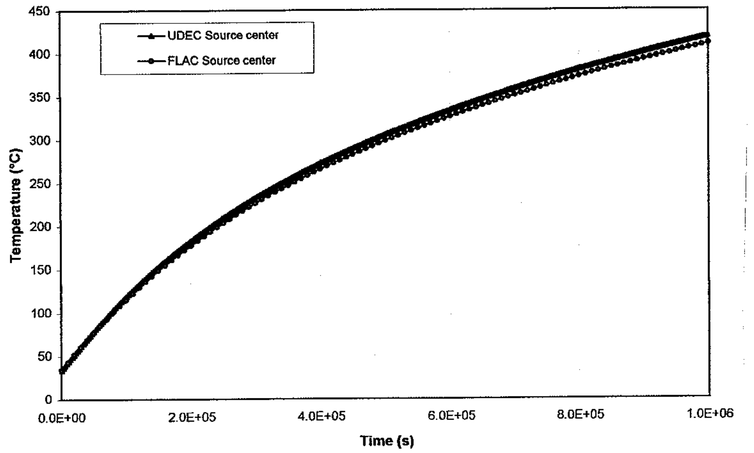
Case 7.4 - Comparison of Results for an Inclined Interface Subjected to a Volumetric Heat Source (Slip Allowed)



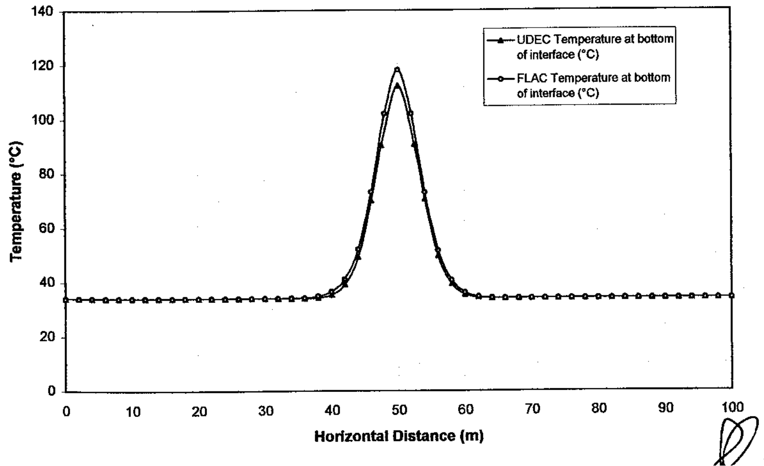
Case 7.4 - Comparison of Results for an Inclined Interface Subjected to a Volumetric Heat Source (Slip Allowed)



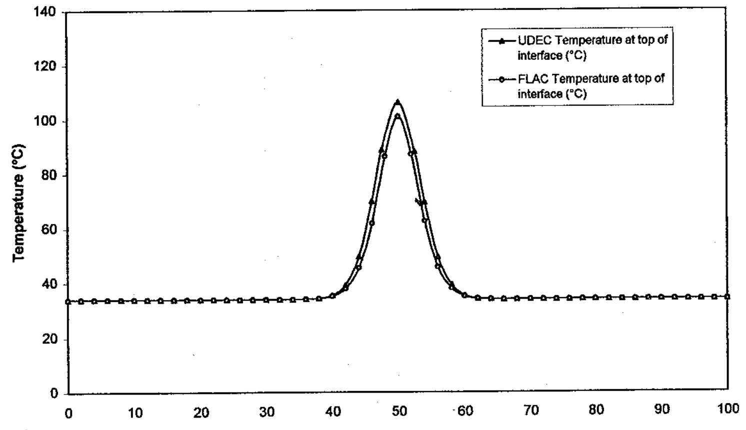
Case 7.4 - Comparison of Results for an Inclined Interface Subjected to a Volumetric Heat Source (Slip Allowed)



Case 7.4 - Comparison of Results for an Inclined Interface Subjected to a Volumetric Heat Source (Slip Allowed)



Case 7.4 - Comparison of Results for an Inclined Interface Subjected to a Volumetric Heat Source (Slip Allowed)



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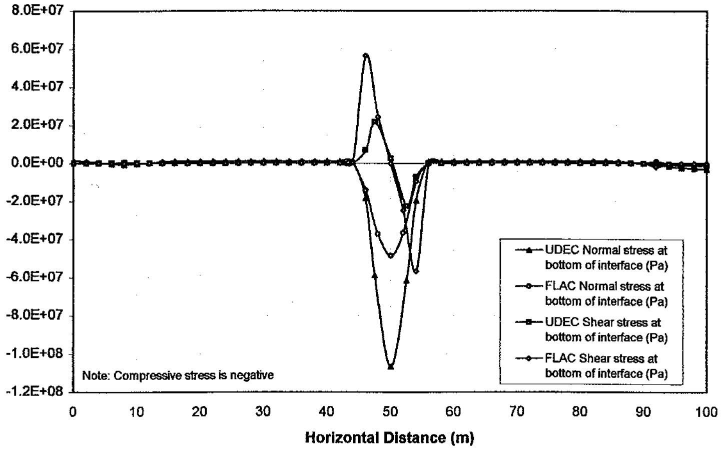
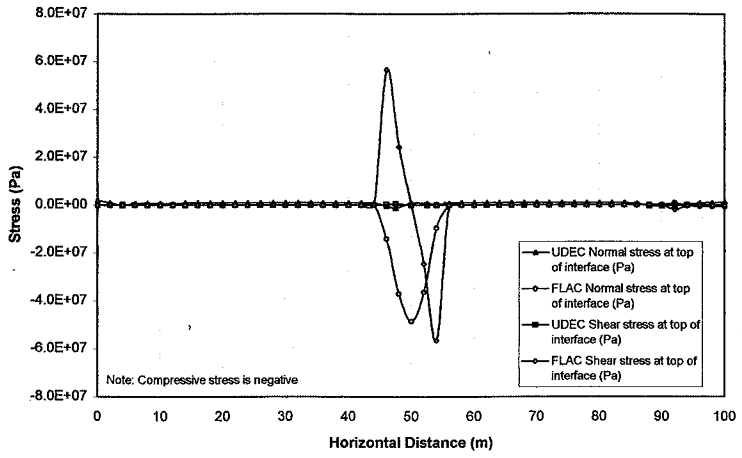
File C74.xls
/Case7/UDEC/

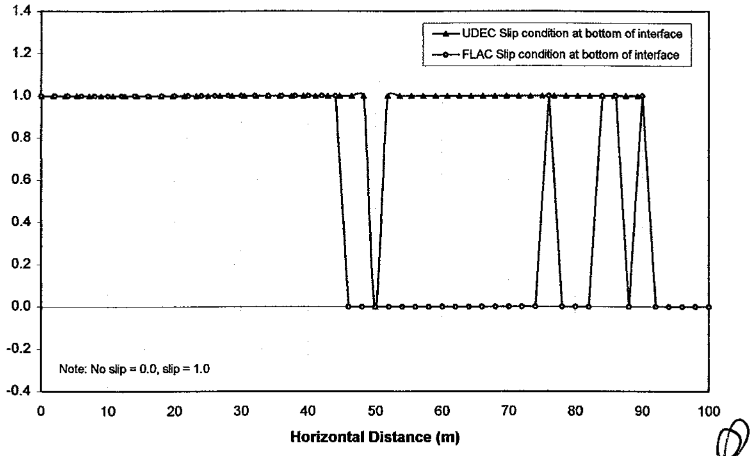
Case 7.4 - Comparison of Results for an Inclined Interface Subjected to a Volumetric Heat Source (Slip Allowed)



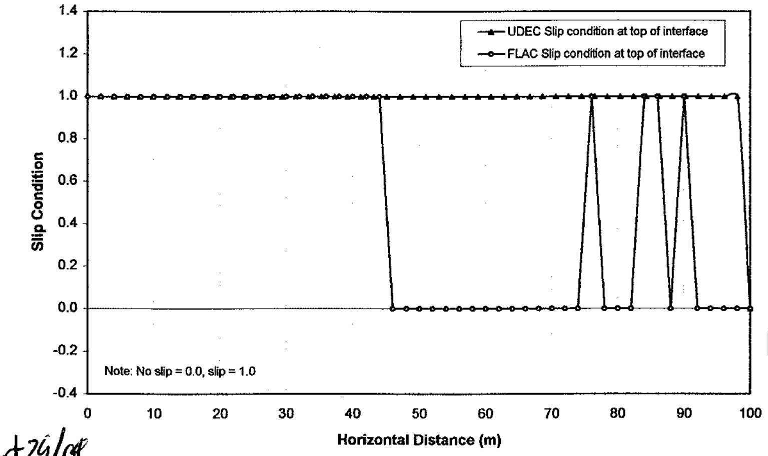
Case 7.4 - Comparison of Results for an Inclined Interface Subjected to a Volumetric Heat Source (Slip Allowed)



Case 7.4 - Comparison of Results for an Inclined Interface Subjected to a Volumetric Heat Source (Slip Allowed)



Case 7.4 - Comparison of Results for an Inclined Interface Subjected to a Volumetric Heat Source (Slip Allowed)



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File C74.xls /Case7/UDEC/.

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Revised U73.xls with new block data (previous file had block data sorted improperly, confusing the upper and lower blocks). New data imported into C73.xls to compare FLAC and UDEC results. Revised summary table shown on page 71.

* FLAC and UDEC license renewed to end of October.

Case 7.3 Summary of Results (FLAC)

Parameter	Maximum		Minimum		Mean	Σ Absolute
	X	Value	X	Value	Value	Values
FLAC Shear displacement at bottom of interface (m)	56.00	7.05E-03	44.00	-6.96E-03	4.89E-05	1.36E-01
FLAC Shear displacement at top of interface (m)	56.00	6.86E-03	44.00	-6.78E-03	5.02E-05	1.34E-01
FLAC Normal displacement at bottom of interface (m)	50.00	1.13E-02	2.00	-9.56E-05	2.02E-03	1.03E-01
FLAC Normal displacement at top of interface (m)	50.00	1.10E-02	2.00	-9.88E-05	2.01E-03	1.03E-01
FLAC Relative normal displacement on interface (m)	60.00	3.81E-05	50.00	-2.70E-04	-1.05E-05	1.37E-03
FLAC Relative shear displacement on interface (m)	46.00	2.15E-04	54.00	-2.21E-04	1.26E-06	1.96E-03
FLAC Total displacement at bottom of interface (m)	50.00	1.13E-02	0.00	1.79E-04	3.60E-03	1.83E-01
FLAC Total displacement at top of interface (m)	50.00	1.10E-02	0.00	1.81E-04	3.55E-03	1.81E-01
FLAC Normal stress at bottom of interface (Pa)	60.00	7.24E+06	50.00	-5.13E+07	0.00E+00	2.60E+08
FLAC Normal stress at top of interface (Pa)	60.00	7.24E+06	50.00	-5.13E+07	0.00E+00	2.60E+08
FLAC Shear stress at bottom of interface (Pa)	46.00	2.80E+07	54.00	-2.87E+07	0.00E+00	2.55E+08
FLAC Shear stress at top of interface (Pa)	46.00	2.80E+07	54.00	-2.87E+07	0.00E+00	2.55E+08
FLAC Temperature at bottom of interface (°C)	50.00	118.14	0.00	34.00	40.95	2088.52
FLAC Temperature at top of interface (°C)	50.00	100.82	0.00	34.00	39.16	1997.40
Maximum temperature at source (°C)	50.00	425.24	-	-	-	
Number of Contacts		51		51		
Number of Contacts at Slip Condition		0		0		

Case 7.3 Summary of Results (UDEC, Interpolated)

Parameter	Maximum		Minimum		Mean	Σ Absolute
	X	Value	X	Value	Value	Values
UDEC Shear displacement at bottom of interface (m)	56.00	7.17E-03	44.00	-7.20E-03	3.43E-05	1.39E-01
UDEC Shear displacement at top of interface (m)	56.00	6.96E-03	44.00	-6.99E-03	3.92E-05	1.37E-01
UDEC Normal displacement at bottom of interface (m)	50.00	1.14E-02	0.00	-1.73E-04	1.99E-03	1.02E-01
UDEC Normal displacement at top of interface (m)	50.00	1.09E-02	0.00	-1.74E-04	1.97E-03	1.01E-01
UDEC Relative normal displacement on interface (m)	58.00	5.51E-05	50.00	-4.94E-04	-1.33E-05	1.93E-03
UDEC Relative shear displacement on interface (m)	46.00	3.75E-04	54.00	-3.73E-04	1.41E-06	2.74E-03
UDEC Total displacement at bottom of interface (m)	50.00	1.14E-02	0.00	1.93E-04	3.62E-03	1.85E-01
UDEC Total displacement at top of interface (m)	50.00	1.11E-02	0.00	1.95E-04	3.58E-03	1.82E-01
UDEC Normal stress at bottom of interface (Pa)	58.00	1.05E+07	50.00	-9.38E+07	-2.51E+06	3.67E+08
UDEC Normal stress at top of interface (Pa)	60.00	5.40E+06	47.50	-1.59E+07	-9.67E+05	1.46E+08
UDEC Shear stress at bottom of interface (Pa)	46.00	4.87E+07	54.00	-4.85E+07	1.83E+05	3.56E+08
UDEC Shear stress at top of interface (Pa)	42.00	1.31E+07	58.00	-1.33E+07	1.95E+05	1.53E+08
UDEC Temperature at bottom of interface (°C)	50.00	1.12E+02	0.00	3.40E+01	4.00E+01	2042.17
UDEC Temperature at top of interface (°C)	50.00	1.06E+02	0.00	3.40E+01	3.99E+01	2033.09
Maximum temperature at source (°C)	50.00	419.20	-	-	-	-
Number of Contacts		56		51		
Number of Contacts at Slip Condition		0		0		

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Case 7.3 Relative Error between UDEC and FLAC Results*

Parameter	Maximum		Minimum		Mean	Total
	ΔX	Error	ΔX	Error	Error	Error
Shear displacement at bottom of interface (m)	0.0	2%	0.0	3%	0%	2%
Shear displacement at top of interface (m)	0.0	1%	0.0	3%	0%	2%
Normal displacement at bottom of interface (m)	0.0	1%	-2.0	1%	0%	1%
Normal displacement at top of interface (m)	0.0	1%	-2.0	1%	0%	2%
Relative normal displacement on interface (m)	-2.0	7%	0.0	86%	1%	41%
Relative shear displacement on interface (m)	0.0	62%	0.0	59%	0%	40%
Total displacement at bottom of interface (m)	0.0	1%	0.0	0%	0%	1%
Total displacement at top of interface (m)	0.0	1%	0.0	0%	0%	1%
Normal stress at bottom of interface (Pa)	-2.0	6%	0.0	83%	5%	41%
Normal stress at top of interface (Pa)	0.0	4%	-2.5	69%	2%	44%
Shear stress at bottom of interface (Pa)	0.0	72%	0.0	69%	1%	40%
Shear stress at top of interface (Pa)	-4.0	52%	4.0	54%	1%	40%
Temperature at bottom of interface (°C)	0.0	8%	0.0	0%	1%	2%
Temperature at top of interface (°C)	0.0	7%	0.0	0%	1%	2%
Maximum temperature at source (°C)	0.0	-1%	-	-	-	
Number of Contacts		10%		0%		
Number of Contacts at Slip Condition		0%		0%		

* Relative error calculated as difference between UDEC and FLAC values normalized to maximum deviation from mean along interface in either total displacement, stress, or temperature

Revised Case 7.3 comparison tables.

Sep30/04

- Created input file u77input.txt and performed a test run. Properties selected to match FLAC case 7.7.
- modified plot parameters in U77input.txt and U73input.txt → rerun both to create new plots. Plots saved under: /Case7/UDEC/.

(Note: Old files overwritten with newest plots).

* Request to submit scientific notebooks for copying received from CNWRA.

- modified portion of U73input.txt on pg 72 (below)
- Results from Case 7.7 (UDEC) and file u77input.txt are attached on paper.

```
; Joint condition plots
;
set out u73jndl.emf
set color iw
plot joint 0 25 100 75 ndisp 2
copy
;
set out u73jnsl.emf
set color iw
plot joint 0 25 100 75 nstr 2
copy
;
set out u73jsdl.emf
set color iw
plot joint 0 25 100 75 sdisp 2
copy
;
set out u73jssl.emf
set color iw
plot joint 0 25 100 75 sstr 2
copy
;
```

Sep 30/04

Modified portion of u73input.txt

```
; Case 7.7 UDEC Base case with inclined transgressing joint
in a heated
; infinite rock mass (no slip allowed on joint, typical Yucca
Mountain
; properties and conditions used, source 1500 W/m).
;
config thermal
set mech on
;
; Key Points
;
;A, 0.000, 37.534
;B, 100.000, 62.466
;C, 0.000, 34.957
;D, 100.000, 59.890
;E, 0.000, 29.804
;F, 100.000, 54.737
;G, 48.179, 46.969
;H, 49.389, 42.118
;I, 53.031, 48.179
;J, 54.240, 43.328
;K, 51.210, 45.149
;L, 50.605, 47.574
;M, 50.000, 50.000
;N, 48.790, 54.851
;O, 45.162, 69.406
;P, 37.534, 100.000
;Q, 0.000, 37.534
;R, 18.465, 42.138
;S, 30.594, 45.162
;T, 40.297, 47.581
;U, 47.574, 49.395
;V, 50.000, 50.000
;W, 52.426, 50.605
;X, 59.703, 52.419
;Y, 69.406, 54.838
;Z, 81.535, 57.862
;AA, 100.000, 62.466
;
; Geometry
;
rou 0.001
bl 0,0 0,100 100,100 100,0
crack 0.000 37.534 100.000 62.466 ; Main joint A-B
crack 0.000 34.957 100.000 59.890 ; Top C-D
crack 0.000 29.804 100.000 54.737 ; Bottom E-F
crack 48.179 46.969 49.389 42.118 ; Left side G-H
crack 53.031 48.179 54.240 43.328 ; Right side I-J
;
;
gen quad 2.0
;
; Material properties
;
prop m=1 de=2210.0 k=19.2e9 g=13.6e9
prop jm=1 jkn=5.0e11 jks=5.0e11
prop jm=1 jcoh=1.0e20 jfric=0.0 jten=1.0e20 jd=0
prop m=1 thexp=10.0e-6 cond=2.13 spec=990.0
;
prop jm=2 jkn=5.0e4 jks=5.0e4
prop jm=2 jcoh=100.0e3 jfric=41.0 jten=40.0e3 jd=0
;
; Initial conditions
;
initemp 25.0 0 100 0 100
;
ini syy -8.1e6 grad 0 0.022e6
ini sxx -2.1546e6 grad 0 0.005852e6
ini sxy 0.0
ini szz -2.1546e6 grad 0 0.005852e6
;
; Boundary conditions
;
bound yvel 0.0 range (0,100) (-0.1, 0.1)
bound yvel 0.0 range (0,100) (99.1, 100.1)
bound xvel 0.0 range (-0.1, 0.1) (0,100)
bound xvel 0.0 range (99.1, 100.1) (0,100)
;
; Apply heat source
;
thapp source 1500 0 range 49.389 53.031 43.328 46.969
;
; Equilibrate model
;
set ovtol 0.1
step 4000
;
; Alter joint properties
;
;change jmat=2 range block 358 143
;change jmat=2 range block 143 358
;
; Zero displacements and velocities
;
ini xd 0
```

```
ini yd 0
ini nd 0
ini sd 0
ini xv 0
ini yv 0
ini bxv 0
ini byv 0
ini brv 0
;
; Thermal histories
;
thist temp 51.210, 45.149  ; 1
thist temp 50.605, 47.574  ; 2
thist temp 50.000, 50.000  ; 3
thist temp 48.790, 54.851  ; 4
thist temp 45.162, 69.406  ; 5
thist temp 37.534, 100.000 ; 6
;
; Time and unbalanced force histories
;
hist thtime ; 1
hist unbal ; 2
;
; Mechanical histories
;
hist ydisp 51.210, 45.149  ; 3
hist ydisp 50.605, 47.574  ; 4
hist ydisp 50.000, 50.000  ; 5
hist ydisp 48.790, 54.851  ; 6
hist ydisp 45.162, 69.406  ; 7
hist ydisp 37.534, 100.000 ; 8
;
hist xdisp 51.210, 45.149  ; 9
hist xdisp 50.605, 47.574  ; 10
hist xdisp 50.000, 50.000  ; 11
hist xdisp 48.790, 54.851  ; 12
hist xdisp 45.162, 69.406  ; 13
hist xdisp 37.534, 100.000 ; 14
;
; Histories of normal displacement along joint
;
hist ndis 0.000  37.534 ;15
hist ndis 18.465 42.138 ;16
hist ndis 30.594 45.162 ;17
hist ndis 40.297 47.581 ;18
hist ndis 47.574 49.395 ;19
hist ndis 50.000 50.000 ;20
hist ndis 52.426 50.605 ;21
hist ndis 59.703 52.419 ;22
hist ndis 69.406 54.838 ;23
hist ndis 81.535 57.862 ;24
hist ndis 100.00 62.466 ;25
;
; Histories of shear displacement along joint
;
hist sdis 0.000  37.534 ;26
hist sdis 18.465 42.138 ;27
hist sdis 30.594 45.162 ;28
hist sdis 40.297 47.581 ;29
hist sdis 47.574 49.395 ;30
hist sdis 50.000 50.000 ;31
hist sdis 52.426 50.605 ;32
hist sdis 59.703 52.419 ;33
hist sdis 69.406 54.838 ;34
hist sdis 81.535 57.862 ;35
hist sdis 100.00 62.466 ;36
;
; Histories of sratio along joint
;
hist srat 0.000  37.534 ;37
hist srat 18.465 42.138 ;38
hist srat 30.594 45.162 ;39
hist srat 40.297 47.581 ;40
hist srat 47.574 49.395 ;41
hist srat 50.000 50.000 ;42
hist srat 52.426 50.605 ;43
hist srat 59.703 52.419 ;44
hist srat 69.406 54.838 ;45
hist srat 81.535 57.862 ;46
hist srat 100.00 62.466 ;47
;
; Thermal mechanical analysis
;
damp auto
run age 50000
step 2000
set nther 2500
set nmech 2000
run age 315400000 temp 50 s 1000000
step 4000
;
cal dispmag.fis
disp_mag
save u77final.sav
;
```

Sep 30/04.

File
u77input.txt
(pg 1 of 3)

```
set plot emf color
title
Case 7.7 Inclined Transgressing Joint (UDEC, No Slip Allowed)
;
; Geometry
;
set out u77grid.emf
set color iw
plo zone green blo iw
copy

; Joint condition plots
;
set out u77jndl.emf
set color iw
plot joint 0 37.534 100 62.466 ndisp 2
copy
;
set out u77jnsl.emf
set color iw
plot joint 0 37.534 100 62.466 nstr 2
copy
;
set out u77jsdl.emf
set color iw
plot joint 0 37.534 100 62.466 sdisp 2
copy
;
set out u77jssl.emf
set color iw
plot joint 0 37.534 100 62.466 sstr 2
copy
;
set out u77shear.emf
set color iw
plo blo iw shear red
copy
;
set out u77slip.emf
set color iw
plo blo iw slip red
copy
;
; Contour plots
;
set out u77temp.emf
set color iw
plot temp fill temp iw blo iw
copy
;
set out u77disp.emf
set color iw
plot gp_extra fill alias 'Displacement' gp_extra iw disp iw
blo iw
copy
;
set out u77xd.emf
set color iw
plot xd fill xd iw blo iw
copy
;
set out u77yd.emf
set color iw
plot yd fill yd iw blo iw
copy
;
set out u77sig1.emf
set color iw
plot sig1 fill sig1 iw blo iw
copy
;
set out u77sig2.emf
set color iw
plot sig2 fill sig2 iw blo iw
copy
;
set out u77sdif.emf
set color iw
plot sdiff fill sdiff iw blo iw
copy
;
; History plots
;
set out u77thist.emf
set color iw
plo thist 1 2 3 4 5 6
copy
;
set out u77ydhist.emf
set color iw
plo hist 3 4 5 6 7 8
copy
;
set out u77xdhist.emf
set color iw
plo hist 9 10 11 12 13 14
copy
;
set out u77unbal.emf
set color iw
plo hist 2
copy
;
set out u77jndh.emf
set color iw
plo hist 15 16 17 18 19 20 21 22 23 24 25 vs 1
copy
;
set out u77jsdh.emf
set color iw
plo hist 26 27 28 29 30 31 32 33 34 35 36 vs 1
copy
;
set out u77jsrh.emf
set color iw
plo hist 37 38 39 40 41 42 43 44 45 46 47 vs 1
copy
;
;
; Create output tables
;
def xxx
  nn=2000
end
xxx
def table_fill
  array u77c(13,nn)
  array u77b(9,nn)
  ic=contact_head
  ib=block_head
  ii=1
  thvalr=thvald*pi/180.0
  mval=tan(thvalr)
  bval=50.0-50.0*mval
;
; Contact information
;
  loop while ic # 0
    xval=c_x(ic)
    yval=c_y(ic)
    ycal=mval*xval+bval
    lval=sqrt(xval^2+(yval-bval)^2)
    blk1=c_b1(ic)
    blk2=c_b2(ic)
    clval=c_length(ic)
    dclos=c_ndis(ic)
    dride=c_sdis(ic)
    nfval=c_nforce(ic)
    sfval=c_sforce(ic)
    nsval=-nfval/clval
    ssval=-sfval/clval
    tyval=c_type(ic)
    slipc=fmem(ic+$kgam)
;
; Create table entries
;
   if abs(yval-ycal)<0.1 then
    table(1,ii)=yval
    table(2,ii)=xval
    table(3,ii)=lval
    table(4,ii)=blk1
    table(5,ii)=blk2
    table(6,ii)=nfval
    table(7,ii)=sfval
    table(8,ii)=dclos
    table(9,ii)=dride
    table(10,ii)=nsval
    table(11,ii)=ssval
    table(12,ii)=tyval
    table(13,ii)=slipc
;
; Array entries
;
    u77c(1,ii)=string(yval)
    u77c(2,ii)=string(xval)
    u77c(3,ii)=string(lval)
    u77c(4,ii)=string(blk1)
    u77c(5,ii)=string(blk2)
    u77c(6,ii)=string(nfval)
    u77c(7,ii)=string(sfval)
    u77c(8,ii)=string(dclos)
    u77c(9,ii)=string(dride)
    u77c(10,ii)=string(nsval)
    u77c(11,ii)=string(ssval)
    u77c(12,ii)=string(tyval)
    u77c(13,ii)=string(slipc)
    ii=ii+1
   end_if
   ic=c_next(ic)
  end_loop
```

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File
u77input.txt
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```
  ii=1
;
; Gridpoints on joint
;
  loop while ib # 0
    cg=b_gp(ib)
    loop while cg # 0
      blkc=ib
      xval=gp_x(cg)
      yval=gp_y(cg)
      ycal=mval*xval+bval
      lval=sqrt(xval^2+(yval-bval)^2)
      dxval=gp_xdis(cg)
      dyval=gp_ydis(cg)
      thetav=atan2(dyval,dxval)
      dtvalb=sqrt((dxval*dxval)+(dyval*dyval))
      dsval=dtvalb*cos(thetav-thvalr)
      dnval=dtvalb*sin(thetav-thvalr)
      gtemp=fmem(cg+$kgtemp)
;
; Create table entries
;
      if abs(yval-ycal)<0.1 then
        table(13,ii)=yval
        table(14,ii)=xval
        table(15,ii)=lval
        table(16,ii)=blkc
        table(17,ii)=dxval
        table(18,ii)=dyval
        table(19,ii)=dsval
        table(20,ii)=dnval
;
; Array entries
;
        u77b(1,ii)=string(yval)
        u77b(2,ii)=string(xval)
        u77b(3,ii)=string(lval)
        u77b(4,ii)=string(blkc)
        u77b(5,ii)=string(dxval)
        u77b(6,ii)=string(dyval)
        u77b(7,ii)=string(dsval)
        u77b(8,ii)=string(dnval)
        u77b(9,ii)=string(gtemp)
        ii=ii+1
      end_if
      cg=gp_next(cg)
    end_loop
    ib=b_next(ib)
  end_loop
  status=open('u77cdata.out',1,1)
  status=write(u77c,2000)
  status=close
  status=open('u77bdata.out',1,1)
  status=write(u77b,2000)
end
;
set thvald=14.0
cal contact.fin
cal jmat.fin
table_fill
;
; Write thermal histories to files
;
thist write 1 u77t1.out
thist write 2 u77t2.out
thist write 3 u77t3.out
thist write 4 u77t4.out
thist write 5 u77t5.out
thist write 6 u77t6.out
;
ret
```

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UDEC file
u77input.txt
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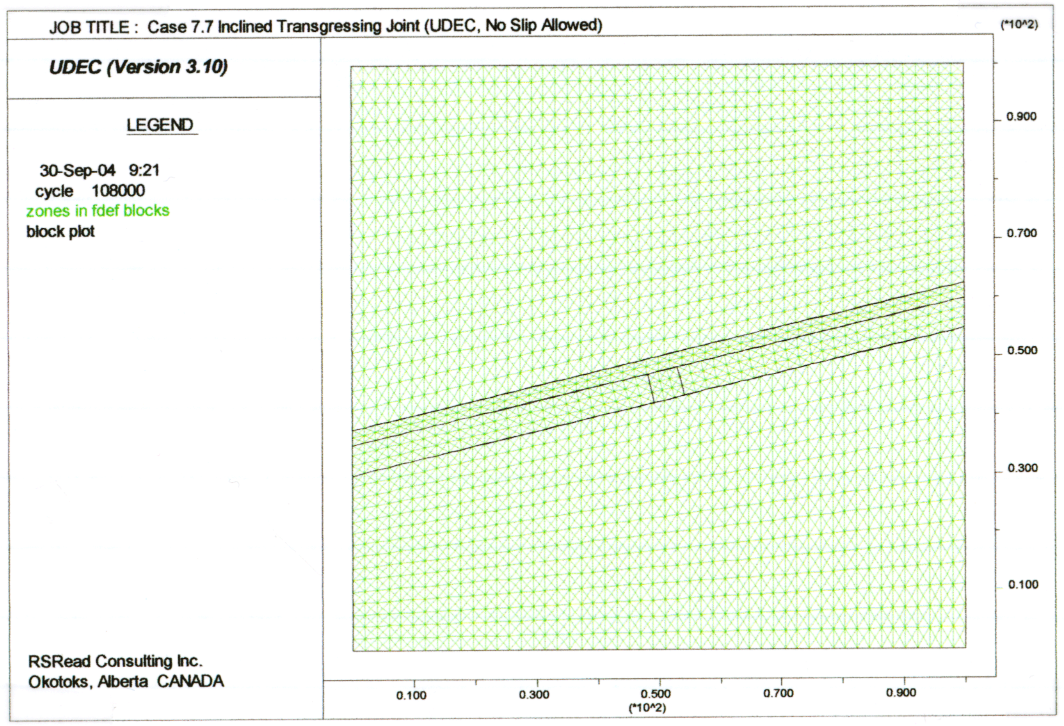

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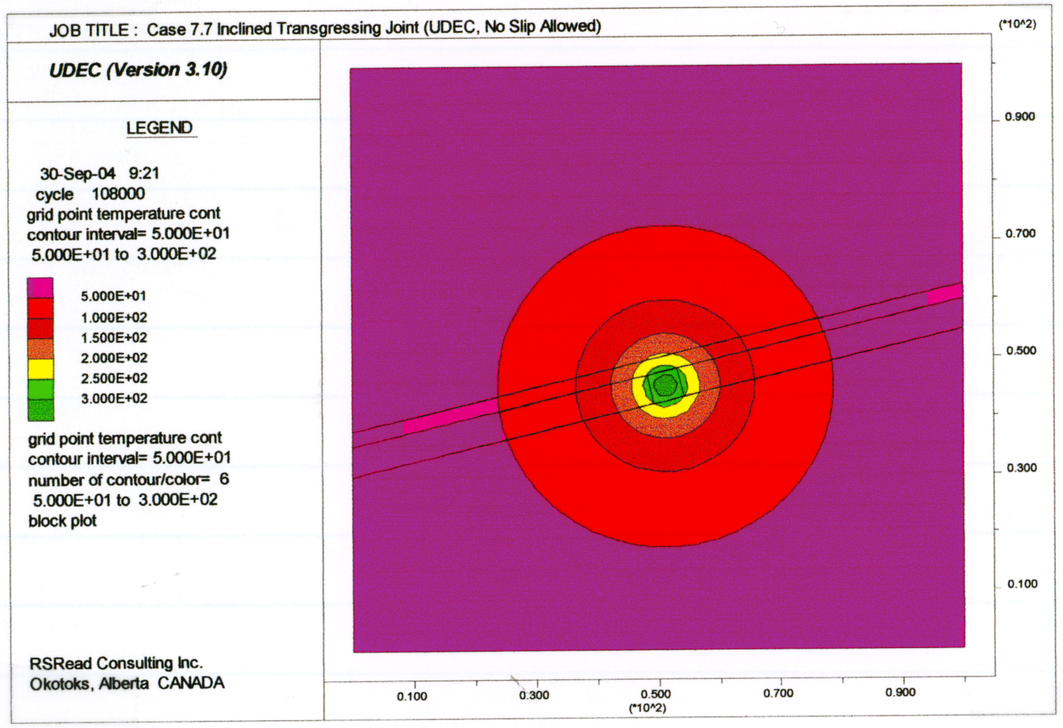
File u77grid.emf Grid for cases 7.7 (UDEC)
7.8, 7.9, 7.10, 7.11, 7.12, 7.13



File u77temp.emf Temperature contours Case 7.7

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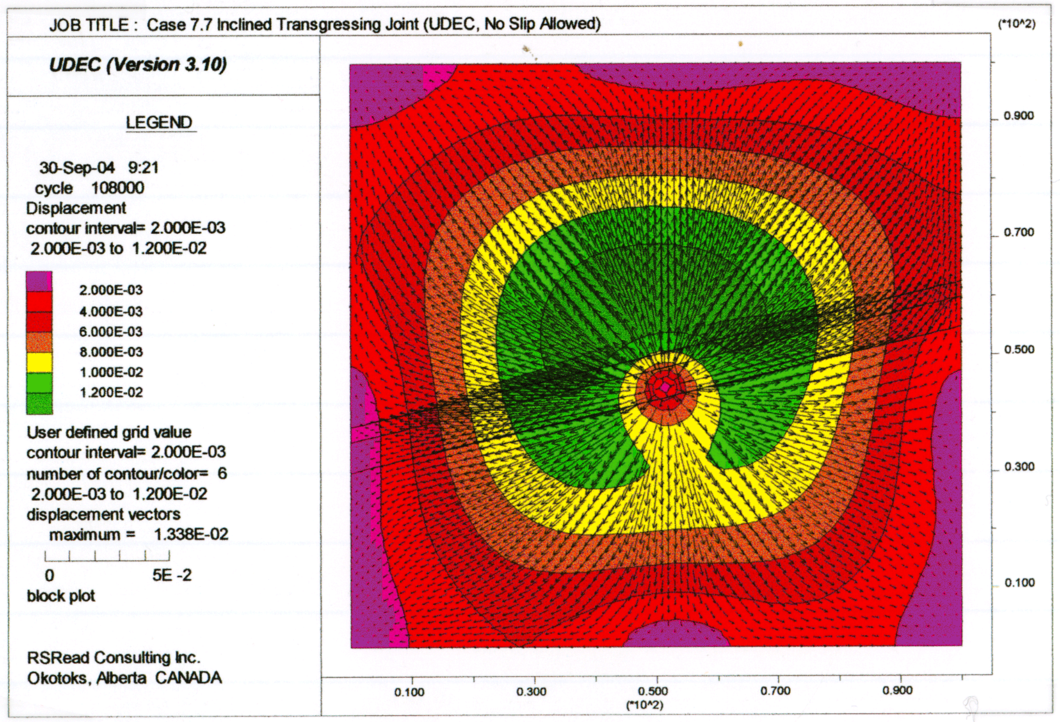

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File u77disp.emf Displacement contours and vectors for Case 7.7 (UDEC

Case 7.7 Summary of Results (FLAC)

Parameter	Maximum		Minimum		Mean	Σ Absolute
	X	Value	X	Value	Value	Values
FLAC Shear displacement at bottom of interface (m)	66.00	1.10E-02	34.00	-1.10E-02	1.37E-04	3.48E-01
FLAC Shear displacement at top of interface (m)	66.00	1.10E-02	34.00	-1.10E-02	1.38E-04	3.47E-01
FLAC Normal displacement at bottom of interface (m)	50.00	9.71E-03	0.00	2.71E-04	4.48E-03	2.29E-01
FLAC Normal displacement at top of interface (m)	50.00	9.60E-03	0.00	2.69E-04	4.46E-03	2.27E-01
FLAC Relative normal displacement on interface (m)	0.00	-1.49E-06	50.00	-1.06E-04	-2.49E-05	1.27E-03
FLAC Relative shear displacement on interface (m)	44.00	1.99E-05	56.00	-2.00E-05	1.81E-06	4.30E-04
FLAC Total displacement at bottom of interface (m)	38.00	1.23E-02	0.00	2.80E-04	8.52E-03	4.34E-01
FLAC Total displacement at top of interface (m)	36.00	1.23E-02	0.00	2.78E-04	8.50E-03	4.33E-01
FLAC Normal stress at bottom of interface (Pa)	0.00	-7.71E+06	50.00	-5.99E+07	0.00E+00	9.77E+08
FLAC Normal stress at top of interface (Pa)	0.00	-7.71E+06	50.00	-5.99E+07	0.00E+00	9.77E+08
FLAC Shear stress at bottom of interface (Pa)	44.00	8.74E+06	56.00	-1.12E+07	0.00E+00	2.06E+08
FLAC Shear stress at top of interface (Pa)	44.00	8.74E+06	56.00	-1.12E+07	0.00E+00	2.06E+08
FLAC Temperature at bottom of interface (°C)	50.00	207.52	100.00	29.42	75.98	3874.99
FLAC Temperature at top of interface (°C)	50.00	207.11	0.00	29.34	75.73	3862.22
Maximum temperature at source (°C)	51.21	322.38	-	-	-	
Number of Contacts		51		51		
Number of Contacts at Slip Condition		0		0		

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Case 7.7 Summary of Results (UDEC, Interpolated)

Parameter	Maximum		Minimum		Mean	Σ Absolute
	X	Value	X	Value	Value	Values
UDEC Shear displacement at bottom of interface (m)	66.00	1.11E-02	34.00	-1.11E-02	1.48E-04	3.52E-01
UDEC Shear displacement at top of interface (m)	66.00	1.11E-02	34.00	-1.11E-02	1.50E-04	3.52E-01
UDEC Normal displacement at bottom of interface (m)	50.00	9.75E-03	0.00	2.33E-04	4.47E-03	2.28E-01
UDEC Normal displacement at top of interface (m)	50.00	9.59E-03	0.00	2.31E-04	4.45E-03	2.27E-01
UDEC Relative normal displacement on interface (m)	8.00	-1.70E-05	50.00	-1.80E-04	-3.89E-05	1.98E-03
UDEC Relative shear displacement on interface (m)	46.00	8.87E-05	54.00	-9.18E-05	-1.41E-07	1.27E-03
UDEC Total displacement at bottom of interface (m)	64.00	1.24E-02	0.00	2.40E-04	8.58E-03	4.38E-01
UDEC Total displacement at top of interface (m)	64.00	1.24E-02	0.00	2.38E-04	8.56E-03	4.37E-01
UDEC Normal stress at bottom of interface (Pa)	8.00	-8.48E+06	50.00	-8.99E+07	-1.94E+07	9.92E+08
UDEC Normal stress at top of interface (Pa)	6.00	-8.31E+06	56.00	-4.16E+07	-1.88E+07	9.57E+08
UDEC Shear stress at bottom of interface (Pa)	46.00	4.43E+07	54.00	-4.59E+07	-7.05E+04	6.34E+08
UDEC Shear stress at top of interface (Pa)	54.00	2.51E+07	46.00	-2.78E+07	-2.23E+05	2.96E+08
UDEC Temperature at bottom of interface (°C)	50.00	2.10E+02	100.00	2.93E+01	7.60E+01	3874.16
UDEC Temperature at top of interface (°C)	50.00	2.08E+02	100.00	2.93E+01	7.59E+01	3871.56
Maximum temperature at source (°C)	50.00	326.70	-	-	-	-
Number of Contacts		52		51		
Number of Contacts at Slip Condition		0		0		

Case 7.7 Relative Error between UDEC and FLAC Results*

Parameter	Maximum		Minimum		Mean	Total
	ΔX	Error	ΔX	Error	Error	Error
Shear displacement at bottom of interface (m)	0.0	1%	0.0	1%	0%	1%
Shear displacement at top of interface (m)	0.0	1%	0.0	1%	0%	1%
Normal displacement at bottom of interface (m)	0.0	1%	0.0	1%	0%	0%
Normal displacement at top of interface (m)	0.0	0%	0.0	1%	0%	0%
Relative normal displacement on interface (m)	8.0	19%	0.0	90%	17%	56%
Relative shear displacement on interface (m)	2.0	84%	-2.0	88%	2%	195%
Total displacement at bottom of interface (m)	26.0	2%	0.0	0%	1%	1%
Total displacement at top of interface (m)	28.0	2%	0.0	0%	1%	1%
Normal stress at bottom of interface (Pa)	8.0	1%	0.0	50%	32%	2%
Normal stress at top of interface (Pa)	6.0	1%	6.0	30%	31%	2%
Shear stress at bottom of interface (Pa)	2.0	317%	-2.0	309%	1%	208%
Shear stress at top of interface (Pa)	10.0	146%	-10.0	148%	2%	43%
Temperature at bottom of interface (°C)	0.0	2%	0.0	0%	0%	0%
Temperature at top of interface (°C)	0.0	1%	100.0	0%	0%	0%
Maximum temperature at source (°C)	-1.2	1%	-	-	-	
Number of Contacts		2%		0%		
Number of Contacts at Slip Condition		0%		0%		

* Relative error calculated as difference between UDEC and FLAC values normalized to maximum deviation from mean along interface in either total displacement, stress, or temperature

Comparison tables for Case 7.7

File C77.XLS