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;-----
;                               Creep of Cylindrical Cavern
;                               anisotropic in-situ stress field
;                               (units: m, MPa, year)
;-----

config creep
;
; create model (quarter-symmetry)
gen zone radcyl size 8 12 6 12  rat 1.0 1.0 1.0 1.2  fill  &
    p2 0 0 0  p4 250 0 0  p5 0 250 0  p7 250 250 0  &
    p0 0 0 45  p1 250 0 45  p3 0 250 45  p6 250 250 45  &
    p10 45 0 0  p11 0 45 0  &
    p8 45 0 45  p9 0 45 45
;
gen zone radcyl size 8 8 6 12  rat 1.0 1.2 1.0 1.2  fill  &
    p0 0 0 45  p3 250 0 45  p1 0 250 45  p6 250 250 45  &
    p2 0 0 250  p5 250 0 250  p4 0 250 250  p7 250 250 250  &
    p10 0 45 250  p11 45 0 250  &
    p8 0 45 45  p9 45 0 45
;
; define four groups
group salt  range z 0 30
group cavern range cyl end1 0 0 0 end2 0 0 15 rad 45
group mat2  range z 30 45
group mat3  range z 45 250
;
; assign material models
model power  range group cavern
model power  range group salt
model elastic range group mat2
model elastic range group mat3
;
; material properties
; salt: E=10e6 psi ; Poisson's ratio=0.3
prop bulk 58.3e3  shear 26.9e3 range group salt
prop bulk 58.3e3  shear 26.9e3 range group cavern
; A = 3.9 MPa**(-n) * yr**(-1) ; n=4.9
prop a_1=3.9e-7 n_1=4.9  range group salt
prop a_1=3.9e-7 n_1=4.9  range group cavern
;
; mat2: E=30e6 psi ; Poisson's ratio=0.3
prop bulk 175e3  shear 80.7e3 range group mat2
;
; mat3: E=10e6 psi ; Poisson's ratio=0.3

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prop bulk 58.3e3 shear 26.9e3 range group mat3
;
; boundary and initial conditions
fix x ran x -0.1 0.1
fix y ran y -0.1 0.1
fix z ran z -0.1 0.1
fix x range x 249 251
fix y range y 249 251
apply szz -35 range z 249 251
ini sxx -56 syy -28 szz -35
;
; creep parameters
set creep on
set cr dt 1.0e-5
set cr mindt 1.0e-5
set cr maxdt 1.0e-3
set cr dt auto on
;
; histories
hist unbal
hist crtime
hist dt
;
hist gp xdis 45 0 0
hist gp ydis 0 45 0
hist gp zdis 0 0 15
;
hist z sxx 0 0 16
hist z syy 0 0 16
hist z szz 0 0 16
;
hist z sxx 0 0 31
hist z syy 0 0 31
hist z szz 0 0 31
;
; solve for pre-excavation state of stress
solve age 4.0
save cavern_1.sav
;
; excavate cavern
model null range group cavern
;
; gradually reduce stress at excavation
def loadhist

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while_stepping
tt = 0.10
if crtime <= tt
    xloadhist = -35 + 28 * crtime / tt
    yloadhist = -35 + 28 * crtime / tt
    zloadhist = -35 + 28 * crtime / tt
else
    xloadhist = -7
    yloadhist = -7
    zloadhist = -7
end_if
end
;
apply sxx 1 his xloadhist range cyl end1 0 0 -0.1 end2 0 0 15.1 rad 45.1
apply syx 1 his yloadhist range cyl end1 0 0 -0.1 end2 0 0 15.1 rad 45.1
apply szz 1 his zloadhist range cyl end1 0 0 -0.1 end2 0 0 15.1 rad 45.1
;
; histories
hist delete
hist unbal
hist crtime
hist dt
;
hist gp xdis 45 0 0
hist gp ydis 0 45 0
hist gp zdis 0 0 15
;
hist xloadhist
hist yloadhist
hist zloadhist

; solve for 0.1 yr excavation
ini xdis=0 ydis=0 zdis=0
set creep time=0.0
set creep dt=1.0e-5
set creep dt auto on
solve age 0.1
save cavern_2.sav
;
; solve for 1 yr of creep
solve age 1.0
save cavern_3.sav
;
ret

```

