Geomechanics Elements and Models in OpenSees

Boris Jeremić

Department of Civil and Environmental Engineering
University of California, Davis

OpenSees User Workshop, RFS, August 26th 2005,
`http://sokocalo.engr.ucdavis.edu/~jeremic/`

Outline

- Material Models
  - Elastic
  - Small Deformation Elastic–Plastic Continuum
  - Small Deformation Elastic–Plastic Multiaxial and Uniaxial
  - Large Deformation Hyperelastic–Plastic Continuum
- Elements
  - Single Phase
  - Multi Phase
- Various Procedures
  - Static, Dynamic, Parallel
- Single Element Examples
  - Template Elastic-Plastic Solids

Elastic Material Models

- Small deformation elasticity (linear isotropic, nonlinear isotropic, cross anisotropic...)
- Large deformation hyperelasticity (Neo–Hookean, Ogden, Logarithmic, Mooney–Rivlin, Simo–Pister...)

Elastic–Plastic Continuum Models

- Small deformation *template* elasto–plasticity
  - Yield surfaces: von Mises, Drucker–Prager, Cam–Clay, Rounded Mohr–Coulomb, Parabolic Leon...
  - Plastic flow directions: Drucker–Prager, von Mises, Cam–Clay, Rounded Mohr–Coulomb, Manzari Dafalias
  - Evolution Laws: Linear scalar, nonlinear scalar (CamClay), Linear (translational and rotational) tensorial, nonlinear (translational and rotational) tensorial (Armstrong Frederick and bounding surface),
- Large deformation *template* hyperelasto–plasticity
  - Yield surfaces: von Mises, Drucker–Prager...
  - Plastic flow directions: Drucker–Prager, von Mises, Cam–Clay, Rounded Mohr–Coulomb, Manzari Dafalias
  - Evolution Laws: Linear/nonlinear scalar, Linear (translational and rotational) tensorial
- Stochastic elasto–plasticity

Elastic–Plastic Continuum Models (Contd.)

- Pressure dependent soil model (for sand and silt)
- Pressure independent soil model (for clays and silts)
- Large deformation *template* hyperelasto–plasticity
- Stochastic elasto–plasticity

Elastic–Plastic Multiaxial and Uniaxial Models

- Generalized foundation rocking material (M, N, T) model
- 2D frictional contact material model
- P–Y spring response material model
- P–Y liquefied spring response material model

Large Deformation Hyperelastic–Plastic Models

- Large deformation hyperelasticity (Neo–Hookean, Ogden, Logarithmic, Mooney–Rivlin, Simo–Pister...)
- Large deformation *template* hyperelasto–plasticity
  - Yield surfaces: von Mises, Drucker–Prager...
  - Plastic flow directions: Drucker–Prager, von Mises, Cam–Clay, Rounded Mohr–Coulomb, Manzari Dafalias
  - Evolution Laws: Linear/nonlinear scalar, Linear (translational and rotational) tensorial

Single Phase Formulations

- Small deformation solid elements (8, 20, 21, 27, 8-20 variable node bricks)
- Large deformation (total Lagrangian) solid elements (20 node brick)

Multi Phase Formulations

- Fully coupled, u–p–U elements (3D) for small deformations
- Fully coupled, u–p (plane strain and 3D) elements for small deformations
- Fully coupled u–p elements for large deformations

Various Procedures

- Hyperspherical Arc–length constraint equations
- Plastic Domain Decomposition (dynamic CPU load balancing distributed parallel implementation)
- Domain reduction method for seismic input/characterization

Single Element Examples

- Solid Template example (various elastic-plastic material models), triaxial compression, monotonic and cyclic)
- u–p–U example for monotonic and cyclic loading
- Large deformation example (shearing to $\gamma = 50$ %)

Elastic Part

```
set  E   1.0e7
set  v     0.2
set rho    1.8

nDMaterial ElasticIsotropic3D  1  $E $v  $rho
```

Yield Function and Plastic Flow Directions

```
set PI 3.1416
set FA   10
set DA   10
set FAr [expr $FA*$PI/180]
set DAr [expr $DA*$PI/180]
set a1  [expr 2*sin($FAr)/sqrt(3)/(3-sin($FAr)) ]
set a2  [expr 2*sin($DAr)/sqrt(3)/(3-sin($DAr)) ]

## Yield function
set ys "-DP"

## Potential function (flow rule)
set ps "-DP $a2"
```

Nonlinear Kinematic Hardening

```
## Isotropic hardening
set ES1  "-Leq 0.0"
set ES2  "-Leq 0.0"

## Kinematic hardening
set ET1  "-AF 35.0 60.0"

## EP state, NOD? NOS? a? k?
set EPS "-NOD 1 -NOS 2  $a1  0.0"
```

Putting it all together

```
## --------Template3Dep matTag? EmatTag? YS?
nDMaterial Template3Dep    2       1     -YS $ys

 PS?     EPState?    ELS?       ELT?
-PS $ps -EPS $EPS -ELS1 $ES1 -ELS2 $ES2 -ELT1 $ET1

## -----Brick8N  eleTag?       nodes    matTag?
element Brick8N    1    1 2 3 4 5 6 7 8    2

  body-forces    density
 0.0   0.0  0.0    $rho
```