```
  mass_density = rho
  xz_plane_vector = ( 1, 0, 1)
  joint_1_offset = (0*m, 0*m, 0*m)
  joint_2_offset = (0*m, 0*m, 0*m);

// add boundary condition
fix node # 1 dofs all;

// add mass
beamMass=rho*A*L;
add mass to node # 2
  mx = beamMass
  my = beamMass
  mz = beamMass
  Imx = 0*beamMass*L^2
  Imy = 0*beamMass*L^2
  Imz = 0*beamMass*L^2;

// // ----------------------------------------------------------------------------
// // --slowLoading---------------------------------------------------------------
// // ----------------------------------------------------------------------------
// new loading stage "slowLoading";
// add load # 1 to node # 2 type path_time_series
// Fz = 1.*N
// series_file = "slowLoading.txt" ;
// define dynamic integrator Newmark with gamma = 0.5 beta = 0.25;
// define algorithm With_no_convergence_check ;
// define solver ProfileSPD;
// simulate 2000 steps using transient algorithm
// time_step = 0.1*s;

// // ----------------------------------------------------------------------------
// // --fastLoading---------------------------------------------------------------
// // ----------------------------------------------------------------------------
// remove load # 1;
// new loading stage "fastLoading";
// add load # 2 to node # 2 type path_time_series
// Fz = 1.*N
// series_file = "fastLoading.txt" ;
// define dynamic integrator Newmark with gamma = 0.5 beta = 0.25;
// define algorithm With_no_convergence_check ;
// define solver ProfileSPD;
// simulate 1000 steps using transient algorithm
// time_step = 0.01*s;

// // ----------------------------------------------------------------------------
// // --freeVibration-------------------------------------------------------------
// // ----------------------------------------------------------------------------
// remove load # 2;
new loading stage "freeVibration";
add load # 3 to node # 2 type path_time_series
```

```
  Fz = 1.*N
  series_file = "freeVibration.txt" ;
define dynamic integrator Newmark with gamma = 0.5 beta = 0.25;
define algorithm With_no_convergence_check ;
define solver ProfileSPD;
simulate 1000 steps using transient algorithm
  time_step = 0.01*s;

bye;
```

Displacement results against time series

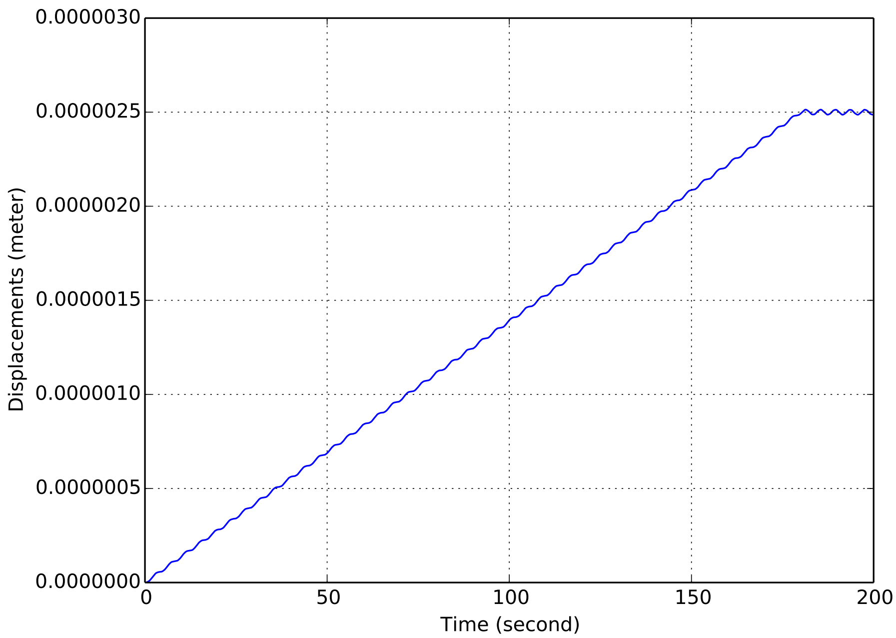


Figure 707.19: Slow loading condition, vertical displacements of the cantilever tip.

The ESSI model fei/DSL files for this example can be downloaded here.

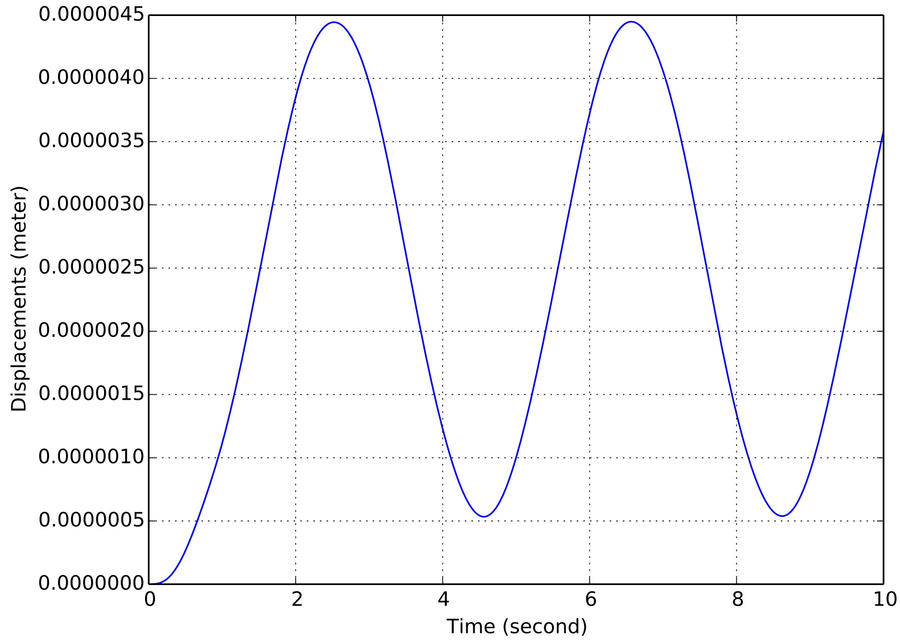


Figure 707.20: Fast loading condition, vertical displacements of the cantilever tip.

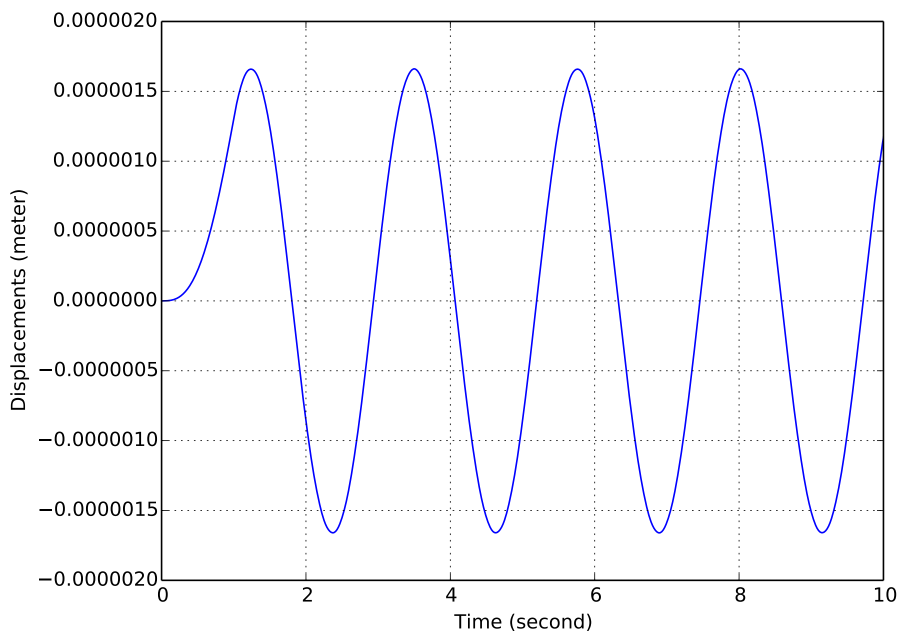


Figure 707.21: Free vibration condition, vertical displacements of the cantilever tip.

707.7 Elastic Beam, 27 Node Brick Model With Concentrated Mass

Problem description:

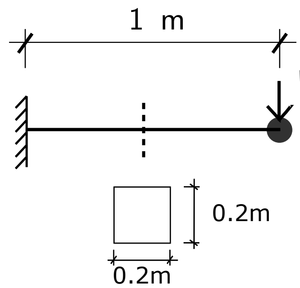


Figure 707.22: The cantilever-mass model.

ESSI model fei/DSL file:

```
model name "brick-mass_1element" ;

// Geometry: width and height
b=0.2*m;
h=0.2*m;

// Materials: properties
natural_period = 1*s;
natural_frequency = 2*pi/natural_period;
elastic_constant = 1e9*N/m^2;
I=b*h^3/12.0;
A=b*h;
L=1*m;
rho = (1.8751)^4*elastic_constant*I/(natural_frequency^2*L^4*A);
possion_ratio=0.3;

add material # 1 type linear_elastic_isotropic_3d_LT
  mass_density = rho
  elastic_modulus = elastic_constant
  poisson_ratio = possion_ratio;

add node # 1 at ( 0.0000 *m, 0.2000 *m, 0.0000 *m) with 3 dofs;
add node # 2 at ( 0.0000 *m, 0.0000 *m, 0.0000 *m) with 3 dofs;
add node # 3 at ( 1.0000 *m, 0.2000 *m, 0.0000 *m) with 3 dofs;
add node # 4 at ( 1.0000 *m, 0.0000 *m, 0.0000 *m) with 3 dofs;
add node # 5 at ( 0.0000 *m, 0.0000 *m, 0.2000 *m) with 3 dofs;
add node # 6 at ( 1.0000 *m, 0.0000 *m, 0.2000 *m) with 3 dofs;
add node # 7 at ( 1.0000 *m, 0.2000 *m, 0.2000 *m) with 3 dofs;
add node # 8 at ( 0.0000 *m, 0.2000 *m, 0.2000 *m) with 3 dofs;
add node # 9 at ( 0.0000 *m, 0.1000 *m, 0.0000 *m) with 3 dofs;
add node # 10 at ( 0.5000 *m, 0.2000 *m, 0.0000 *m) with 3 dofs;
```

```
add node # 11 at ( 1.0000 *m, 0.1000 *m, 0.0000 *m) with 3 dofs;
add node # 12 at ( 0.5000 *m, 0.0000 *m, 0.0000 *m) with 3 dofs;
add node # 13 at ( 0.0000 *m, 0.1000 *m, 0.2000 *m) with 3 dofs;
add node # 14 at ( 0.5000 *m, 0.2000 *m, 0.2000 *m) with 3 dofs;
add node # 15 at ( 1.0000 *m, 0.1000 *m, 0.2000 *m) with 3 dofs;
add node # 16 at ( 0.5000 *m, 0.0000 *m, 0.2000 *m) with 3 dofs;
add node # 17 at ( 0.0000 *m, 0.0000 *m, 0.1000 *m) with 3 dofs;
add node # 18 at ( 0.0000 *m, 0.2000 *m, 0.1000 *m) with 3 dofs;
add node # 19 at ( 1.0000 *m, 0.2000 *m, 0.1000 *m) with 3 dofs;
add node # 20 at ( 1.0000 *m, 0.0000 *m, 0.1000 *m) with 3 dofs;
add node # 21 at ( 0.5000 *m, 0.1000 *m, 0.1000 *m) with 3 dofs;
add node # 22 at ( 0.0000 *m, 0.1000 *m, 0.1000 *m) with 3 dofs;
add node # 23 at ( 0.5000 *m, 0.2000 *m, 0.1000 *m) with 3 dofs;
add node # 24 at ( 1.0000 *m, 0.1000 *m, 0.1000 *m) with 3 dofs;
add node # 25 at ( 0.5000 *m, 0.0000 *m, 0.1000 *m) with 3 dofs;
add node # 26 at ( 0.5000 *m, 0.1000 *m, 0.0000 *m) with 3 dofs;
add node # 27 at ( 0.5000 *m, 0.1000 *m, 0.2000 *m) with 3 dofs;

add element # 1 type 27NodeBrickLT with nodes( 2, 1, 3, 4, 5, 8, 7, 6, 9, 10, ↩
    11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27) use ↩
    material # 1;

fix node # 1 dofs all;
fix node # 2 dofs all;
fix node # 5 dofs all;
fix node # 8 dofs all;
fix node # 9 dofs all;
fix node # 13 dofs all;
fix node # 17 dofs all;
fix node # 18 dofs all;
fix node # 22 dofs all;


// Mapping from 3 dofs to 6 dofs.
add node # 1003 at ( 1.0000 *m, 0.2000 *m, 0.0000 *m) with 6 dofs;
add node # 1004 at ( 1.0000 *m, 0.0000 *m, 0.0000 *m) with 6 dofs;
add node # 1006 at ( 1.0000 *m, 0.0000 *m, 0.2000 *m) with 6 dofs;
add node # 1007 at ( 1.0000 *m, 0.2000 *m, 0.2000 *m) with 6 dofs;
// And connect the nodes at the same location.
add constraint equal dof with master node # 3 and slave node # 1003 dof to ↩
    constrain ux uy uz;
add constraint equal dof with master node # 4 and slave node # 1004 dof to ↩
    constrain ux uy uz;
add constraint equal dof with master node # 6 and slave node # 1006 dof to ↩
    constrain ux uy uz;
add constraint equal dof with master node # 7 and slave node # 1007 dof to ↩
    constrain ux uy uz;

add mass to node # 24 mx = rho*A*L my = rho*A*L mz = rho*A*L;

// add 6 beams to connect the mass
```

```
smallb=0.01*m;
smallh=0.01*m;
smallE = 1e9*N/m^2;
smallnu=0.3;
smallrho=0*kg/m^3;
smallI=smallb*smallh^3/12.0;
add element # 11 type beam_elastic with nodes (1003,1004)
  cross_section = smallb*smallh
  elastic_modulus = smallE
  shear_modulus = smallE/2/(1+smallnu)
  torsion_Jx = 0.33*smallb*smallh^3
  bending_Iy = smallI
  bending_Iz = smallI
  mass_density = smallrho
  xz_plane_vector = ( 1, 0, 1)
  joint_1_offset = (0*m, 0*m, 0*m)
  joint_2_offset = (0*m, 0*m, 0*m);
add element # 12 type beam_elastic with nodes (1003,1006)
  cross_section = smallb*smallh
  elastic_modulus = smallE
  shear_modulus = smallE/2/(1+smallnu)
  torsion_Jx = 0.33*smallb*smallh^3
  bending_Iy = smallI
  bending_Iz = smallI
  mass_density = smallrho
  xz_plane_vector = ( 1, 0, 1)
  joint_1_offset = (0*m, 0*m, 0*m)
  joint_2_offset = (0*m, 0*m, 0*m);
add element # 13 type beam_elastic with nodes (1003,1007)
  cross_section = smallb*smallh
  elastic_modulus = smallE
  shear_modulus = smallE/2/(1+smallnu)
  torsion_Jx = 0.33*smallb*smallh^3
  bending_Iy = smallI
  bending_Iz = smallI
  mass_density = smallrho
  xz_plane_vector = ( 1, 0, 1)
  joint_1_offset = (0*m, 0*m, 0*m)
  joint_2_offset = (0*m, 0*m, 0*m);
add element # 14 type beam_elastic with nodes (1004,1006)
  cross_section = smallb*smallh
  elastic_modulus = smallE
  shear_modulus = smallE/2/(1+smallnu)
  torsion_Jx = 0.33*smallb*smallh^3
  bending_Iy = smallI
  bending_Iz = smallI
  mass_density = smallrho
  xz_plane_vector = ( 1, 0, 1)
  joint_1_offset = (0*m, 0*m, 0*m)
  joint_2_offset = (0*m, 0*m, 0*m);
add element # 15 type beam_elastic with nodes (1004,1007)
```

```
  cross_section = smallb*smallh
  elastic_modulus = smallE
  shear_modulus = smallE/2/(1+smallnu)
  torsion_Jx = 0.33*smallb*smallh^3
  bending_Iy = smallI
  bending_Iz = smallI
  mass_density = smallrho
  xz_plane_vector = ( 1, 0, 1)
  joint_1_offset = (0*m, 0*m, 0*m)
  joint_2_offset = (0*m, 0*m, 0*m);
add element # 16 type beam_elastic with nodes (1006,1007)
  cross_section = smallb*smallh
  elastic_modulus = smallE
  shear_modulus = smallE/2/(1+smallnu)
  torsion_Jx = 0.33*smallb*smallh^3
  bending_Iy = smallI
  bending_Iz = smallI
  mass_density = smallrho
  xz_plane_vector = ( 1, 0, 1)
  joint_1_offset = (0*m, 0*m, 0*m)
  joint_2_offset = (0*m, 0*m, 0*m);


// // ---------------------------------------------------------------
// // --slowLoading-------------------------------------------------
// // add the 1 Newton load in 180 seconds.
// // ---------------------------------------------------------------
// new loading stage "slowLoading";
// add load # 1 to node # 4 type path_time_series Fz=1/36.0*N series_file = "slowLoading.txt" ;
// add load # 2 to node # 6 type path_time_series Fz=1/36.0*N series_file = "slowLoading.txt" ;
// add load # 3 to node # 3 type path_time_series Fz=1/36.0*N series_file = "slowLoading.txt" ;
// add load # 4 to node # 7 type path_time_series Fz=1/36.0*N series_file = "slowLoading.txt" ;
// add load # 5 to node # 20 type path_time_series Fz=1/9.0*N series_file = "slowLoading.txt" ;
// add load # 6 to node # 11 type path_time_series Fz=1/9.0*N series_file = "slowLoading.txt" ;
// add load # 7 to node # 15 type path_time_series Fz=1/9.0*N series_file = "slowLoading.txt" ;
// add load # 8 to node # 19 type path_time_series Fz=1/9.0*N series_file = "slowLoading.txt" ;
// add load # 9 to node # 24 type path_time_series Fz=4/9.0*N series_file = "slowLoading.txt" ;
// // add algorithm and solver
// define dynamic integrator Newmark with gamma = 0.5 beta = 0.25;
// define algorithm With_no_convergence_check ;
// define solver ProfileSPD;
// simulate 2000 steps using transient algorithm
```

```
// time_step = 0.1*s;

// // ---------------------------------------------------------------------------
// // --fastLoading--------------------------------------------------------------
// // add the 1 Newton load in 0.6 seconds.
// // ---------------------------------------------------------------------------
// new loading stage "fastLoading";
// add load # 101 to node # 4 type path_time_series Fz=1/36.0*N series_file = "fastLoading.txt" ;
// add load # 102 to node # 6 type path_time_series Fz=1/36.0*N series_file = "fastLoading.txt" ;
// add load # 103 to node # 3 type path_time_series Fz=1/36.0*N series_file = "fastLoading.txt" ;
// add load # 104 to node # 7 type path_time_series Fz=1/36.0*N series_file = "fastLoading.txt" ;
// add load # 105 to node # 20 type path_time_series Fz=1/9.0*N series_file = "fastLoading.txt" ;
// add load # 106 to node # 11 type path_time_series Fz=1/9.0*N series_file = "fastLoading.txt" ;
// add load # 107 to node # 15 type path_time_series Fz=1/9.0*N series_file = "fastLoading.txt" ;
// add load # 108 to node # 19 type path_time_series Fz=1/9.0*N series_file = "fastLoading.txt" ;
// add load # 109 to node # 24 type path_time_series Fz=4/9.0*N series_file = "fastLoading.txt" ;
// // add algorithm and solver
// define dynamic integrator Newmark with gamma = 0.5 beta = 0.25;
// define algorithm With_no_convergence_check ;
// define solver ProfileSPD;
// simulate 1000 steps using transient algorithm
// time_step = 0.01*s;

// // ---------------------------------------------------------------------------
// // --freeVibration-------------------------------------------------------------
// // ---------------------------------------------------------------------------
new loading stage "freeVibration";
add load # 201 to node # 4 type path_time_series Fz=1/36.0*N series_file = "freeVibration.txt" ;
add load # 202 to node # 6 type path_time_series Fz=1/36.0*N series_file = "freeVibration.txt" ;
add load # 203 to node # 3 type path_time_series Fz=1/36.0*N series_file = "freeVibration.txt" ;
add load # 204 to node # 7 type path_time_series Fz=1/36.0*N series_file = "freeVibration.txt" ;
add load # 205 to node # 20 type path_time_series Fz=1/9.0*N series_file = "freeVibration.txt" ;
add load # 206 to node # 11 type path_time_series Fz=1/9.0*N series_file = "freeVibration.txt" ;
add load # 207 to node # 15 type path_time_series Fz=1/9.0*N series_file = "freeVibration.txt" ;
```

```
add load # 208 to node # 19 type path_time_series Fz=1/9.0*N series_file = ↩
    "freeVibration.txt" ;
add load # 209 to node # 24 type path_time_series Fz=4/9.0*N series_file = ↩
    "freeVibration.txt" ;
// add algorithm and solver
define dynamic integrator Newmark with gamma = 0.5 beta = 0.25;
define algorithm With_no_convergence_check ;
define solver ProfileSPD;
simulate 100 steps using transient algorithm
  time_step = 0.1*s;

// end
bye;
```

Displacement Results.

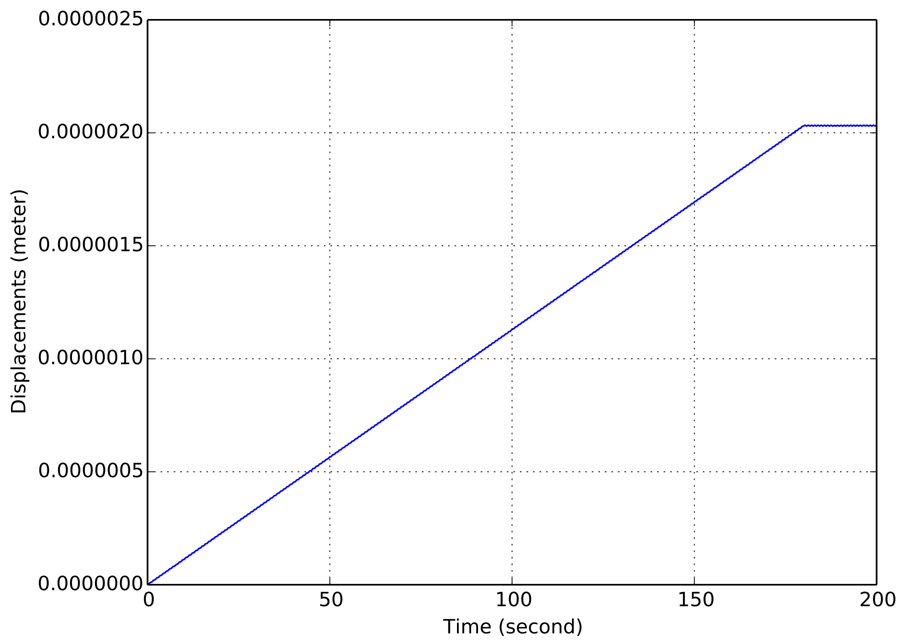


Figure 707.23: Slow loading condition, vertical displacements of the cantilever tip.

The ESSI model fei/DSL files for this example can be downloaded here.

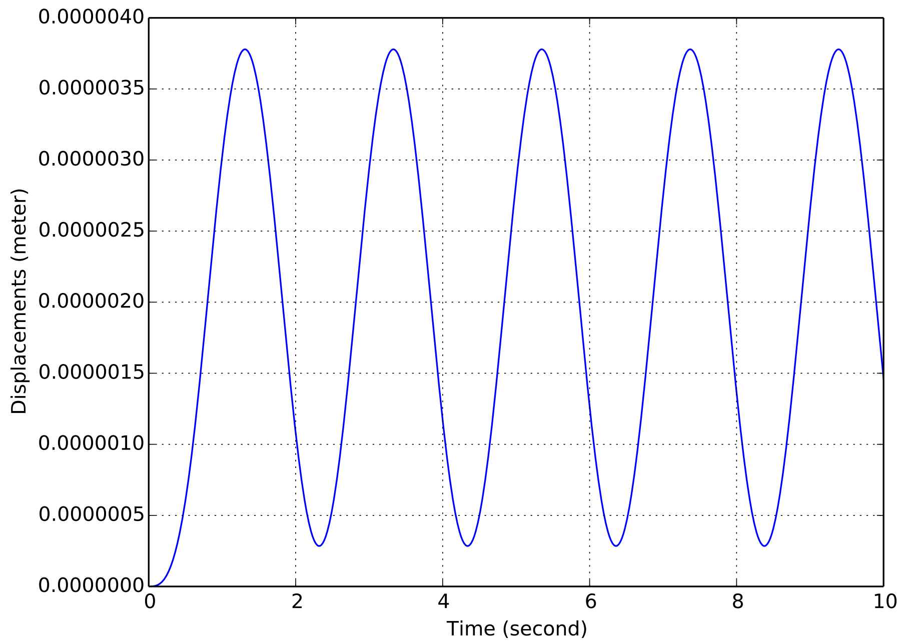


Figure 707.24: Fast loading condition, vertical displacements of the cantilever tip.

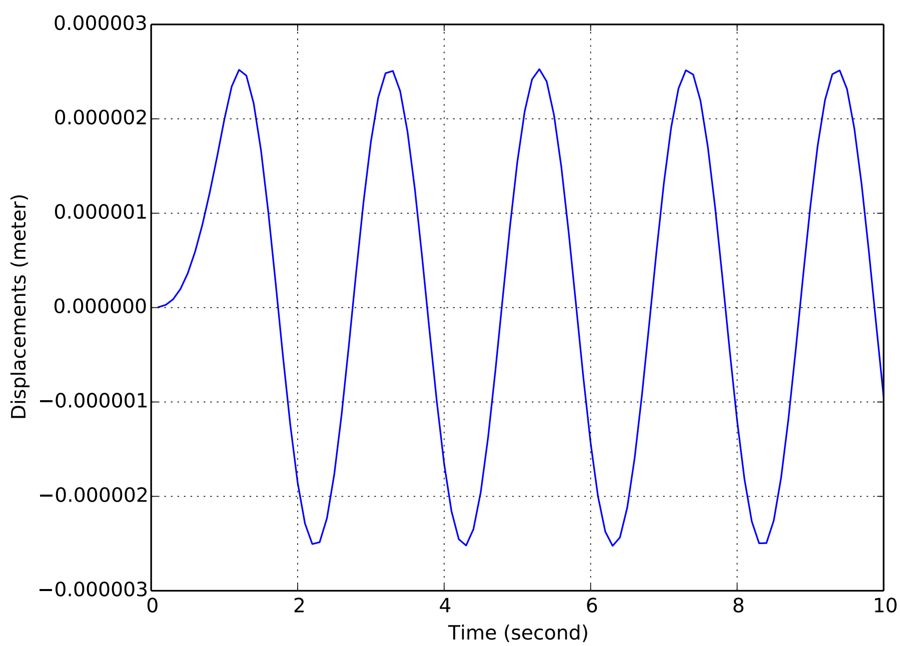


Figure 707.25: Free vibration condition, vertical displacements of the cantilever tip.

707.8 Elastic Beam Element, Dynamic Loading, Viscous (Rayleigh/Caughey) and Numerical (Newmark/HHT) Damping

Problem description:

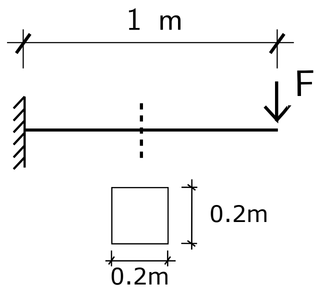


Figure 707.26: The cantilever-mass model.

ESSI model fei/DSL file:

```
model name "beam_1element" ;

// add node
add node # 1 at ( 0.0*m , 0.0*m, 0.0*m) with 6 dofs;
add node # 2 at ( 1.0*m , 0.0*m, 0.0*m) with 6 dofs;

// Geometry: width and height
b=0.2*m;
h=0.2*m;

// Materials: properties
natural_period = 1*s;
natural_frequency = 2*pi/natural_period;
elastic_constant = 1e9*N/m^2;
I=b*h^3/12.0;
A=b*h;
L=1*m;
rho = (1.8751)^4*elastic_constant*I/(natural_frequency^2*L^4*A);
possion_ratio=0.3;

// add elements
add element # 1 type beam_elastic with nodes (1,2)
  cross_section = b*h
  elastic_modulus = elastic_constant
  shear_modulus = elastic_constant/2/(1+possion_ratio)
  torsion_Jx = 0.33*b*h^3
  bending_Iy = b*h^3/12
  bending_Iz = b*h^3/12
  mass_density = rho
```

```
  xz_plane_vector = ( 1, 0, 1)
  joint_1_offset = (0*m, 0*m, 0*m)
  joint_2_offset = (0*m, 0*m, 0*m);

// add boundary condition
fix node # 1 dofs all;

// // -------------------------------------------------------------------------
// // --no-damping-------------------------------------------------------------
// // -------------------------------------------------------------------------
// new loading stage "no-damping";
// add load # 1 to node # 2 type path_time_series
// Fz = 1.*N
// series_file = "freeVibration.txt" ;
// define dynamic integrator Newmark with gamma = 0.5 beta = 0.25;
// define algorithm With_no_convergence_check ;
// define solver ProfileSPD;
// simulate 100 steps using transient algorithm
// time_step = 0.1*s;

// // -------------------------------------------------------------------------
// // ↩
   --Newmark-damping-------------------------------------------------------------
// // -------------------------------------------------------------------------
// remove load # 2;
// new loading stage "Newmark-damping";
// add load # 3 to node # 2 type path_time_series
// Fz = 1.*N
// series_file = "freeVibration.txt" ;
// define dynamic integrator Newmark with gamma = 0.6 beta = 0.3025;
// define algorithm With_no_convergence_check ;
// define solver ProfileSPD;
// simulate 100 steps using transient algorithm
// time_step = 0.1*s;
// // -------------------------------------------------------------------------
// // --HHT-damping------------------------------------------------------------
// // -------------------------------------------------------------------------
// remove load # 3;
// new loading stage "HHT-damping";
// add load # 4 to node # 6 type path_time_series
// Fz = 1.*kN
// series_file = "freeVibration.txt" ;
// define dynamic integrator Hilber_Hughes_Taylor with alpha = -0.20;
// define algorithm With_no_convergence_check ;
// define solver ProfileSPD;
// simulate 300 steps using transient algorithm
// time_step = 0.1*s;
// // -------------------------------------------------------------------------
// // ↩
   --Rayleigh-damping--------------------------------------------------------------
// // -------------------------------------------------------------------------
```

```
// remove load # 4;
// simulate using eigen algorithm number_of_modes = 2;
f1=0.996807/s;
f2=0.996807/s;
w1 = 2*pi*f1;
w2 = 2*pi*f2;
xi=0.05;
rayl_a1 = 2*xi/(w1 + w2);
rayl_a0 = rayl_a1*w1*w2;

add damping # 1 type Rayleigh with
  a0 = rayl_a0
  a1 = rayl_a1
  stiffness_to_use = Initial_Stiffness;
add damping # 1 to element # 1;

new loading stage "Rayleigh-damping";
add load # 5 to node # 2 type path_time_series
  Fz = 1.*N
  series_file = "freeVibration.txt" ;
define dynamic integrator Newmark with gamma = 0.5 beta = 0.25;
define algorithm With_no_convergence_check ;
define solver ProfileSPD;
simulate 100 steps using transient algorithm
  time_step = 0.1*s;

// // ----------------------------------------------------------------------------
// // --Caughey3rd-damping--------------------------------------------------------
// // ----------------------------------------------------------------------------
// add damping # 2 type Caughey3rd with
// a0 = 0.560523/s
// a1 = 0.0730746*s
// a2 = 0.000361559*s^3
// stiffness_to_use = Last_Committed_Stiffness;
// kk=1;
// while (kk<6) {
// add damping # 2 to element # kk;
// kk+=1;
// }
// new loading stage "Caughey3rd-damping";
// add load # 6 to node # 6 type path_time_series
// Fz = 10.*kN
// series_file = "freeVibration.txt" ;
// For Caughey3rd damping, we have to add some Newmark damping,
// Otherwise, there will be some high frequency noise.
// define dynamic integrator Newmark with gamma = 0.6 beta = 0.3025;
// define algorithm With_no_convergence_check ;
// define solver ProfileSPD;
// simulate 100 steps using transient algorithm
// time_step = 0.2*s;
```

```

// // ----------------------------------------------------------------------------
// // --Caughey4th-damping----------------------------------------------------------
// // ----------------------------------------------------------------------------
// add damping # 2 type Caughey4th with
// a0 = 0.560523/s
// a1 = 0.0756472*s
// a2 = 0.000517195*s^3
// a3 = 1.20005*10^(-6)*s^5
// stiffness_to_use = Last_Committed_Stiffness;
// kk=1;
// while (kk<6) {
// add damping # 2 to element # kk;
// kk+=1;
// }
// new loading stage "Caughey4th-damping";
// add load # 6 to node # 6 type path_time_series
// Fz = 10.*kN
// series_file = "freeVibration.txt" ;
// For Caughey4th damping, we have to add some Newmark damping,
// Otherwise, there will be some high frequency noise.
// define dynamic integrator Newmark with gamma = 0.6 beta = 0.3025;
// define algorithm With_no_convergence_check ;
// define solver ProfileSPD;
// simulate 100 steps using transient algorithm
// time_step = 0.2*s;

bye;
```

Displacement results against time series

The ESSI model fei/DSL files for this example can be downloaded here.

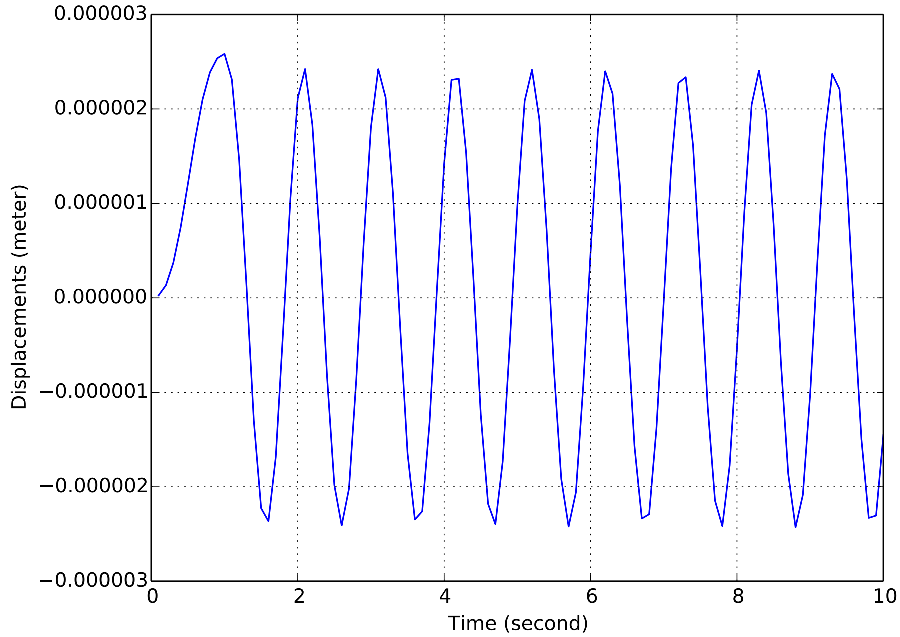


Figure 707.27: Free vibration condition, no damping, vertical displacements of the cantilever tip.

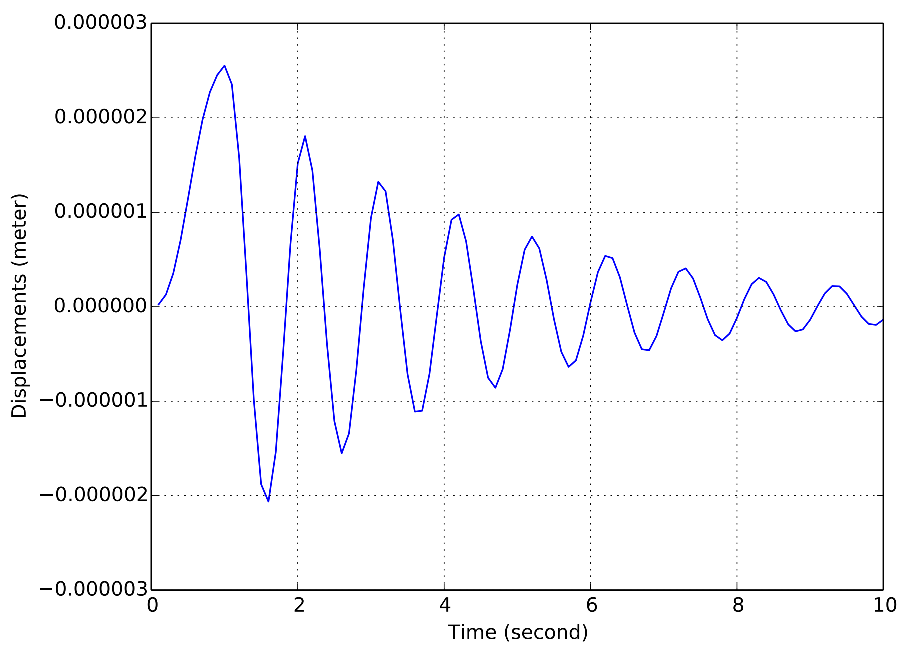


Figure 707.28: Free vibration condition, viscous (Rayleigh) damping, vertical displacements of the cantilever tip.

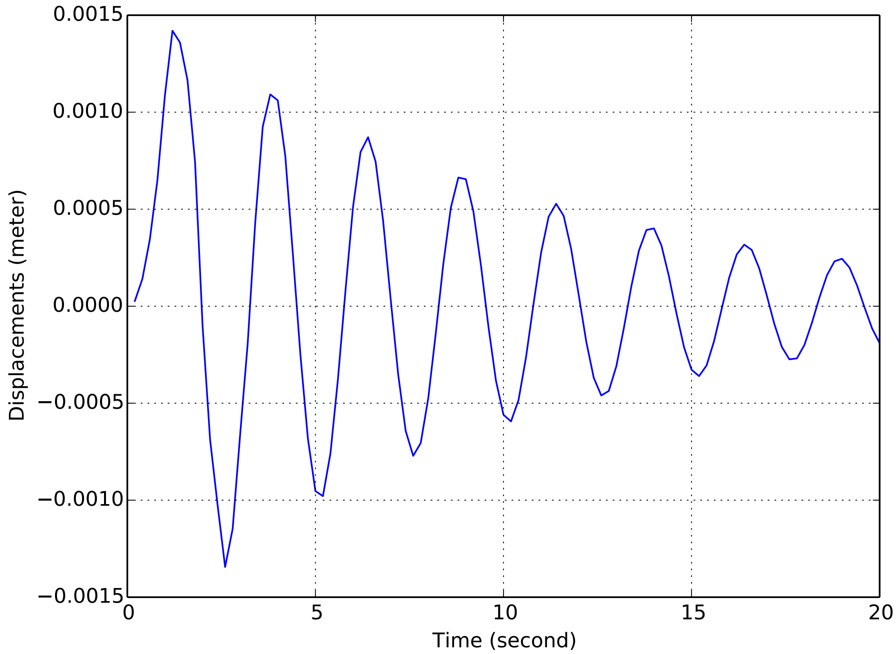


Figure 707.29: Free vibration condition, viscous (Caughey3rd) damping, vertical displacements of the cantilever tip.

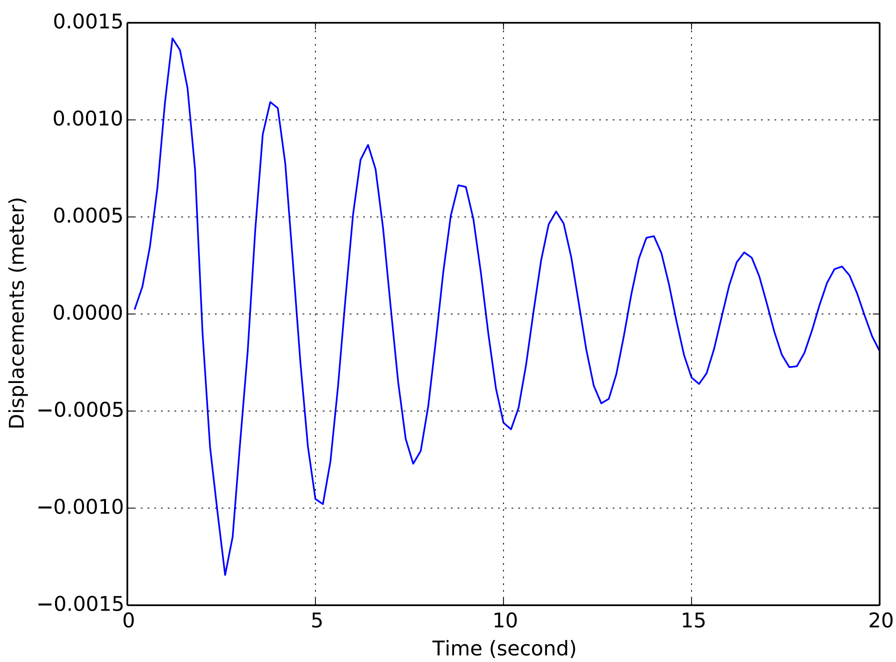


Figure 707.30: Free vibration condition, viscous (Caughey4th) damping, vertical displacements of the cantilever tip.

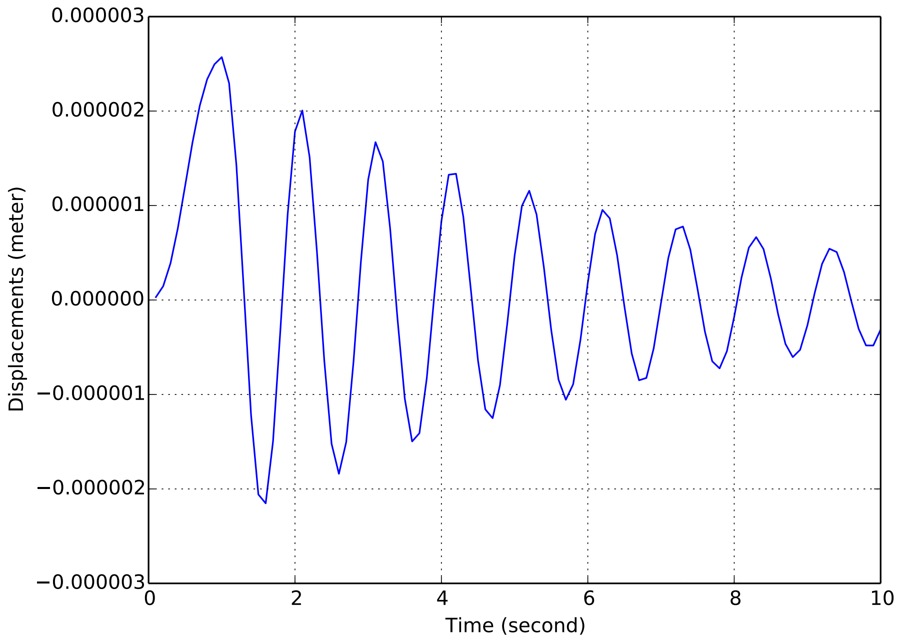


Figure 707.31: Free vibration condition, numerical (Newmark) damping, vertical displacements of the cantilever tip.

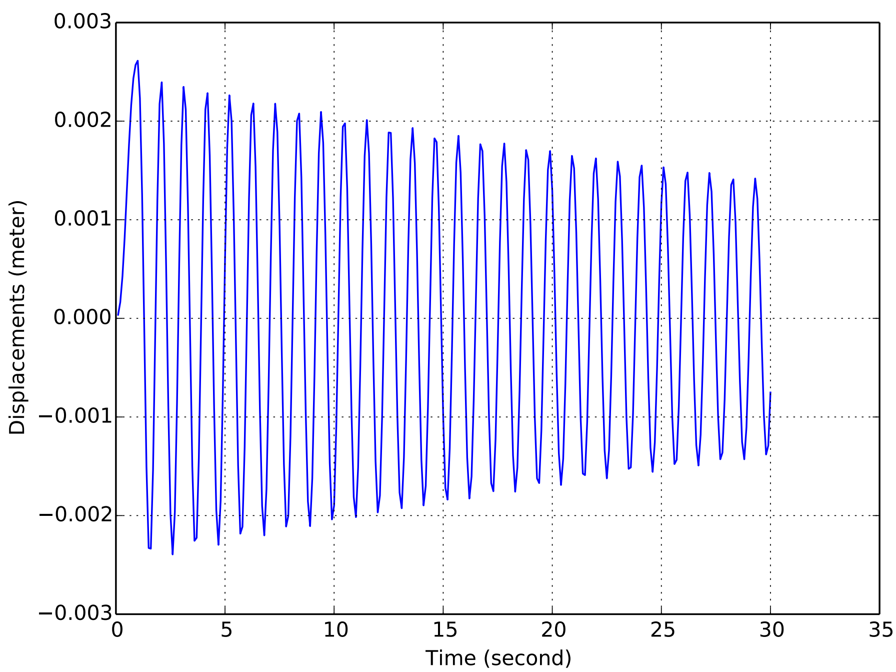


Figure 707.32: Free vibration condition, numerical (HHT) damping, vertical displacements of the cantilever tip.

707.9 Elastic Beam Element for a Simple Frame Structure

Problem Description

- Dimensions: hidth=$6m$, height=$6m$, force=$100N$
- Element dimensions: length=6m, cross section width=1m, cross section height=1m, mass density $\rho = 0.0\mathrm{kN/m^3}$, Young's modulus $E = 1E8$ Pa, Poisson's ratio $\nu = 0.0$.

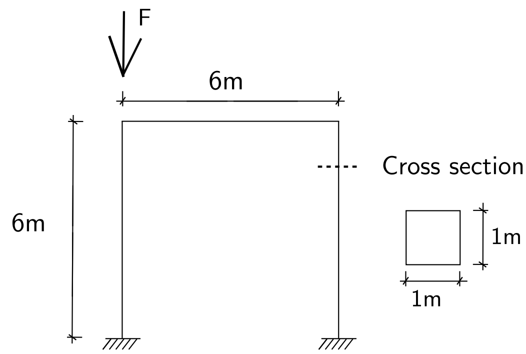


Figure 707.33: Elastic frame with beam_elastic elements.

ESSI model fei/DSL file:

```
model name "beam_element_presentation" ;

add node # 1 at ( 0.00*m, 0.00*m, 0.00*m) with 6 dofs;
add node # 2 at ( 0.00*m, 0.00*m, 6.00*m) with 6 dofs;
add node # 3 at ( 6.00*m, 0.00*m, 6.00*m) with 6 dofs;
add node # 4 at ( 6.00*m, 0.00*m, 0.00*m) with 6 dofs;

elastic_constant = 1e8*N/m^2;
b=1*m;
h=1*m;
rho = 0*kg/m^3; // Mass density

add element # 1 type beam_elastic with nodes (1, 2)
 cross_section = b*h elastic_modulus = elastic_constant
 shear_modulus = elastic_constant/2
 torsion_Jx = 0.33*b*h^3 bending_Iy = b*h^3/12 bending_Iz = h*b^3/12
 mass_density = rho xz_plane_vector = (1, 0, 1 )
   joint_1_offset = (0*m, 0*m, 0*m ) joint_2_offset = (0*m, 0*m, 0*m );

add element # 2 type beam_elastic with nodes (2,3)
```

```
 cross_section = b*h elastic_modulus = elastic_constant
 shear_modulus = elastic_constant/2
 torsion_Jx = 0.33*b*h^3 bending_Iy = b*h^3/12 bending_Iz = h*b^3/12
 mass_density = rho xz_plane_vector = (1, 0, 1 )
   joint_1_offset = (0*m, 0*m, 0*m ) joint_2_offset = (0*m, 0*m, 0*m );

add element # 3 type beam_elastic with nodes (3,4)
 cross_section = b*h elastic_modulus = elastic_constant
 shear_modulus = elastic_constant/2
 torsion_Jx = 0.33*b*h^3 bending_Iy = b*h^3/12 bending_Iz = h*b^3/12
 mass_density = rho xz_plane_vector = (1, 0, 1 )
   joint_1_offset = (0*m, 0*m, 0*m ) joint_2_offset = (0*m, 0*m, 0*m );

fix node #1 dofs all;
fix node #4 dofs all;

new loading stage "Fz";

add load # 1 to node # 2 type linear Fz=50*N;

define algorithm With_no_convergence_check;
define solver ProfileSPD;
define load factor increment 1;
simulate 1 steps using static algorithm;

bye;
```

The ESSI model fei/DSL files for this example can be downloaded here.

707.10 27NodeBrick Cantilever Beam, Static Load

Problem description:

Length=6m, Width=1m, Height=1m, Force=100N, E=1E8Pa, $\nu = 0.0$. The force direction is shown in Figure (707.34).

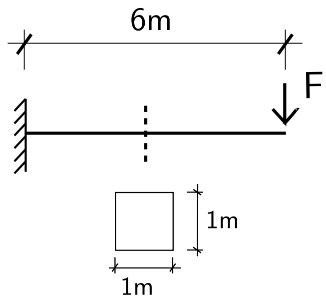


Figure 707.34: Problem description for cantilever beam.

Numerical model:

The 27NodeBrick elements for cantilever beams is shown in Figure (707.35):

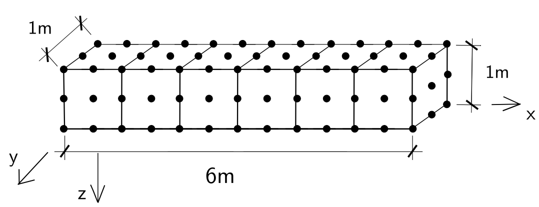


Figure 707.35: 27NodeBrick elements for cantilever beams made of solid elements.

ESSI model fei/DSL file:

```
model name "6meter_cantilever_27brick" ;

add material # 1 type linear_elastic_isotropic_3d
  mass_density = 0*kg/m^3
  elastic_modulus = 1e8*N/m^2
  poisson_ratio = 0.0;

add node # 1 at ( 0.00 *m, 1.00 *m, 0.00 *m) with 3 dofs;
add node # 2 at ( 0.00 *m, 0.00 *m, 0.00 *m) with 3 dofs;
```

```
add node # 3 at ( 6.00 *m, 1.00 *m, 0.00 *m) with 3 dofs;
add node # 4 at ( 5.00 *m, 1.00 *m, 0.00 *m) with 3 dofs;
add node # 5 at ( 4.00 *m, 1.00 *m, 0.00 *m) with 3 dofs;
add node # 6 at ( 3.00 *m, 1.00 *m, 0.00 *m) with 3 dofs;
...
...
add node #117 at ( 5.50 *m, 0.50 *m, 1.00 *m) with 3 dofs;

add element # 1 type 27NodeBrickLT with nodes( 2, 10, 8, 1, 15, 17, 28, 23, 29, ↩
    30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47) use ↩
    material # 1;
add element # 2 type 27NodeBrickLT with nodes( 10, 11, 7, 8, 17, 18, 27, 28, ↩
    48, 49, 50, 30, 51, 52, 53, 34, 38, 54, 55, 39, 56, 57, 58, 59, 43, 60, 61) ↩
    use material # 1;
add element # 3 type 27NodeBrickLT with nodes( 11, 12, 6, 7, 18, 19, 26, 27, ↩
    62, 63, 64, 49, 65, 66, 67, 52, 54, 68, 69, 55, 70, 71, 72, 73, 58, 74, 75) ↩
    use material # 1;
add element # 4 type 27NodeBrickLT with nodes( 12, 13, 5, 6, 19, 20, 25, 26, ↩
    76, 77, 78, 63, 79, 80, 81, 66, 68, 82, 83, 69, 84, 85, 86, 87, 72, 88, 89) ↩
    use material # 1;
add element # 5 type 27NodeBrickLT with nodes( 13, 14, 4, 5, 20, 21, 24, 25, ↩
    90, 91, 92, 77, 93, 94, 95, 80, 82, 96, 97, 83, 98, 99, 100, 101, 86, 102, ↩
    103) use material # 1;
add element # 6 type 27NodeBrickLT with nodes( 14, 9, 3, 4, 21, 16, 22, 24, ↩
    104, 105, 106, 91, 107, 108, 109, 94, 96, 110, 111, 97, 112, 113, 114, 115, ↩
    100, 116, 117) use material # 1;

fix node # 1 dofs all;
fix node # 2 dofs all;
fix node # 15 dofs all;
fix node # 23 dofs all;
fix node # 32 dofs all;
fix node # 36 dofs all;
fix node # 37 dofs all;
fix node # 40 dofs all;
fix node # 45 dofs all;

new loading stage "Fz";
add load # 1 to node # 13 type linear Fz=2.777778*N;
add load # 2 to node # 24 type linear Fz=2.777778*N;
add load # 3 to node # 3 type linear Fz=2.777778*N;
add load # 4 to node # 34 type linear Fz=2.777778*N;
add load # 5 to node # 182 type linear Fz=11.111111*N;
add load # 6 to node # 177 type linear Fz=11.111111*N;
add load # 7 to node # 180 type linear Fz=11.111111*N;
add load # 8 to node # 183 type linear Fz=11.111111*N;
add load # 9 to node # 186 type linear Fz=44.444444*N;

define algorithm With_no_convergence_check ;
define solver UMFPack;
define load factor increment 1;
```

```
simulate 1 steps using static algorithm;

bye;
```

The ESSI model fei/DSL files for this example can be downloaded here.

707.11 4NodeANDES Cantilever Beam, Force Perpendicular to Plane

Problem description:

Length=6m, Width=1m, Height=1m, Force=100N, E=1E8Pa, $\nu = 0.0$.

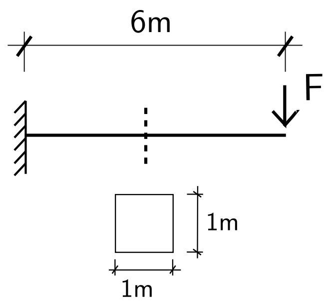


Figure 707.36: Cantilever beams

Numerical model:

For a force direction perpendicular to the plane, only the bending deformation is present.

The model is shown in Figure (707.37).

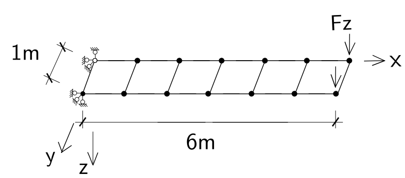


Figure 707.37: 4NodeANDES elements for cantilever beams under force perpendicular to plane.

ESSI model fei/DSL file:

```
 model name "6meter_cantilever_4NodeANDES" ;

add material # 1 type linear_elastic_isotropic_3d
  mass_density = 0*kg/m^3
  elastic_modulus = 1e8*N/m^2
  poisson_ratio = 0.0;

add node # 1 at ( 0.0*m, 0.0*m, 0.0*m) with 6 dofs;
add node # 2 at ( 6.0*m, 0.0*m, 0.0*m) with 6 dofs;
add node # 3 at ( 1.0*m, 0.0*m, 0.0*m) with 6 dofs;
```

```
add node # 4 at ( 2.0*m, 0.0*m, 0.0*m) with 6 dofs;
add node # 5 at ( 3.0*m, 0.0*m, 0.0*m) with 6 dofs;
add node # 6 at ( 4.0*m, 0.0*m, 0.0*m) with 6 dofs;
add node # 7 at ( 5.0*m, 0.0*m, 0.0*m) with 6 dofs;
add node # 8 at ( 6.0*m, 1.0*m, 0.0*m) with 6 dofs;
add node # 9 at ( 0.0*m, 1.0*m, 0.0*m) with 6 dofs;
add node # 10 at ( 5.0*m, 1.0*m, 0.0*m) with 6 dofs;
add node # 11 at ( 4.0*m, 1.0*m, 0.0*m) with 6 dofs;
add node # 12 at ( 3.0*m, 1.0*m, 0.0*m) with 6 dofs;
add node # 13 at ( 2.0*m, 1.0*m, 0.0*m) with 6 dofs;
add node # 14 at ( 1.0*m, 1.0*m, 0.0*m) with 6 dofs;

h = 1*m;
add element # 1 type 4NodeShell_ANDES with nodes (1,3,14,9) use material # 1 ↩
    thickness = h ;
add element # 2 type 4NodeShell_ANDES with nodes (3,4,13,14) use material # 1 ↩
    thickness = h ;
add element # 3 type 4NodeShell_ANDES with nodes (4,5,12,13) use material # 1 ↩
    thickness = h ;
add element # 4 type 4NodeShell_ANDES with nodes (5,6,11,12) use material # 1 ↩
    thickness = h ;
add element # 5 type 4NodeShell_ANDES with nodes (6,7,10,11) use material # 1 ↩
    thickness = h ;
add element # 6 type 4NodeShell_ANDES with nodes (7,2,8,10) use material # 1 ↩
    thickness = h ;

fix node # 1 dofs all ;
fix node # 9 dofs all ;

new loading stage "Fz";
add load # 1 to node # 8 type linear Fz=50*N;
add load # 2 to node # 2 type linear Fz=50*N;

define algorithm With_no_convergence_check ;
define solver ProfileSPD;
define load factor increment 1;
simulate 1 steps using static algorithm;

bye;
```

The ESSI model fei/DSL files for this example can be downloaded here.

707.12 4NodeANDES Cantilever Beams, In-Plane Force

Problem description:

Length=6m, Width=1m, Height=1m, Force=100N, E=1E8Pa, $\nu = 0.0$.

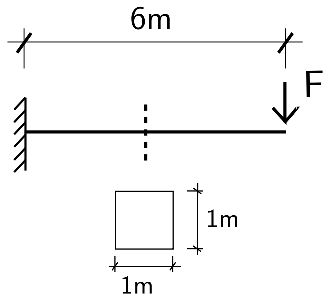


Figure 707.38: Problem description for cantilever beams with in plane force

Numerical model:

The 4NodeANDES elements under in-plane force is shown in Figure (707.39).

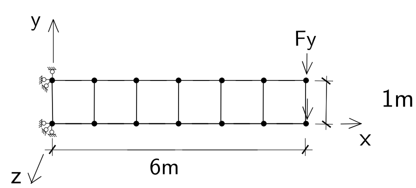


Figure 707.39: 4NodeANDES elements for cantilever beams under in-plane force

ESSI model fei/DSL file:

```
model name "6meter_cantilever_4NodeANDES" ;

add material # 1 type linear_elastic_isotropic_3d
  mass_density = 0*kg/m^3
  elastic_modulus = 1e8*N/m^2
  poisson_ratio = 0.0;

add node # 1 at ( 0.00*m, 0.00*m, 0.00*m) with 6 dofs;
add node # 2 at ( 6.00*m, 0.00*m, 0.00*m) with 6 dofs;
add node # 3 at ( 1.00*m, 0.00*m, 0.00*m) with 6 dofs;
add node # 4 at ( 2.00*m, 0.00*m, 0.00*m) with 6 dofs;
```

```
add node # 5 at ( 3.00*m, 0.00*m, 0.00*m) with 6 dofs;
add node # 6 at ( 4.00*m, 0.00*m, 0.00*m) with 6 dofs;
add node # 7 at ( 5.00*m, 0.00*m, 0.00*m) with 6 dofs;
add node # 8 at ( 6.00*m, 1.00*m, 0.00*m) with 6 dofs;
add node # 9 at ( 0.00*m, 1.00*m, 0.00*m) with 6 dofs;
add node # 10 at ( 5.00*m, 1.00*m, 0.00*m) with 6 dofs;
add node # 11 at ( 4.00*m, 1.00*m, 0.00*m) with 6 dofs;
add node # 12 at ( 3.00*m, 1.00*m, 0.00*m) with 6 dofs;
add node # 13 at ( 2.00*m, 1.00*m, 0.00*m) with 6 dofs;
add node # 14 at ( 1.00*m, 1.00*m, 0.00*m) with 6 dofs;

h = 1*m;
add element # 1 type 4NodeShell_ANDES with nodes (1,3,14,9) use material # 1 ↩
    thickness = h ;
add element # 2 type 4NodeShell_ANDES with nodes (3,4,13,14) use material # 1 ↩
    thickness = h ;
add element # 3 type 4NodeShell_ANDES with nodes (4,5,12,13) use material # 1 ↩
    thickness = h ;
add element # 4 type 4NodeShell_ANDES with nodes (5,6,11,12) use material # 1 ↩
    thickness = h ;
add element # 5 type 4NodeShell_ANDES with nodes (6,7,10,11) use material # 1 ↩
    thickness = h ;
add element # 6 type 4NodeShell_ANDES with nodes (7,2,8,10) use material # 1 ↩
    thickness = h ;

fix node # 1 dofs all;
fix node # 9 dofs all;

new loading stage "Fy";
add load # 1 to node # 8 type linear Fy=50*N;
add load # 2 to node # 2 type linear Fy=50*N;

define algorithm With_no_convergence_check ;
define solver ProfileSPD;
define load factor increment 1;
simulate 1 steps using static algorithm;

bye;
```

The ESSI model fei/DSL files for this example can be downloaded here.

707.13 27NodeBrick Cantilever Beams, Dynamic Input

Problem description:

Length=20m, Width=1m, Height=1m, E=504MPa, $\nu = 0.4$.

All degree of freedoms at the bottom nodes are fixed.

The load is a self weight with a dynamic displacement of supports.

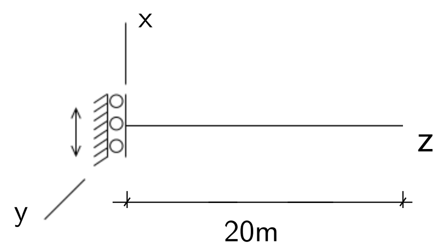


Figure 707.40: Problem description for one simple dynamic example

Numerical model:

The numerical model applied 27NodeBrick to simulate the 1C (1 component) motion.

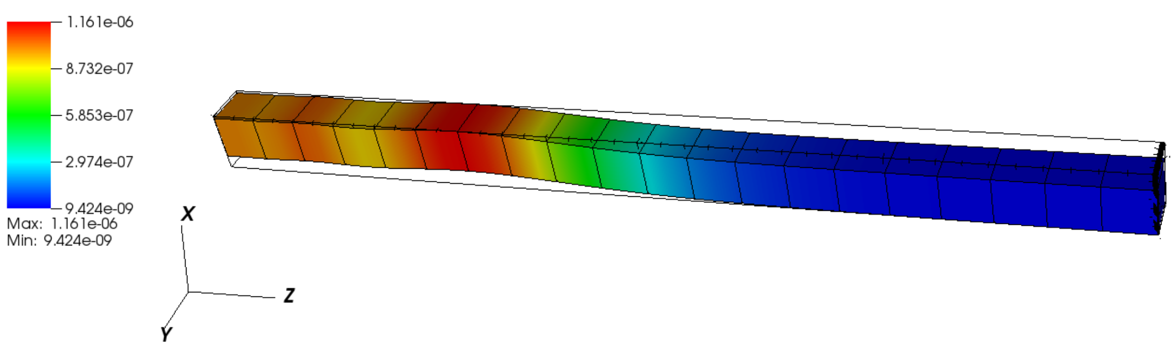


Figure 707.41: Numerical model for one simple dynamic example

ESSI model fei/DSL file:

```
model name "dynamic_example";

add material # 1 type linear_elastic_isotropic_3d_LT
 mass_density = 2000*kg/m^3
```

```
 elastic_modulus = 504000000.00*Pa
 poisson_ratio = 0.4;

add node No 1 at (0*m, 0*m, 0*m) with 3 dofs;
add node No 2 at (0*m, 0.5*m, 0*m) with 3 dofs;
add node No 3 at (0*m, 1*m, 0*m) with 3 dofs;
add node No 4 at (0.5*m, 0*m, 0*m) with 3 dofs;
add node No 5 at (0.5*m, 0.5*m, 0*m) with 3 dofs;
add node No 6 at (0.5*m, 1*m, 0*m) with 3 dofs;
...
...
add node No 369 at (1*m, 1*m, 20*m) with 3 dofs;

add element # 1 type 27NodeBrickLT with nodes (27,21,19,25,9,3,1,7,24,20,22,26,6,2,4,8,18,12,10,16,14,15,11,13,17,23,5) use material # 1 ;
add element # 2 type 27NodeBrickLT with nodes (45,39,37,43,27,21,19,25,42,38,40,44,24,20,22,26,36,30,28,34,32,33,29,31,35,41,23) use material # 1 ;
add element # 3 type 27NodeBrickLT with nodes (63,57,55,61,45,39,37,43,60,56,58,62,42,38,40,44,54,48,46,52,50,51,47,49,53,59,41) use material # 1 ;
add element # 4 type 27NodeBrickLT with nodes (81,75,73,79,63,57,55,61,78,74,76,80,60,56,58,62,72,66,64,70,68,69,65,67,71,77,59) use material # 1 ;
add element # 5 type 27NodeBrickLT with nodes (99,93,91,97,81,75,73,79,96,92,94,98,78,74,76,80,90,84,82,88,86,87,83,85,89,95,77) use material # 1 ;
...
...
add element # 20 type 27NodeBrickLT with nodes (369,363,361,367,351,345,343,349,366,362,364,368,348,
 344,346,350,360,354,352,358,356,357,353,355,359,365,347) use material # 1 ;

add acceleration field # 1 ax = 0*g ay = 0*g az = -1*g ;
add load # 1 to element # 1 type self_weight use acceleration field # 1;
add load # 2 to element # 2 type self_weight use acceleration field # 1;
add load # 3 to element # 3 type self_weight use acceleration field # 1;
add load # 4 to element # 4 type self_weight use acceleration field # 1;
add load # 5 to element # 5 type self_weight use acceleration field # 1;
add load # 6 to element # 6 type self_weight use acceleration field # 1;
...
...
add load # 20 to element # 20 type self_weight use acceleration field # 1;

fix node No 1 dofs uy uz;
fix node No 2 dofs uy uz;
fix node No 3 dofs uy uz;
fix node No 4 dofs uy uz;
fix node No 5 dofs uy uz;
fix node No 6 dofs uy uz;
```

```
...
...
fix node No 369 dofs uy uz;

zeta = 0.0166667;
fq1 = 3.75;
fq2 = 11.25;
omega1 = 2*pi*fq1;
omega2 = 2*pi*fq2;
zeta1 = zeta;
zeta2 = zeta;
alpha1 = 2*omega1*omega2*(zeta1*omega2-zeta2*omega1)/(omega2*omega2-omega1*omega1);
beta1 = 2* (zeta2*omega2-zeta1*omega1)/(omega2*omega2-omega1*omega1);
add damping # 1
   type Rayleigh
   with
   a0 = alpha1/s
   a1 = beta1*s
   stiffness_to_use = Initial_Stiffness;

add damping # 1 to element # 1;
add damping # 1 to element # 2;
add damping # 1 to element # 3;
add damping # 1 to element # 4;
add damping # 1 to element # 5;
add damping # 1 to element # 6;
...
...
add damping # 1 to element # 20;

new loading stage "impose_motion";

add imposed motion # 1001 to node # 1 dof ux
 displacement_scale_unit = 1*m displacement_file = "dis.txt"
 velocity_scale_unit = 1*m/s velocity_file = "vel.txt"
 acceleration_scale_unit = 1*m/s^2 acceleration_file = "acc.txt";

add imposed motion # 1002 to node # 2 dof ux
 displacement_scale_unit = 1*m displacement_file = "dis.txt"
 velocity_scale_unit = 1*m/s velocity_file = "vel.txt"
 acceleration_scale_unit = 1*m/s^2 acceleration_file = "acc.txt";

add imposed motion # 1003 to node # 3 dof ux
 displacement_scale_unit = 1*m displacement_file = "dis.txt"
 velocity_scale_unit = 1*m/s velocity_file = "vel.txt"
 acceleration_scale_unit = 1*m/s^2 acceleration_file = "acc.txt";
...
...
add imposed motion # 1009 to node # 9 dof ux
 displacement_scale_unit = 1*m displacement_file = "dis.txt"
```

```
 velocity_scale_unit = 1*m/s velocity_file = "vel.txt"
 acceleration_scale_unit = 1*m/s^2 acceleration_file = "acc.txt";

define dynamic integrator Newmark with gamma = 0.5 beta = 0.25;
define algorithm With_no_convergence_check;
define solver ProfileSPD;
simulate 50 steps using transient algorithm time_step = 0.005*s;

bye;
```

The ESSI model fei/DSL files for this example can be downloaded here.

707.14 4NodeANDES Square Plate, Four Edges Clamped

Problem description:

Length=20m, Width=20m, Height=1m, Force=100N, E=1E8Pa, $\nu = 0.3$.

The four edges are clamped.

The load is a self weight.

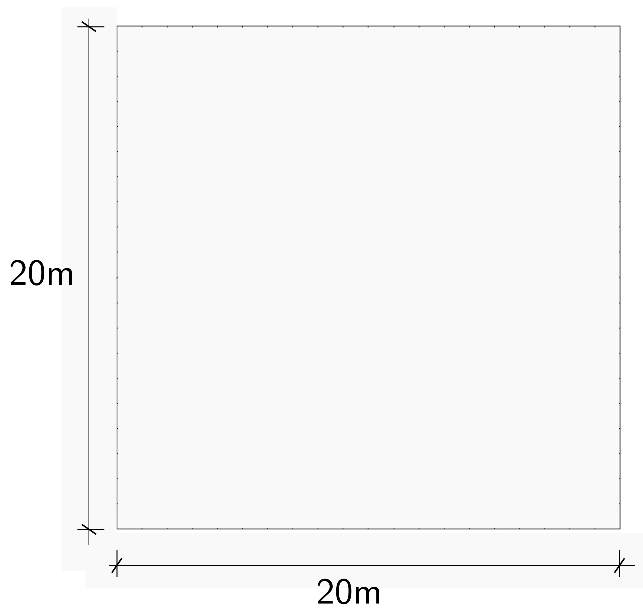


Figure 707.42: Square plate with four edges clamped

Numerical model:

The element side length is 1 meter.

ESSI model fei/DSL file:

```
model name "square_plate" ;

add material # 1 type linear_elastic_isotropic_3d
  mass_density = 1e2*kg/m^3 elastic_modulus = 1e8*N/m^2 poisson_ratio = 0.3;

add node # 1 at ( 0.00*m, 0.00*m, 0.00*m) with 6 dofs;
add node # 2 at ( 20.00*m, 0.00*m, 0.00*m) with 6 dofs;
add node # 3 at ( 1.00*m, 0.00*m, 0.00*m) with 6 dofs;
add node # 4 at ( 2.00*m, 0.00*m, 0.00*m) with 6 dofs;
add node # 5 at ( 3.00*m, 0.00*m, 0.00*m) with 6 dofs;
```

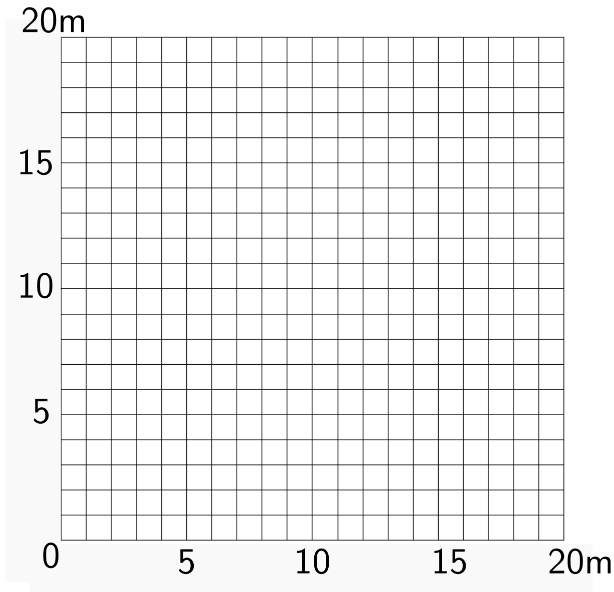


Figure 707.43: 4NodeANDES edge clamped square plate with element side length 1m

```
add node # 6 at ( 4.00*m, 0.00*m, 0.00*m) with 6 dofs;
...
...
add node # 441 at ( 19.00*m, 19.00*m, 0.00*m) with 6 dofs;

h = 1*m;
add element # 1 type 4NodeShell_ANDES with nodes( 1, 3, 81, 80) use material # 1 thickness=h;
add element # 2 type 4NodeShell_ANDES with nodes( 3, 4, 100, 81) use material # 1 thickness=h;
add element # 3 type 4NodeShell_ANDES with nodes( 4, 5, 119, 100) use material # 1 thickness=h;
add element # 4 type 4NodeShell_ANDES with nodes( 5, 6, 138, 119) use material # 1 thickness=h;
add element # 5 type 4NodeShell_ANDES with nodes( 6, 7, 157, 138) use material # 1 thickness=h;
add element # 6 type 4NodeShell_ANDES with nodes( 7, 8, 176, 157) use material # 1 thickness=h;
...
...
add element # 400 type 4NodeShell_ANDES with nodes( 441, 41, 22, 43) use material # 1 thickness=h;


fix node # 1 dofs all ;
fix node # 2 dofs all ;
```

```
fix node # 3 dofs all ;
fix node # 4 dofs all ;
fix node # 5 dofs all ;
fix node # 6 dofs all ;
...
...
fix node # 80 dofs all ;


new loading stage "self_weight";
add acceleration field # 1 ax = 0*g ay = 0*g az = 1*m/s^2;
add load # 1 to element # 1 type self_weight use acceleration field # 1;
add load # 2 to element # 2 type self_weight use acceleration field # 1;
add load # 3 to element # 3 type self_weight use acceleration field # 1;
add load # 4 to element # 4 type self_weight use acceleration field # 1;
add load # 5 to element # 5 type self_weight use acceleration field # 1;
add load # 6 to element # 6 type self_weight use acceleration field # 1;
...
...
add load # 400 to element # 400 type self_weight use acceleration field # 1;


define algorithm With_no_convergence_check ;
define solver ProfileSPD;
define load factor increment 1;
simulate 1 steps using static algorithm;

bye;
```

The ESSI model fei/DSL files for this example can be downloaded here.

707.15 One Dimensional DRM Model

Problem description:

A simple 1D DRM model is shown in Fig.(707.44). The "DRM element", "Exterior node" and "Boundary node" are required to be designated in the DRM HDF5 input. The format and script for the HDF5 input is available in DSL/input manual.

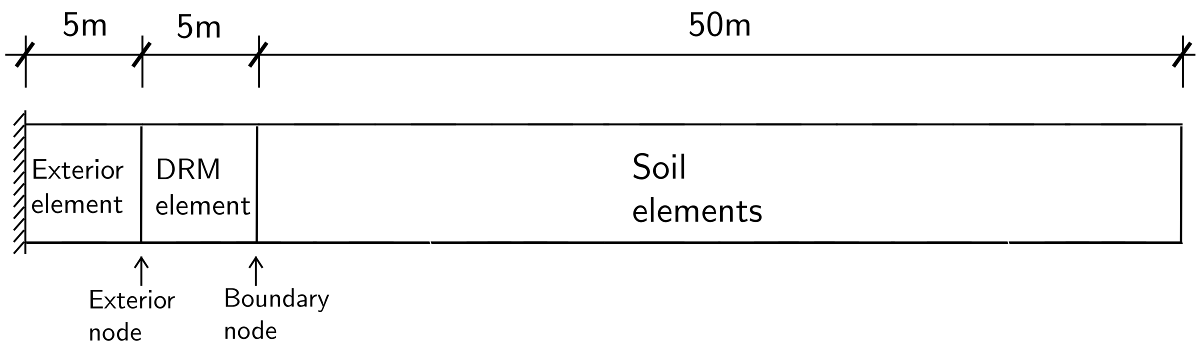


Figure 707.44: 1D DRM model.

Numerical model:

ESSI model fei/DSL file:

```
model name "DRM" ;

//Material for soil
add material # 1 type linear_elastic_isotropic_3d_LT
  mass_density = 2000*kg/m^3
  elastic_modulus = 1300*MPa
  poisson_ratio = 0.3;

//Material for DRM layer
add material # 2 type linear_elastic_isotropic_3d_LT
  mass_density = 2000*kg/m^3
  elastic_modulus = 1300*MPa
  poisson_ratio = 0.3;

//Material for exterior layer
add material # 3 type linear_elastic_isotropic_3d_LT
  mass_density = 2000*kg/m^3
  elastic_modulus = 1300*MPa
  poisson_ratio = 0.3;
//
```

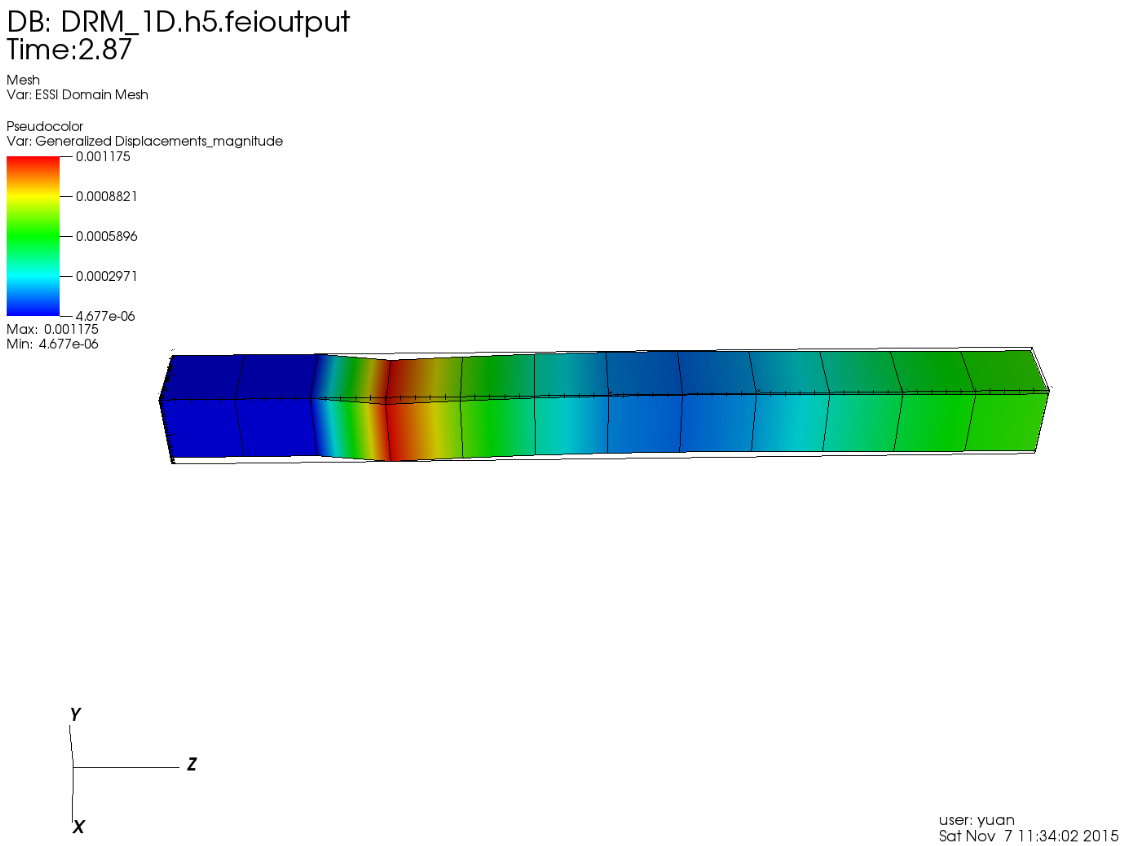


Figure 707.45: 1D DRM model.

```
add node # 1 at ( 0.00*m, 0.00*m, 0.00*m) with 3 dofs;
add node # 2 at ( 5.00*m, 0.00*m, 0.00*m) with 3 dofs;
add node # 3 at ( 5.00*m, 5.00*m, 0.00*m) with 3 dofs;
add node # 4 at ( 0.00*m, 5.00*m, 0.00*m) with 3 dofs;
add node # 5 at ( 5.00*m, 0.00*m, 50.00*m) with 3 dofs;
add node # 6 at ( 5.00*m, 0.00*m, 5.00*m) with 3 dofs;
...
...
add node # 52 at ( 0.00*m, 5.00*m, -5.00*m) with 3 dofs;

//
add element # 1 type 8NodeBrickLT with nodes( 1, 4, 3, 2, 24, 44, 34, 6) use ↩
    material # 1;
add element # 2 type 8NodeBrickLT with nodes( 24, 44, 34, 6, 23, 43, 33, 7) use ↩
    material # 1;
...
add element # 12 type 8NodeBrickLT with nodes( 48, 47, 45, 46, 52, 51, 49, 50) ↩
    use material # 3;

//
fix node # 1 dofs uy ;
fix node # 1 dofs uz ;
```

```
fix node # 2 dofs uy ;
fix node # 2 dofs uz ;
fix node # 3 dofs uy ;
fix node # 3 dofs uz ;
fix node # 4 dofs uy ;
fix node # 4 dofs uz ;
...
fix node # 51 dofs ux ;


new loading stage "1D";
add domain reduction method loading # 1
  hdf5_file = "input.hdf5";

define algorithm With_no_convergence_check ;
define solver ProfileSPD;
define dynamic integrator Newmark with gamma = 0.5 beta = 0.25;
simulate 999 steps using transient algorithm time_step = 0.01*s;

bye;
```

The ESSI model fei/DSL files for this example can be downloaded here.

The same model for this example with 27NodeBrickLT can be downloaded here.

Long 1D DRM model 1000:1

To show the wave propagation explicitly, a long 1D model (1000:1) similar to the 1D DRM model above was made in this section.

The model description is same to Fig.(707.44) except this model use far more soil elements.

The general view is shown in Fig.(707.46) below.

There is still now outgoing waves at the exterior layers, which is shown in Fig(707.47).

The ESSI model fei/DSL files for this example can be downloaded here.

The results can also be seen in this animation.

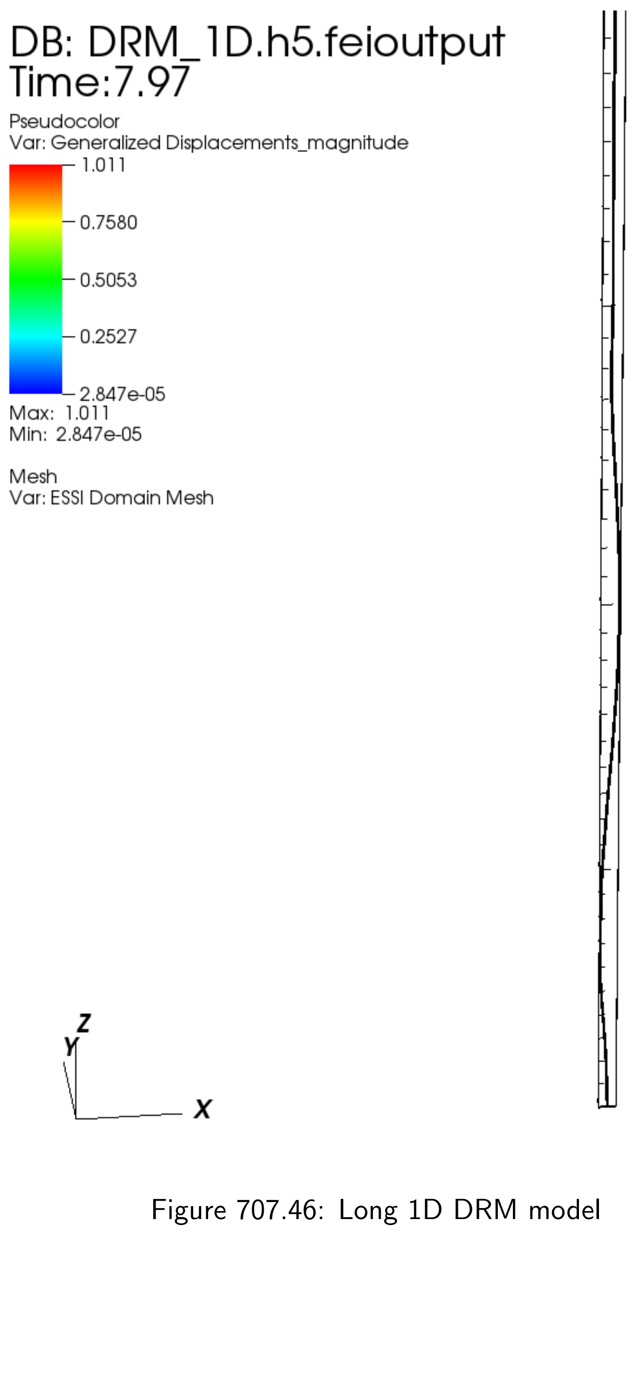


Figure 707.46: Long 1D DRM model

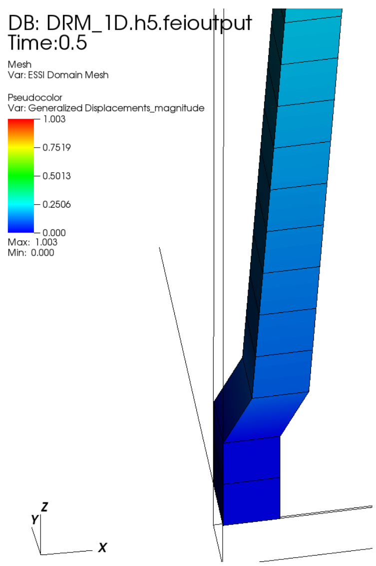


Figure 707.47: Long 1D DRM model: exterior layer

707.16 Three Dimensional DRM Model

Problem description:

As shown in Fig.(707.48), the DRM layer is used to add the earthquake motion.

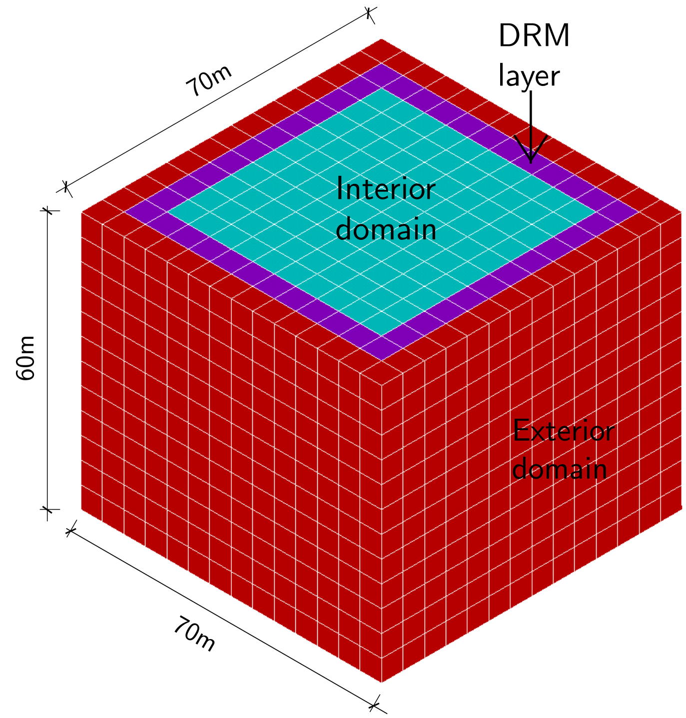


Figure 707.48: The diagram for 3D Domain Reduction Method example.

Numerical result:

ESSI model fei/DSL file:

```
model name "DRM" ;

//Material for soil
add material # 1 type linear_elastic_isotropic_3d_LT
  mass_density = 2000*kg/m^3
  elastic_modulus = 1300*MPa
  poisson_ratio = 0.3;

//Material for DRM layer
add material # 2 type linear_elastic_isotropic_3d_LT
  mass_density = 2000*kg/m^3
  elastic_modulus = 1300*MPa
  poisson_ratio = 0.3;
```

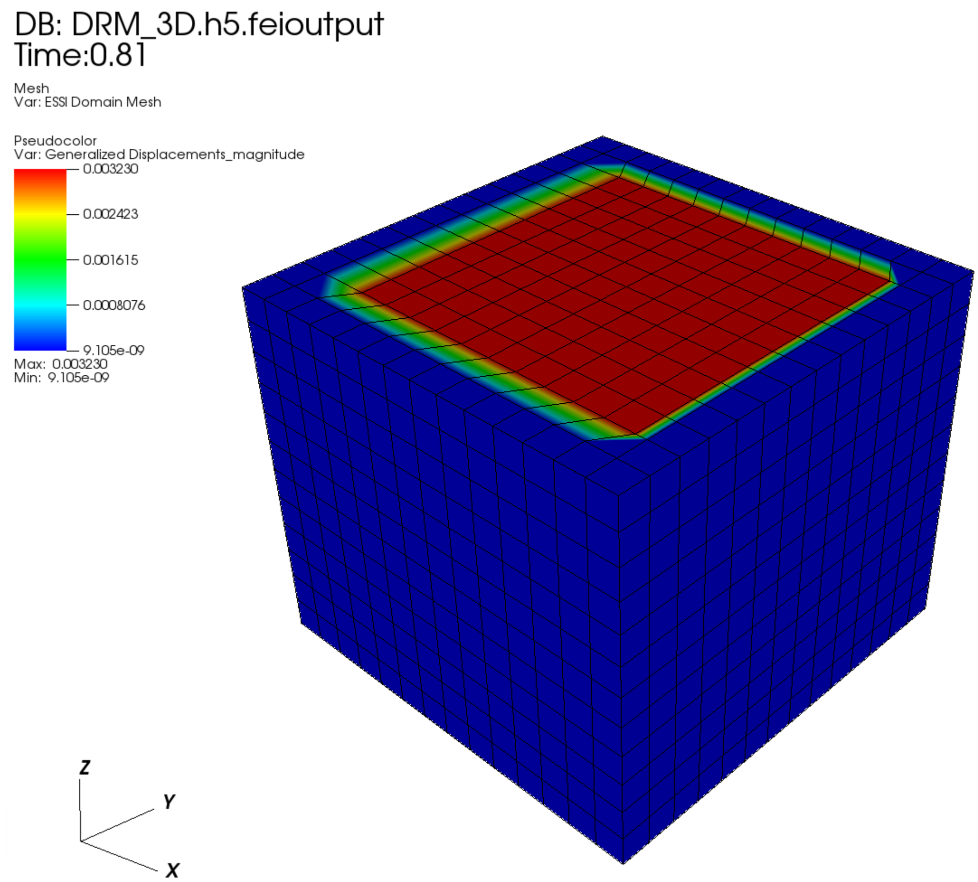


Figure 707.49: Diagram for the 3D DRM model.

```

//Material for exterior layer
add material # 3 type linear_elastic_isotropic_3d_LT
  mass_density = 2000*kg/m^3
  elastic_modulus = 1300*MPa
  poisson_ratio = 0.3;

//
add node # 1 at ( 0.00*m, 0.00*m, 0.00*m) with 3 dofs;
add node # 2 at ( 50.00*m, 0.00*m, 0.00*m) with 3 dofs;
add node # 3 at ( 5.00*m, 0.00*m, 0.00*m) with 3 dofs;
add node # 4 at ( 10.00*m, 0.00*m, 0.00*m) with 3 dofs;
add node # 5 at ( 15.00*m, 0.00*m, 0.00*m) with 3 dofs;
add node # 6 at ( 20.00*m, 0.00*m, 0.00*m) with 3 dofs;
add node # 7 at ( 25.00*m, 0.00*m, 0.00*m) with 3 dofs;
...
...
add node # 2925 at ( 55.00*m, 55.00*m, -5.00*m) with 3 dofs;

//
add element # 1 type 8NodeBrickLT with nodes( 1, 40, 41, 3, 150, 441, 603, 151) ↩
```

```
    use material # 1;
add element # 2 type 8NodeBrickLT with nodes( 3, 41, 50, 4, 151, 603, 684, 160) ↩
    use material # 1;
...
add element # 2352 type 8NodeBrickLT with nodes( 2925, 2924, 2922, 2923, 2921, ↩
    2920, 2918, 2919) use material # 3;

//
fix node # 1332 dofs all ;
fix node # 1334 dofs all ;
...
...
fix node # 2924 dofs all ;

new loading stage "3D";
add domain reduction method loading # 1
  hdf5_file = "input.hdf5";

define algorithm With_no_convergence_check ;
define solver ProfileSPD;
define dynamic integrator Newmark with gamma = 0.5 beta = 0.25;

simulate 999 steps using transient algorithm time_step = 0.01*s;

bye;
```

The ESSI model fei/DSL files for this example can be downloaded here.

The same model for this example with 27NodeBrickLT can be downloaded here.

707.17 ShearBeam Element, Pisano Material

Problem description:

In the element type "ShearBeamLT", only one Gauss point exists. ShearBeamLT element was used here to test the Pisanó material model.

Vertical force F_z was used to apply confinement to the element. Then, cyclic force F_x is used to load. point.

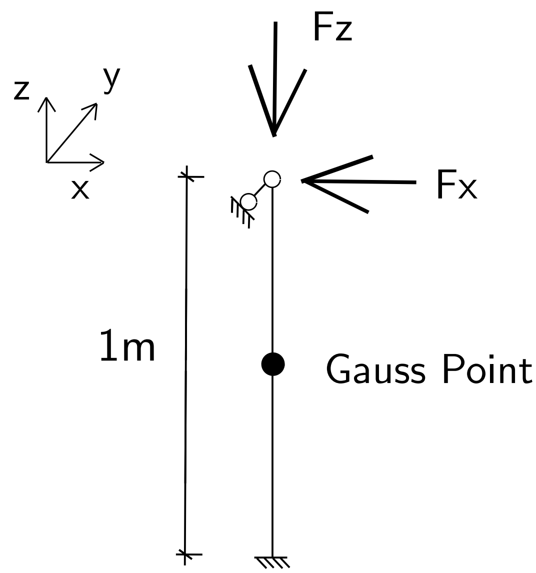


Figure 707.50: ShearBeam element.

Results

Resulting stress-strain relationship is shown in Fig.(707.51).

ESSI model fei/DSL file:

```
model name "pisanoLT";

add node # 1 at (0*m,0*m,0*m) with 3 dofs;
add node # 2 at (0*m,0*m,1*m) with 3 dofs;

fix node # 1 dofs all;
```

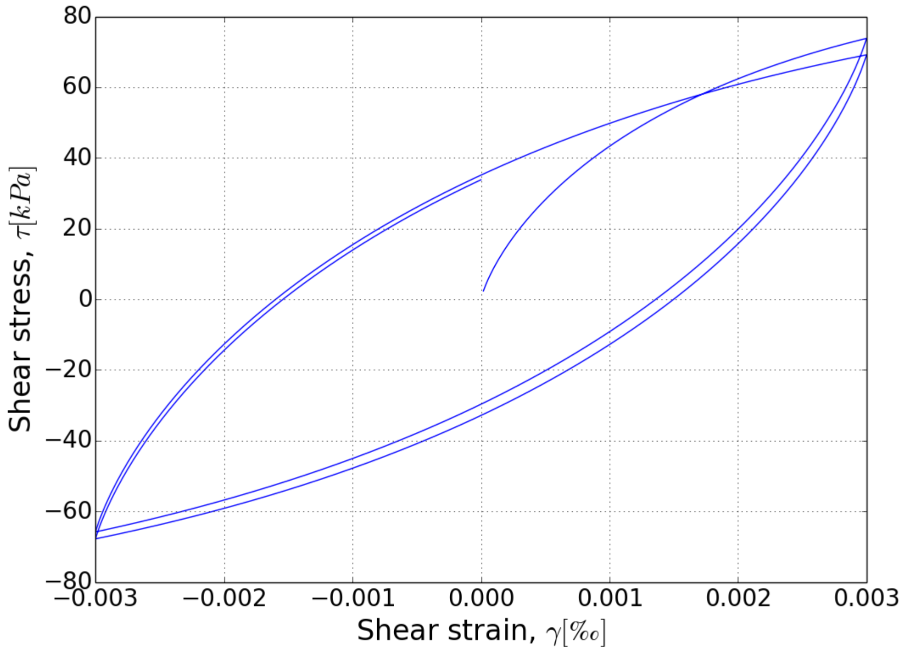


Figure 707.51: Shear stress-strain response.

```
fix node # 2 dofs uy;

add material # 1 type New_PisanoLT
 mass_density = 2000*kg/m^3
 elastic_modulus_1atm = 325*MPa poisson_ratio = 0.3
 M_in = 1.4 kd_in = 0.0 xi_in = 0.0 h_in = 700 m_in = 0.7
 initial_confining_stress = 0*kPa n_in = 0 a_in = 0.0 eplcum_cr_in = 1e-6;

add element # 1 type ShearBeamLT with nodes (1, 2) \
     cross_section = 1*m^2 use material # 1;

new loading stage "confinement";

add load # 1 to node # 2 type linear Fz = -200*kN;
define load factor increment 0.01;
define algorithm With_no_convergence_check ;
define solver UMFPack;
simulate 100 steps using static algorithm;

new loading stage "test01";
gamma_max = 3e-3;
add imposed motion # 2 to node # 2 dof ux
 displacement_scale_unit = gamma_max*m displacement_file = "input_sine.txt"
 velocity_scale_unit = gamma_max*m/s velocity_file = "input_sine.txt"
 acceleration_scale_unit = gamma_max*m/s^2 acceleration_file = "input_sine.txt";

define load factor increment 0.0005;
```

```
define algorithm With_no_convergence_check;
define solver UMFPack;
simulate 2000 steps using static algorithm;

bye;
```

The ESSI model fei/DSL files for this example can be downloaded here.

707.18 8NodeBrickLT Element, Drucker-Prager Material, Armstrong-Frederick Rotational Kinematic Hardening

Problem description:

This example is used to test the materials properties, such as G/Gmax against strains. The element type is 8NodeBrickLT. And there are two stages of loading. The first loading stage is confinement and the second loading stage is shearing.

The boundary condition is specially designed such that each Gauss point has the same stress state.

Results

Resulting stress-strain relationship is shown in Fig.(707.52).

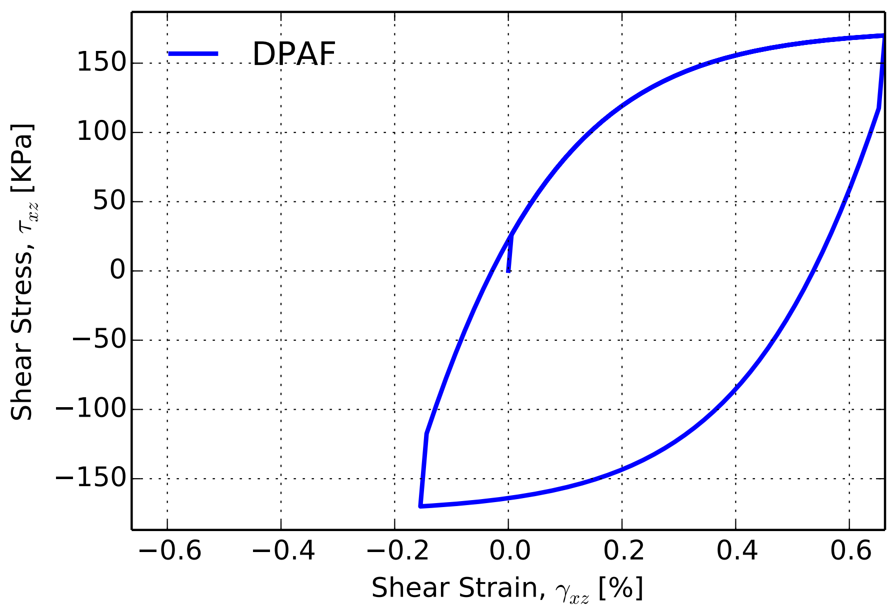


Figure 707.52: Shear stress-strain response.

ESSI model fei/DSL file:

```
// Drucker Prager Armstrong Frederick
// This model is created by Jose.
model name "druckeraf";

// Parameters:
phi = 5;
ha = 1000;
cr = 973;
```

```
gam = 0.01;
Ncyc = 5;
Nsteps = 1000;
H=1;
vp=1000*m/s;
vs=500*m/s;
rho=2000*kg/m^3;
p0 = 250*kPa;
G = rho*vs^2;
M = rho*vp^2;

E = G*(3*M-4*G)/(M-G);
nu = (M-2*G)/(2*M-2*G);

K0 = 1.0;
phirad = pi*phi/180;
M = 6*sin(phirad)/(3-sin(phirad));

// Define the material:
add material # 1 type DruckerPragerArmstrongFrederickLT
    mass_density = 0*kg/m^3
    elastic_modulus = E
    poisson_ratio = nu
    druckerprager_k = M
    armstrong_frederick_ha = ha*Pa
    armstrong_frederick_cr = cr*Pa
    isotropic_hardening_rate = 0*E
    initial_confining_stress = 1*Pa;

// define the node:
add node # 1 at (0*m,0*m,1*m) with 3 dofs;
add node # 2 at (1*m,0*m,1*m) with 3 dofs;
add node # 3 at (1*m,1*m,1*m) with 3 dofs;
add node # 4 at (0*m,1*m,1*m) with 3 dofs;

add node # 5 at (0*m,0*m,0*m) with 3 dofs;
add node # 6 at (1*m,0*m,0*m) with 3 dofs;
add node # 7 at (1*m,1*m,0*m) with 3 dofs;
add node # 8 at (0*m,1*m,0*m) with 3 dofs;

// add equal degree of freedom in three directions
add constraint equal dof with master node # 2 and slave node # 3 dof to constrain ux;
add constraint equal dof with master node # 2 and slave node # 6 dof to constrain ux;
add constraint equal dof with master node # 2 and slave node # 7 dof to constrain ux;

add constraint equal dof with master node # 3 and slave node # 4 dof to constrain uy;
add constraint equal dof with master node # 3 and slave node # 8 dof to
```

```
    constrain uy;
add constraint equal dof with master node # 3 and slave node # 7 dof to constrain uy;

add constraint equal dof with master node # 1 and slave node # 2 dof to constrain uz;
add constraint equal dof with master node # 1 and slave node # 3 dof to constrain uz;
add constraint equal dof with master node # 1 and slave node # 4 dof to constrain uz;

// Define the element.
add element # 1 type 8NodeBrickLT with nodes (1, 2,3 , 4, 5, 6,7, 8) use material # 1;

new loading stage "confinement";
fix node # 1 dofs ux uy;
fix node # 2 dofs uy;
fix node # 4 dofs ux;

fix node # 5 dofs ux uy uz;
fix node # 6 dofs uy uz;
fix node # 7 dofs uz;
fix node # 8 dofs ux uz;

sigma_z = -3*p0/(1+2*K0);
sigma_x = K0*sigma_z;
sigma_y = K0*sigma_z;

//Z-face
add load # 1 to node # 1 type linear Fz = sigma_z*m^2/4;
add load # 2 to node # 2 type linear Fz = sigma_z*m^2/4;
add load # 3 to node # 3 type linear Fz = sigma_z*m^2/4;
add load # 4 to node # 4 type linear Fz = sigma_z*m^2/4;

//X-face
add load # 5 to node # 2 type linear Fx = sigma_x*m^2/4;
add load # 6 to node # 6 type linear Fx = sigma_x*m^2/4;
add load # 7 to node # 7 type linear Fx = sigma_x*m^2/4;
add load # 8 to node # 3 type linear Fx = sigma_x*m^2/4;

add load # 9 to node # 3 type linear Fy = sigma_y*m^2/4;
add load # 10 to node # 7 type linear Fy = sigma_y*m^2/4;
add load # 11 to node # 8 type linear Fy = sigma_y*m^2/4;
add load # 12 to node # 4 type linear Fy = sigma_y*m^2/4;

Nsteps_static=100;
define load factor increment 1/Nsteps_static;

define solver UMFPack;
define convergence test Norm_Displacement_Increment
```

```
    tolerance = 1e-6
    maximum_iterations = 100
    verbose_level = 4;
define algorithm Newton ;

define NDMaterialLT constitutive integration algorithm Euler_One_Step
    yield_function_relative_tolerance = 0.002
    stress_relative_tolerance = 0.002
    maximum_iterations = 1000;

simulate Nsteps_static steps using static algorithm;


new loading stage "shearing";
compute reaction forces;
add load # 13 to node # 1 type from_reactions;
add load # 14 to node # 4 type from_reactions;

free node # 1 dofs ux;
free node # 4 dofs ux;
fix node # 3 dofs uy;
fix node # 6 dofs ux;
fix node # 7 dofs ux uy;
fix node # 8 dofs uy;

add constraint equal dof with master node # 1 and slave node # 3 dof to ↩
    constrain ux;
add constraint equal dof with master node # 1 and slave node # 4 dof to ↩
    constrain ux;
add constraint equal dof with master node # 1 and slave node # 2 dof to ↩
    constrain ux;
remove constraint equaldof node # 6;
remove constraint equaldof node # 7;
remove constraint equaldof node # 8;

n = 1;
while(n<=1)
{
    add load # 14+n to node # n type path_time_series
     Fx = 170.*kN
     series_file = "path.txt";
    n+=1;
}

define load factor increment 1/Nsteps;

define solver UMFPack;
define convergence test Norm_Displacement_Increment
    tolerance = 1e-5
    maximum_iterations = 100
    verbose_level = 4;
```

```
define algorithm Newton ;

define NDMaterialLT constitutive integration algorithm Euler_One_Step
    yield_function_relative_tolerance = 0.0002
    stress_relative_tolerance = 0.002
    maximum_iterations = 1000;

simulate Ncyc*Nsteps steps using static algorithm;

bye;
```

The ESSI model fei/DSL files for this example can be downloaded here.

707.19 Contact Element Under Static Loading

Two Bar Normal Contact Problem Under Monotonic Loading.

This is an example of normal monotonic loading on a 1-D contact/interface between two bars separated by an initial gap of 0.1 unit. An illustrative diagram of the problem statement is shown below.

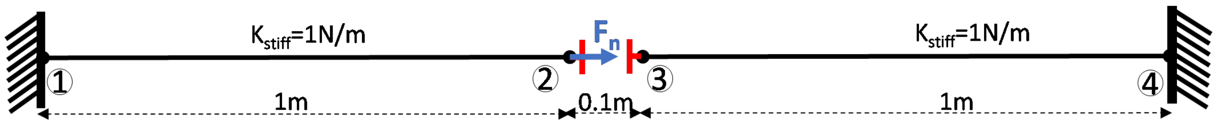


Figure 707.53: Illustration of Two Bar Normal Contact Problem under monotonic loading with intial gap

ESSI model fei/DSL file:

```
model name "Two_Bar_Contact_Under_Normal_Monotonic_Loading" ;

// Adding material
add material #1 type uniaxial_elastic elastic_modulus = 1*Pa viscoelastic_modulus = 0*Pa*s;

// Adding Nodes
add node #1 at (0*m,0*m,0*m) with 3 dofs;
add node #2 at (1*m,0*m,0*m) with 3 dofs;
add node #3 at (1.1*m,0*m,0*m) with 3 dofs;
add node #4 at (2.1*m,0*m,0*m) with 3 dofs;

// Adding Fixities
fix node #1 dofs ux uy uz;
fix node #4 dofs ux uy uz;
fix node #2 dofs uy uz ;
fix node #3 dofs uy uz ;

// Adding Truss Elements
add element #1 type truss with nodes (1,2) use material # 1 cross_section = 1*m^2 mass_density = 1*kg/m^3;
add element #2 type truss with nodes (3,4) use material # 1 cross_section = 1*m^2 mass_density = 1*kg/m^3;

// Adding Contact Element
add element #3 type FrictionalPenaltyContact with nodes (2,3)
 normal_stiffness =1e10*N/m
 tangential_stiffness = 1e10*Pa*m
 normal_damping = 0*kN/m*s
 tangential_damping = 0*kN/m*s
 friction_ratio = 0.3
```

```
 contact_plane_vector = (1,0,0);

new loading stage "Adding_Normal_Load";

 add load #1 to node #2 type linear Fx = 0.3*N;

 Nsteps = 10;

 tol = 5e-12;
 define convergence test Norm_Displacement_Increment
   tolerance = tol
   maximum_iterations = 10
   verbose_level = 4;

 define algorithm Newton;
 define solver UMFPack;

 define load factor increment 1/Nsteps;
 simulate Nsteps steps using static algorithm;

bye;
```

The displacement output of *Node 2 and Node 3* are shown below.

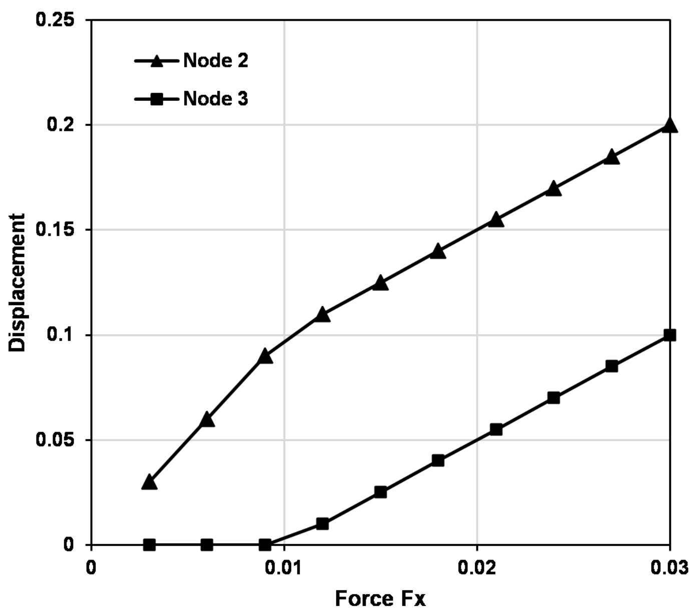


Figure 707.54: Displacemnet of Nodes 2 and 3

The ESSI model fei/DSL files for this example can be downloaded here.

707.20 Four Bar Contact Problem With Normal and Shear Force Under Monotonic Loading

This is an example to show the normal and tangential behaviour (stick and slip case) of contacts/interfaces using four bars in 2-D plane. The bars in x-directions are in contact (initial gap=0).

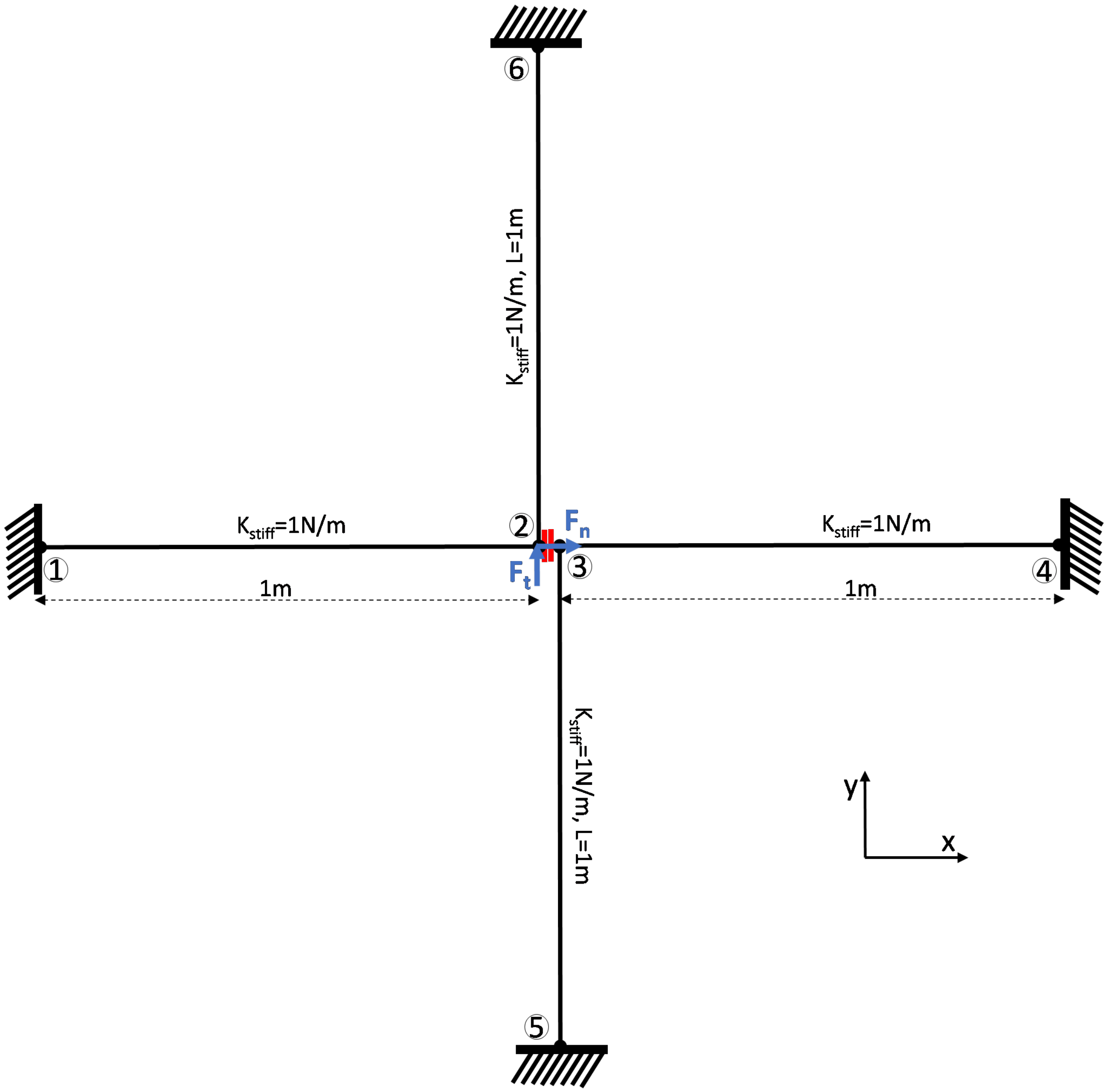


Figure 707.55: Illustration of Four Bar Normal Contact Problem With Normal and Shear Force Under Monotonic Loading with no initial gap

ESSI model fei/DSL file:

```
model name "Four_Bar_Contact_Under_Monotonic_Normal_and_Shear_Loading";

// Adding material
add material #1 type uniaxial_elastic elastic_modulus = 1*Pa viscoelastic_modulus = 0*Pa*s;

// Adding Nodes
add node #1 at (0*m,0*m,0*m) with 3 dofs;
add node #2 at (1*m,0*m,0*m) with 3 dofs;
add node #3 at (1*m,0*m,0*m) with 3 dofs;
add node #4 at (2*m,0*m,0*m) with 3 dofs;
add node #5 at (1*m,-1*m,0*m) with 3 dofs;
add node #6 at (1*m,1*m,0*m) with 3 dofs;

// Adding Truss Elements
add element #1 type truss with nodes (1,2) use material # 1 cross_section = 1*m^2 mass_density = 1*kg/m^3;
add element #2 type truss with nodes (3,4) use material # 1 cross_section = 1*m^2 mass_density = 1*kg/m^3;
add element #3 type truss with nodes (3,5) use material # 1 cross_section = 1*m^2 mass_density = 1*kg/m^3;
add element #4 type truss with nodes (2,6) use material # 1 cross_section = 1*m^2 mass_density = 1*kg/m^3;

// Adding Contact Element
add element #5 type FrictionalPenaltyContact with nodes (2,3)
 normal_stiffness = 1e12*N/m
 tangential_stiffness = 1e12*N/m
 normal_damping = 0*N/m*s
 tangential_damping = 0*N/m*s
 friction_ratio = 0.4
 contact_plane_vector = (1,0,0);

// Adding Fixities
fix node #1 dofs ux uy uz ;
fix node #4 dofs ux uy uz ;
fix node #5 dofs ux uy uz ;
fix node #6 dofs ux uy uz ;
fix node #2 dofs uz ;
fix node #3 dofs uz ;

new loading stage "Normal_Loading";

 add load #1 to node #2 type linear Fx = 0.1*N;

 tol = 1e-10;
 define convergence test Norm_Displacement_Increment
   tolerance = tol
   maximum_iterations = 10
   verbose_level = 4;
```

```

 define algorithm Newton;

 Nsteps= 10;
 define solver UMFPack;
 define load factor increment 1/Nsteps;
 simulate Nsteps steps using static algorithm;

new loading stage "Shear_Loading";

 add load #2 to node #2 type linear Fy = 0.2*N;

 tol = 1e-10;
 define convergence test Norm_Displacement_Increment
   tolerance = tol
   maximum_iterations = 10
   verbose_level = 4;

 define algorithm Newton;

 Nsteps= 100;
 define solver UMFPack;
 define load factor increment 1/Nsteps;
 simulate Nsteps steps using static algorithm;

bye;
```

The displacement output of *Node 2 and Node 3* are shown below.

The ESSI model fei/DSL files for this example can be downloaded here.

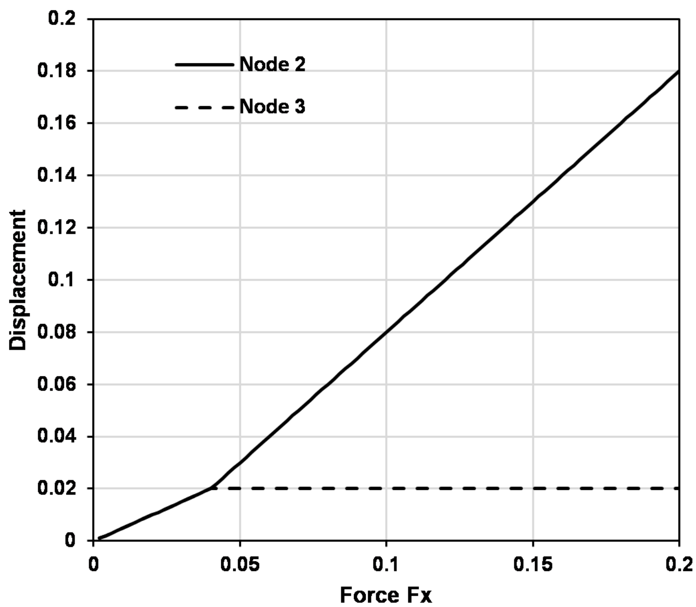


Figure 707.56: Displacemnet of Nodes 2 and 3 along y direction

707.21 3-D Truss example with normal confinement and Shear Loading

A simple 3-D truss example with Normal confinement in z-direction of $F_N = 0.5N$, friction coefficient $\mu = 0.2$ and shear loading of magnitude $F_s = 0.5N$. Figure 707.57 below, shows the description of the problem.

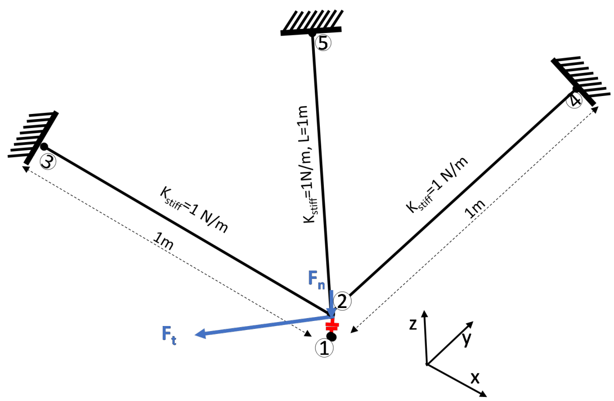


Figure 707.57: Illustration of 3-D Truss Problem with confinement loading in z-direction of 0.5N and then shear loading of 0.5N in x-y plane

ESSI model fei/DSL file:

```
model name "3-D_Contact_Under_Normal_And_Tangential_Loading" ;

// Adding material
add material #1 type uniaxial_elastic elastic_modulus = 1*Pa viscoelastic_modulus = 0*Pa*s;

// Adding Nodes
add node #1 at (0*m,0*m,0*m) with 3 dofs;
add node #2 at (0*m,0*m,0*m) with 3 dofs;
add node #3 at (-1*m,0*m,0*m) with 3 dofs;
add node #4 at (0*m,1*m,0*m) with 3 dofs;
add node #5 at (0*m,0*m,1*m) with 3 dofs;

// Adding Fixities
fix node #1 dofs ux uy uz;
fix node #3 dofs ux uy uz;
fix node #4 dofs ux uy uz;
fix node #5 dofs ux uy uz;

// Adding Truss Elements
add element #1 type truss with nodes (2,3) use material # 1 cross_section = 1*m^2 mass_density = 1*kg/m^3;
add element #2 type truss with nodes (2,4) use material # 1 cross_section =
```

```
    1*m^2 mass_density = 1*kg/m^3;
add element #3 type truss with nodes (2,5) use material # 1 cross_section = ↩
    1*m^2 mass_density = 1*kg/m^3;

// Adding Contact Element
add element #4 type FrictionalPenaltyContact with nodes (1,2)
normal_stiffness =1e10*N/m
tangential_stiffness = 1e10*Pa*m
normal_damping = 0*kN/m*s
tangential_damping = 0*kN/m*s
friction_ratio = 0.2
contact_plane_vector = (0,0,1);

new loading stage "Adding_Normal_Load";

add load #1 to node #2 type linear Fz = -0.5*N;

Nsteps = 1;

tol = 1e-10;
define convergence test Norm_Displacement_Increment
  tolerance = tol
  maximum_iterations = 1
  verbose_level = 4;

define algorithm Newton;
define solver UMFPack;

define load factor increment 1/Nsteps;
simulate Nsteps steps using static algorithm;

new loading stage "Shear_Loading";

add load #2 to node #2 type linear Fx = 0.4;
add load #3 to node #2 type linear Fy = 0.3;

tol = 1e-12;
define convergence test Norm_Displacement_Increment
  tolerance = tol
  maximum_iterations = 10
  verbose_level = 4;

define algorithm Newton;

Nsteps= 20;
define solver UMFPack;
define load factor increment 1/Nsteps;
simulate Nsteps steps using static algorithm;

bye;
```

The generalized displacement response of the tangential loading stage is shown below.

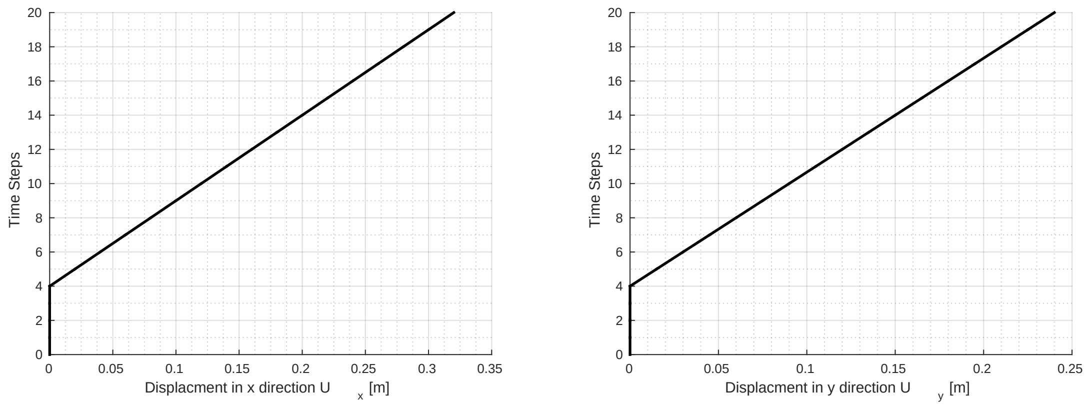


Figure 707.58: Displacements of Node 2 with applied shear tangential load step.

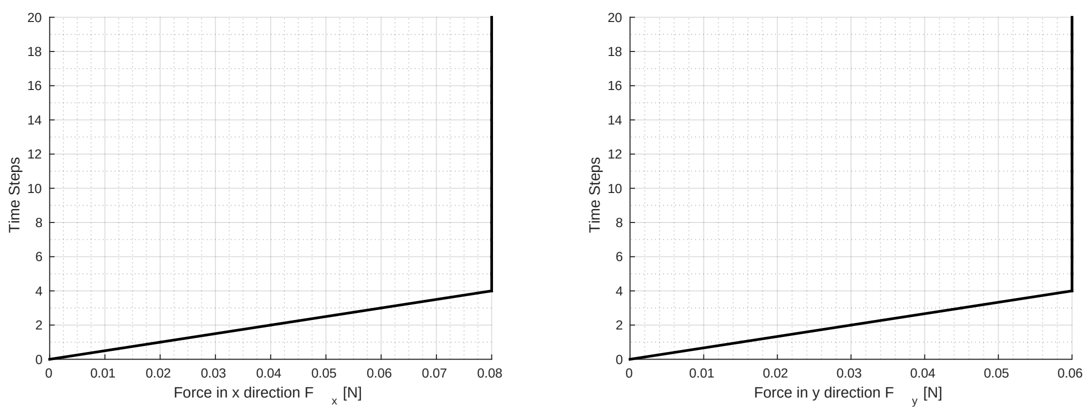


Figure 707.59: Resisting force by the contact/interface element with applied shear tangential load step.

The ESSI model fei/DSL files for this example can be downloaded here.

707.22 Six Solid Blocks Example With Contact

This is a 3-D solid block example withi initial normal and then tangential load on different surfaces as shown below.

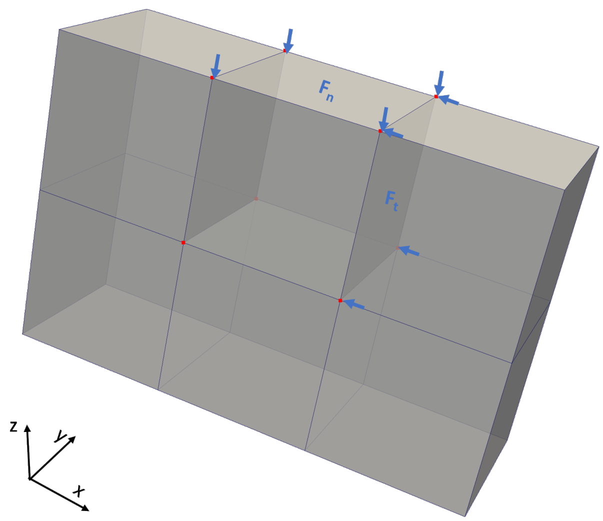


Figure 707.60: Illustration of Six Solid Blocks Example with Contact having first normal and then tangential loading stages.

ESSI model fei/DSL file:

```

model name "Six_Solid_Blocks_Example_With_Contact";

// Adding material
 add material #1 type linear_elastic_isotropic_3d_LT mass_density=2000*kg/m^3 ↩
     elastic_modulus=200*MPa poisson_ratio=0.3;

// Adding Nodes
 add node # 1 at (-1.500000*m,-0.500000*m,0.000000*m) with 3 dofs;
 add node # 2 at (-1.500000*m,0.500000*m,0.000000*m) with 3 dofs;
 add node # 3 at (1.500000*m,-0.500000*m,0.000000*m) with 3 dofs;
 add node # 4 at (1.500000*m,0.500000*m,0.000000*m) with 3 dofs;
 add node # 5 at (-1.500000*m,-0.500000*m,-2.000000*m) with 3 dofs;
 add node # 6 at (-1.500000*m,0.500000*m,-2.000000*m) with 3 dofs;
 add node # 7 at (1.500000*m,0.500000*m,-2.000000*m) with 3 dofs;
 add node # 8 at (1.500000*m,-0.500000*m,-2.000000*m) with 3 dofs;
 add node # 9 at (-0.500000*m,-0.500000*m,0.000000*m) with 3 dofs;
 add node # 10 at (0.500000*m,-0.500000*m,0.000000*m) with 3 dofs;
 add node # 11 at (-0.500000*m,0.500000*m,0.000000*m) with 3 dofs;
 add node # 12 at (0.500000*m,0.500000*m,0.000000*m) with 3 dofs;
 add node # 13 at (-0.500000*m,0.500000*m,-2.000000*m) with 3 dofs;
```

```
 add node # 14 at (0.500000*m,0.500000*m,-2.000000*m) with 3 dofs;
 add node # 15 at (0.500000*m,-0.500000*m,-2.000000*m) with 3 dofs;
 add node # 16 at (-0.500000*m,-0.500000*m,-2.000000*m) with 3 dofs;
 add node # 17 at (-1.500000*m,-0.500000*m,-1.000000*m) with 3 dofs;
 add node # 18 at (-1.500000*m,0.500000*m,-1.000000*m) with 3 dofs;
 add node # 19 at (1.500000*m,0.500000*m,-1.000000*m) with 3 dofs;
 add node # 20 at (1.500000*m,-0.500000*m,-1.000000*m) with 3 dofs;
 add node # 21 at (-0.500000*m,0.500000*m,-1.000000*m) with 3 dofs;
 add node # 22 at (0.500000*m,0.500000*m,-1.000000*m) with 3 dofs;
 add node # 23 at (-0.500000*m,-0.500000*m,-1.000000*m) with 3 dofs;
 add node # 24 at (0.500000*m,-0.500000*m,-1.000000*m) with 3 dofs;

 add node # 25 at (-0.500000*m,-0.500000*m,0.000000*m) with 3 dofs;
 add node # 26 at (0.500000*m,-0.500000*m,0.000000*m) with 3 dofs;
 add node # 27 at (-0.500000*m,0.500000*m,0.000000*m) with 3 dofs;
 add node # 28 at (0.500000*m,0.500000*m,0.000000*m) with 3 dofs;

 add node # 29 at (-0.500000*m,0.500000*m,-1.000000*m) with 3 dofs;
 add node # 30 at (0.500000*m,0.500000*m,-1.000000*m) with 3 dofs;
 add node # 31 at (-0.500000*m,-0.500000*m,-1.000000*m) with 3 dofs;
 add node # 32 at (0.500000*m,-0.500000*m,-1.000000*m) with 3 dofs;

// Adding Solid 8 Node Brick Elements
 add element #1 type 8NodeBrickLT with nodes (21,23,17,18,11,9,1,2) use material #1;
 add element #2 type 8NodeBrickLT with nodes (13,16,5,6,21,23,17,18) use material #1;
 add element #3 type 8NodeBrickLT with nodes (30,32,31,29,28,26,25,27) use material #1;
 add element #4 type 8NodeBrickLT with nodes (14,15,16,13,22,24,23,21) use material #1;
 add element #5 type 8NodeBrickLT with nodes (19,20,24,22,4,3,10,12) use material #1;
 add element #6 type 8NodeBrickLT with nodes (7,8,15,14,19,20,24,22) use material #1;

//Adding some variables
 Kn = 1e12*N/m; // normal penalty stiffness
 Kt = 1e12*N/m; // tangential penalty stiffness
 Cn = 0*N/m*s; // normal penalty damping
 Ct = 0*N/m*s; // tangential penalty damping
 nu = 0.4; // friction ratio

// Adding Contact Element
 add element #7 type FrictionalPenaltyContact with nodes (9,25)
  normal_stiffness = Kn
  tangential_stiffness = Kt
  normal_damping = Cn
  tangential_damping = Ct
  friction_ratio = nu
  contact_plane_vector = (1,0,0);
```

```
add element #8 type FrictionalPenaltyContact with nodes (10,26)
 normal_stiffness = Kn
 tangential_stiffness = Kt
 normal_damping = Cn
 tangential_damping = Ct
 friction_ratio = nu
 contact_plane_vector = (-1,0,0);

add element #9 type FrictionalPenaltyContact with nodes (11,27)
 normal_stiffness = Kn
 tangential_stiffness = Kt
 normal_damping = Cn
 tangential_damping = Ct
 friction_ratio = nu
 contact_plane_vector = (1,0,0);

add element #10 type FrictionalPenaltyContact with nodes (12,28)
 normal_stiffness = Kn
 tangential_stiffness = Kt
 normal_damping = Cn
 tangential_damping = Ct
 friction_ratio = nu
 contact_plane_vector = (-1,0,0);

add element #11 type FrictionalPenaltyContact with nodes (21,29)
 normal_stiffness = Kn
 tangential_stiffness = Kt
 normal_damping = Cn
 tangential_damping = Ct
 friction_ratio = nu
 contact_plane_vector = (1,0,0);

add element #12 type FrictionalPenaltyContact with nodes (22,30)
 normal_stiffness = Kn
 tangential_stiffness = Kt
 normal_damping = Cn
 tangential_damping = Ct
 friction_ratio = nu
 contact_plane_vector = (-1,0,0);

add element #13 type FrictionalPenaltyContact with nodes (23,31)
 normal_stiffness = Kn
 tangential_stiffness = Kt
 normal_damping = Cn
 tangential_damping = Ct
 friction_ratio = nu
 contact_plane_vector = (1,0,0);

add element #14 type FrictionalPenaltyContact with nodes (24,32)
 normal_stiffness = Kn
```

```
  tangential_stiffness = Kt
  normal_damping = Cn
  tangential_damping = Ct
  friction_ratio = nu
  contact_plane_vector = (-1,0,0);

 add element #15 type FrictionalPenaltyContact with nodes (21,29)
  normal_stiffness = Kn
  tangential_stiffness = Kt
  normal_damping = Cn
  tangential_damping = Ct
  friction_ratio = nu
  contact_plane_vector = (0,0,1);

 add element #16 type FrictionalPenaltyContact with nodes (22,30)
  normal_stiffness = Kn
  tangential_stiffness = Kt
  normal_damping = Cn
  tangential_damping = Ct
  friction_ratio = nu
  contact_plane_vector = (0,0,1);

 add element #17 type FrictionalPenaltyContact with nodes (23,31)
  normal_stiffness = Kn
  tangential_stiffness = Kt
  normal_damping = Cn
  tangential_damping = Ct
  friction_ratio = nu
  contact_plane_vector = (0,0,1);

 add element #18 type FrictionalPenaltyContact with nodes (24,32)
  normal_stiffness = Kn
  tangential_stiffness = Kt
  normal_damping = Cn
  tangential_damping = Ct
  friction_ratio = nu
  contact_plane_vector = (0,0,1);

// Adding Fixities
 fix node #5 dofs ux uy uz;
 fix node #6 dofs ux uy uz;
 fix node #13 dofs ux uy uz;
 fix node #16 dofs ux uy uz;
 fix node #15 dofs ux uy uz;
 fix node #14 dofs ux uy uz;
 fix node #7 dofs ux uy uz;
 fix node #8 dofs ux uy uz;
 fix node #17 dofs ux uy;
 fix node #18 dofs ux uy;
 fix node #1 dofs ux uy;
 fix node #2 dofs ux uy;
```

```
 fix node #20 dofs ux uy;
 fix node #19 dofs ux uy;
 fix node #3 dofs ux uy;
 fix node #4 dofs ux uy;
 fix node #9 dofs uy;
 fix node #10 dofs uy;
 fix node #23 dofs uy;
 fix node #24 dofs uy;
 fix node #11 dofs uy;
 fix node #21 dofs uy;
 fix node #12 dofs uy;
 fix node #22 dofs uy;
 fix node #25 dofs uy;
 fix node #26 dofs uy;
 fix node #27 dofs uy;
 fix node #28 dofs uy;
 fix node #29 dofs uy;
 fix node #30 dofs uy;
 fix node #31 dofs uy;
 fix node #32 dofs uy;

new loading stage "Normal_Loading";

 add load #1 to element #3 type surface at nodes (25,26,27,28) with magnitude ↩
    (-1*Pa);

 tol = 1e-12;
 define convergence test Norm_Displacement_Increment
   tolerance = tol
   maximum_iterations = 100
   verbose_level = 4;

 define algorithm Newton;

 Nsteps= 10;
 define solver UMFPack;
 define load factor increment 1/Nsteps;
 simulate Nsteps steps using static algorithm;

new loading stage "Shear_Loading";

 add load #2 to element #3 type surface at nodes (26,28,30,32) with magnitude ↩
    (-1*Pa);

 tol = 1e-12;
 define convergence test Norm_Displacement_Increment
   tolerance = tol
   maximum_iterations = 100
   verbose_level = 4;

 define algorithm Newton;
```

```
 Nsteps= 10;
 define solver UMFPack;
 define load factor increment 1/Nsteps;
 simulate Nsteps steps using static algorithm;

bye;
```

The generalized displacement field of the two loading stages normal loading and tangentiual loading is shown below..

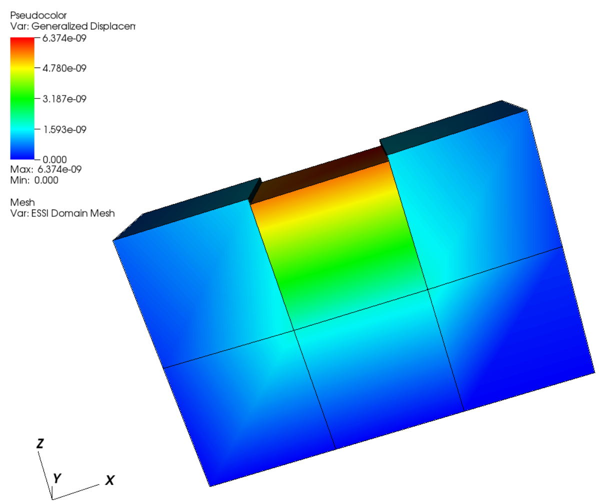


Figure 707.61: Generalized displacement magnitude visualization of normal loading

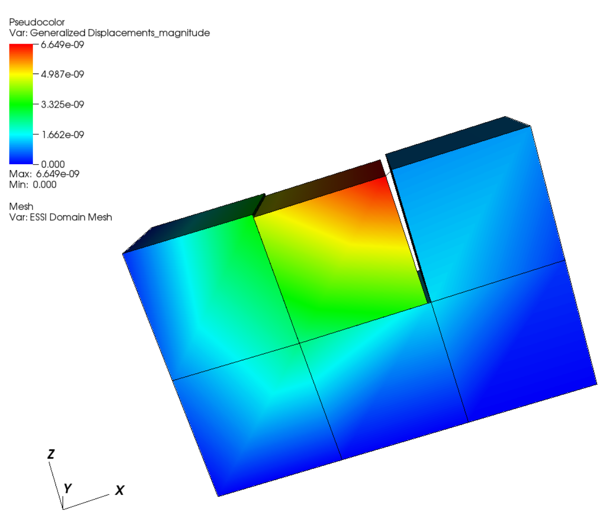


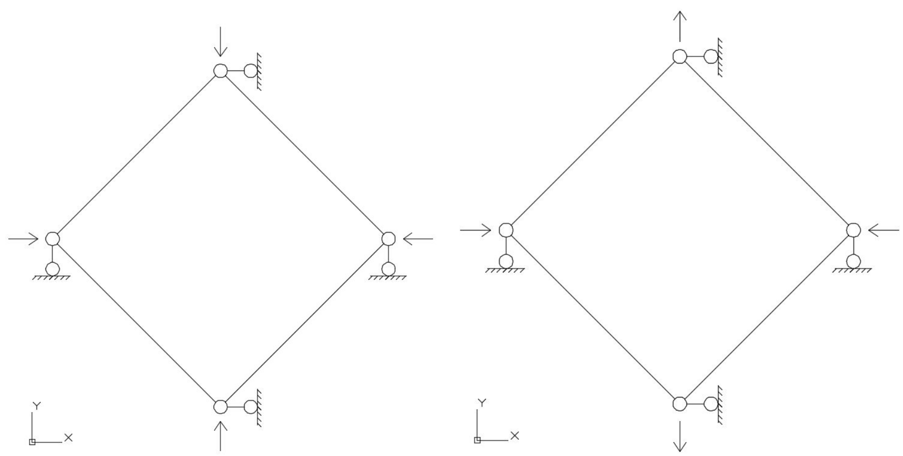
Figure 707.62: Generalized displacement magnitude visualization of tangential loading

The ESSI model fei/DSL files for this example can be downloaded here.

707.23 Pure shear model for G/Gmax plot

Problem description:

The pure shear model for G/Gmax plot



(a) (b)

Figure 707.63: The pure shear model for (a) confinment and (b) shearing

ESSI model fei/DSL file:

```
model name "GGmax" ;
// Parameters:
phi = 0.0135713590083;
ha = 2.94767923453;
cr = 1854.31984573;

rho=1922.5 ;
depth=0.1524/2;
confinstress=9.8*depth*rho;
G=12388.33;

p0 = confinstress*Pa;
phirad = pi*phi/180;
M = 6*sin(phirad)/(3-sin(phirad));
nu=0.3;
add material # 1 type DruckerPragerArmstrongFrederickLT
    mass_density = rho*kg/m^3
    elastic_modulus = 2*G*(1+nu)*Pa
    poisson_ratio = nu
    druckerprager_k = M
    armstrong_frederick_ha = ha*Pa
    armstrong_frederick_cr = cr*Pa
```

```
    isotropic_hardening_rate = 0*Pa
    initial_confining_stress = 10*Pa;
add node # 1 at ( 1.0000 *m, 0.0000 *m, 0.0000 *m) with 3 dofs;
add node # 2 at ( 0.0000 *m, 1.0000 *m, 0.0000 *m) with 3 dofs;
add node # 3 at ( 1.0000 *m, 2.0000 *m, 0.0000 *m) with 3 dofs;
add node # 4 at ( 2.0000 *m, 1.0000 *m, 0.0000 *m) with 3 dofs;
add node # 5 at ( 1.0000 *m, 0.0000 *m, 1.0000 *m) with 3 dofs;
add node # 6 at ( 0.0000 *m, 1.0000 *m, 1.0000 *m) with 3 dofs;
add node # 7 at ( 1.0000 *m, 2.0000 *m, 1.0000 *m) with 3 dofs;
add node # 8 at ( 2.0000 *m, 1.0000 *m, 1.0000 *m) with 3 dofs;
add element # 1 type 8NodeBrickLT with nodes(1,2,3,4,5,6,7,8) use material # 1;

// fix the y direction for node 2,4,6,8
fix node # 2 dofs uy ;
fix node # 4 dofs uy ;
fix node # 6 dofs uy ;
fix node # 8 dofs uy ;
// fix the x direction for node 1,3,5,7
fix node # 1 dofs ux ;
fix node # 3 dofs ux ;
fix node # 5 dofs ux ;
fix node # 7 dofs ux ;
// Stage 1: confinement
new loading stage "confinement";
add load # 1 to node # 1 type linear Fy= p0*m^2;
add load # 2 to node # 3 type linear Fy= - p0*m^2;
add load # 3 to node # 5 type linear Fy= p0*m^2;
add load # 4 to node # 7 type linear Fy= - p0*m^2;

add load # 5 to node # 2 type linear Fx= p0*m^2;
add load # 6 to node # 4 type linear Fx= - p0*m^2;
add load # 7 to node # 6 type linear Fx= p0*m^2;
add load # 8 to node # 8 type linear Fx= - p0*m^2;

// confinement at z direction
add load # 101 to node # 1 type linear Fz= p0*m^2;
add load # 102 to node # 2 type linear Fz= p0*m^2;
add load # 103 to node # 3 type linear Fz= p0*m^2;
add load # 104 to node # 4 type linear Fz= p0*m^2;

add load # 105 to node # 5 type linear Fz= - p0*m^2;
add load # 106 to node # 6 type linear Fz= - p0*m^2;
add load # 107 to node # 7 type linear Fz= - p0*m^2;
add load # 108 to node # 8 type linear Fz= - p0*m^2;

// add algorithm and solver
Nsteps=100;
define load factor increment 1/Nsteps;
define solver ProfileSPD;
define convergence test Norm_Displacement_Increment
    tolerance = 1e-5
```

```
    maximum_iterations = 100
    verbose_level = 4;
// define algorithm With_no_convergence_check ;
define algorithm Newton ;
define NDMaterialLT constitutive integration algorithm Euler_One_Step
    yield_function_relative_tolerance = 0.00002
    stress_relative_tolerance = 0.0002
    maximum_iterations = 1000;
simulate Nsteps steps using static algorithm;
// ----------------------------------------------------------------------
// Stage 2: shear
new loading stage "shear";
// fix all the uz, since we want plane strain.
i=1;
while (i<9) {
    remove load # 100+i ;
    fix node # i dofs uz;
    i=i+1;
};
shearforce=1.6*kN;


add load # 9 to node # 1 type linear Fy= shearforce;// series_file = "path.txt" ;
add load # 10 to node # 3 type linear Fy=-shearforce;// series_file = ↩
    "path.txt" ;
add load # 11 to node # 5 type linear Fy= shearforce;// series_file = ↩
    "path.txt" ;
add load # 12 to node # 7 type linear Fy=-shearforce;// series_file = ↩
    "path.txt" ;

add load # 13 to node # 2 type linear Fx=-shearforce;// series_file = ↩
    "path.txt" ;
add load # 14 to node # 4 type linear Fx= shearforce;// series_file = ↩
    "path.txt" ;
add load # 15 to node # 6 type linear Fx=-shearforce;// series_file = ↩
    "path.txt" ;
add load # 16 to node # 8 type linear Fx= shearforce;// series_file = ↩
    "path.txt" ;

// add algorithm and solver
Nsteps=1e4 ;
define static integrator displacement_control using node # 1 dof uy increment ↩
    1e-2/Nsteps*m;
define convergence test Norm_Displacement_Increment tolerance = 0.000001 ↩
    maximum_iterations = 100 verbose_level = 0;
define solver ProfileSPD;
define algorithm Newton ;
define NDMaterialLT constitutive integration algorithm Euler_One_Step
    yield_function_relative_tolerance = 0.00002
    stress_relative_tolerance = 0.0002
    maximum_iterations = 1000;
```

```

simulate Nsteps steps using static algorithm;
bye;
```

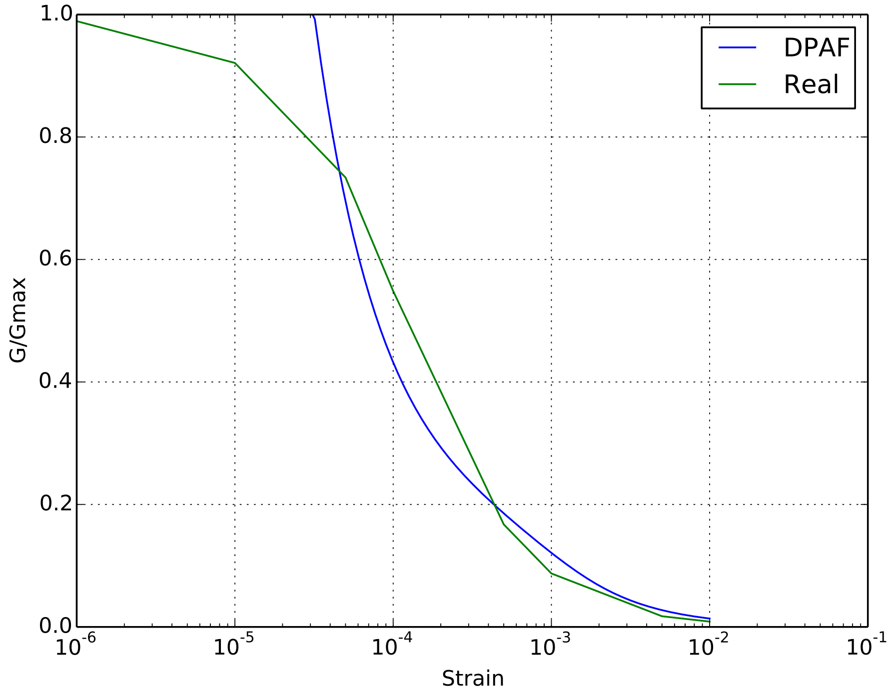


Figure 707.64: The G/Gmax results

The ESSI model fei/DSL files for this example can be downloaded here.

707.24 Multi-yield-surface von-Mises for G/Gmax plot

Problem description:

This model illustates the G/Gmax input to multi-yield-surface von-Mises material. This example is based on one Gauss-point with multi-yield-surface von-Mises material. The G/Gmax is converted to material modelingn parameters (yield-surface size and hardening parameter) inside the DSL.

ESSI model fei/DSL file:

```
model name "GGmax";
add material # 1 type vonMisesMultipleYieldSurfaceGoverGmax
  mass_density = 0.0*kg/m^3
  initial_shear_modulus = 3E8 * Pa
  poisson_ratio = 0.0
  total_number_of_shear_modulus = 9
  GoverGmax =
  "1,0.995,0.966,0.873,0.787,0.467,0.320,0.109,0.063"
  ShearStrainGamma =
  "0,1E-6,1E-5,5E-5,1E-4, 0.0005, 0.001, 0.005, 0.01"
  ;

incr_size = 0.000001 ;
max_strain= 0.005 ;
num_of_increm = max_strain/incr_size -1 ;
simulate constitutive testing strain control pure shear use material # 1
  confinement_strain = 0.0
  strain_increment_size = incr_size
  maximum_strain = max_strain
  number_of_increment = num_of_increm;
bye;
```

Computed G/Gmax curve exactly matches the one used for input at control points.

The difference in G/Gmax between control points can be reduced by using more than just 9 control points as in this example.

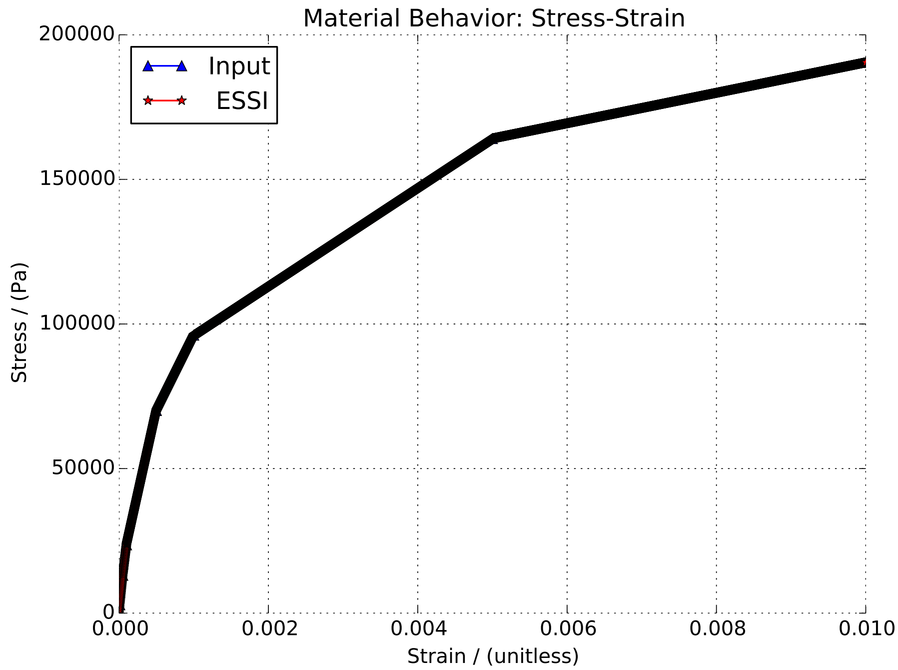


Figure 707.65: Stress-Strain Relationship

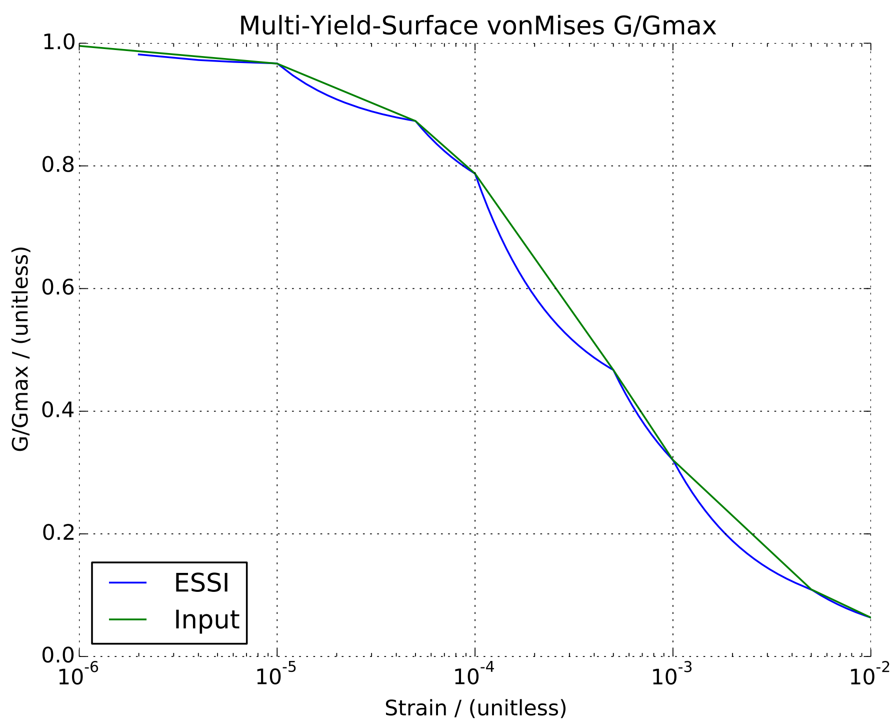


Figure 707.66: The G/Gmax results.

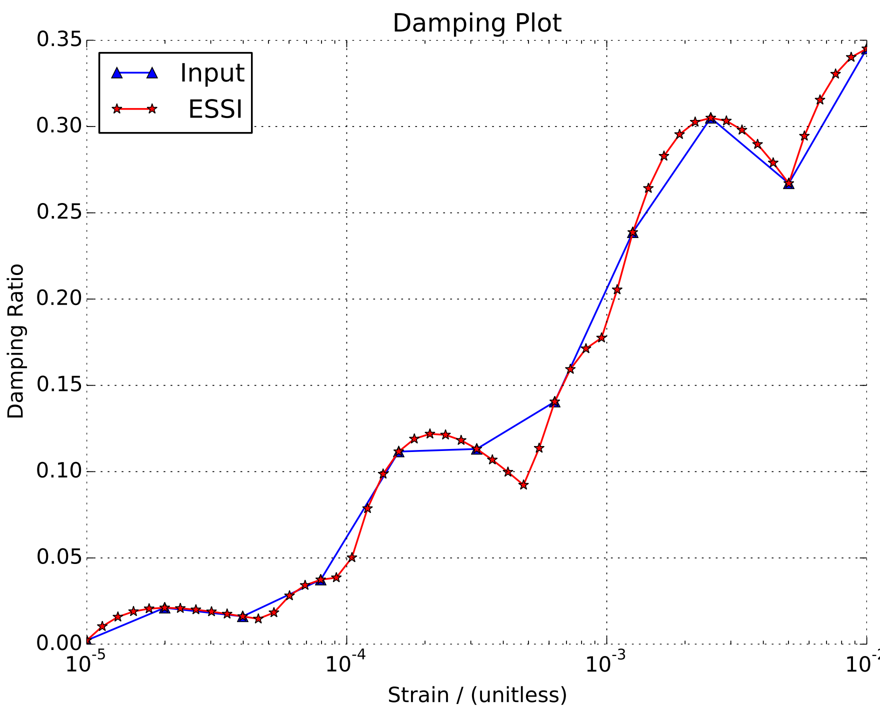


Figure 707.67: Damping Ratio Plot

707.25 Multi-yield-surface Drucker-Prager for G/Gmax plot

Problem description:

This model illustrates the G/Gmax input to multi-yield-surface Drucker-Prager material. Purely deviatoric plastic flow is used in this material, which means that the parameter dilation_scale is set to zero. If user wants to model change of volume (dilation or compression) for this material, then G/Gmax curve need to be iterated upon manually by changing yield surface size directly, which is done using different DruckerPragerMultipleYieldSurface command. This example is based on one Gauss-point which use multi-yield-surface Drucker-Prager material. The G/Gmax is converted to the yield-surface size and hardening parameter inside the DSL.

ESSI model fei/DSL file:

```
model name "GGmax";
add material # 1 type DruckerPragerMultipleYieldSurfaceGoverGmax
  mass_density = 0.0*kg/m^3
  initial_shear_modulus = 3E8 * Pa
  poisson_ratio = 0.0
  initial_confining_stress = 1E5 * Pa
  reference_pressure = 1E5 * Pa
  pressure_exponential_n = 0.5
  cohesion = 0. * Pa
  dilation_angle_eta =1.0
  dilation_scale = 0.0
  total_number_of_shear_modulus = 9
  GoverGmax =
  "1,0.995,0.966,0.873,0.787,0.467,0.320,0.109,0.063"
  ShearStrainGamma =
  "0,1E-6,1E-5,5E-5,1E-4, 0.0005, 0.001, 0.005, 0.01"
  ;

incr_size = 0.000001 ;
max_strain= 0.005 ;
num_of_increm = max_strain/incr_size -1 ;
simulate constitutive testing strain control pure shear use material # 1
  confinement_strain = 0.0
  strain_increment_size = incr_size
  maximum_strain = max_strain
  number_of_increment = num_of_increm;
bye;
```

Inside the DSL, the yield surface radius is calculated as $\sqrt{3}\sigma_y$, where σ_y is the yield stress of the corresponding yield surface. Then, the radius is divided by the confinement to obtain the slope (opening angle).

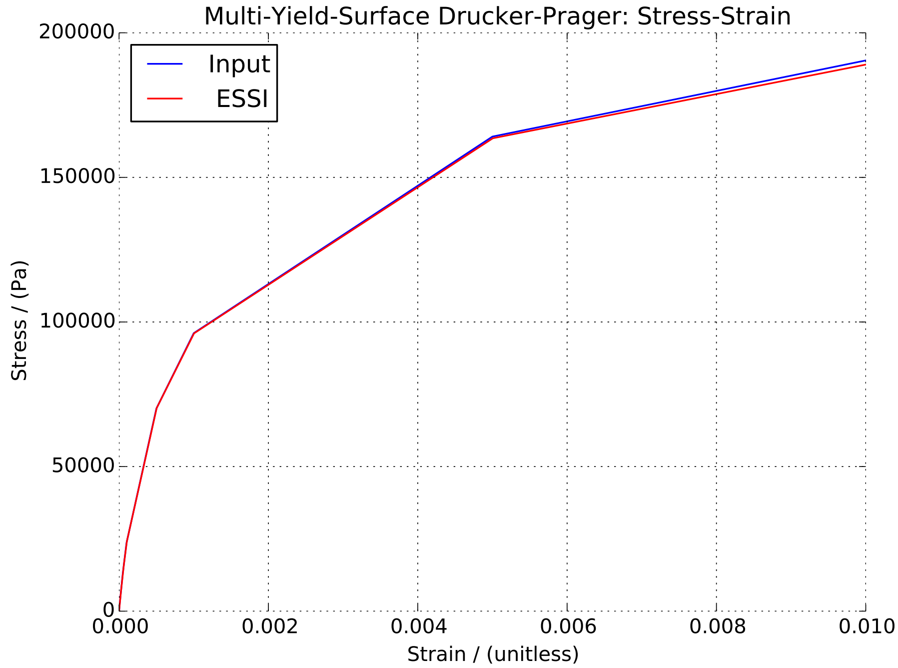


Figure 707.68: Nested-Yield-Surface Drucker-Prager Stress-Strain Relationship

The hardening parameter is calculated as

$$\frac{1}{H'_i} = \frac{1}{H_i} - \frac{1}{2G} \tag{707.1}$$

where H'_i is the current hardening parameter corresponding to yield surface i. H_i is the current tangent shear modulus to surface i, namely, $H_i = 2(\frac{\tau_{i+1}-\tau_i}{\gamma_{i+1}-\gamma_i})$. And G is the initial shear modulus.

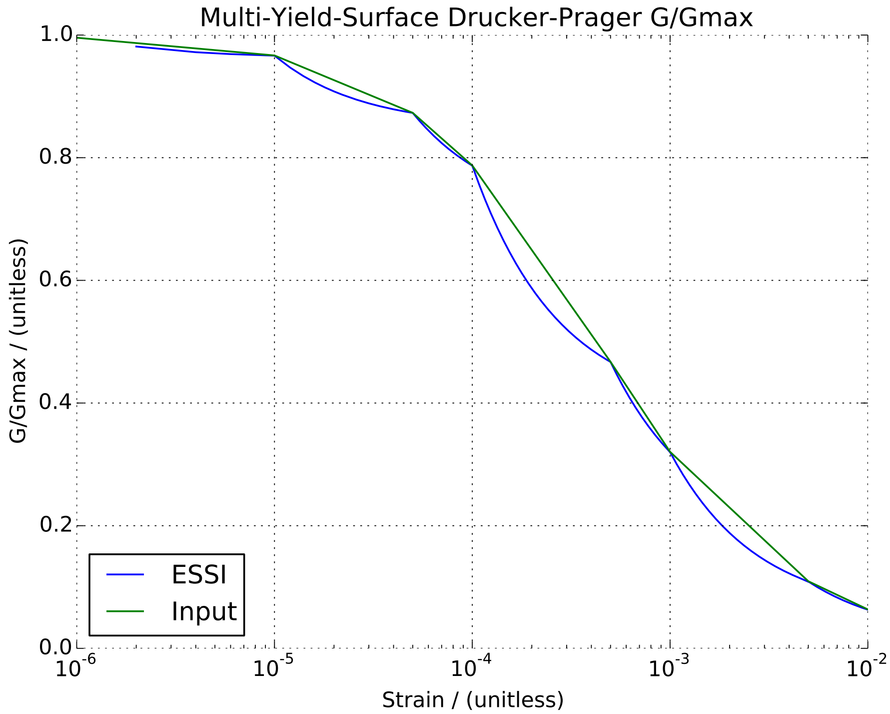


Figure 707.69: Nested-Yield-Surface Drucker-Prager G/Gmax results

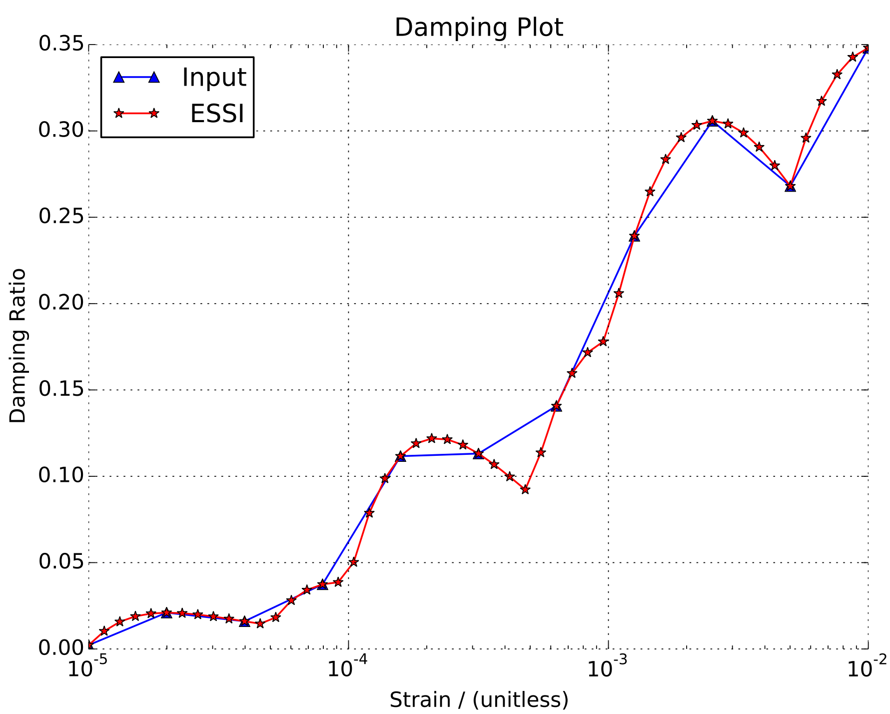


Figure 707.70: Damping Ratio Plot

Appendix 708

Brief History of the Real-ESSI Simulator Development

(1986-)

This section briefly describes history of the development of the Finite Element Interpreted, FEI, that is currently represented by the Real-ESSI Simulator system. Developments are presented chronologically, with very brief description of capabilities, and with references to further reading and documents with more information.

1986-1988: Development of the `FRAME_and_GRID` program, in 2D, using BASIC programming language, on SHARP 1500, CASIO 1000 (48KB RAM) and ZX Spectrum (128KB RAM), by Boris Jeremić, undergraduate student at the University of Belgrade.

1988-1989: Development of the Earthquake Soil Structure Interaction (ESSI) Program in time domain for axisymmetric solids with general 3D loads, using higher modes of response in circumferential direction, expanded in Fourier series, so that any general 3D loading and deformation can be modeled, earthquake shaking applied through "heavy" rock at the bottom of the model, using FORTRAN programming language, on PC-DOS, x286+287, 640KB+384KB RAM, by Boris Jeremić, undergraduate student at the University of Belgrade, as part of his Diploma Thesis (Jeremić, 1989).

1989-1992: Development of the Finite Element Interpreter (FEI), a general purpose static and dynamic, elastic and elastic-plastic finite element program for solids (3D), rudimentary parser for a simple Domain Specific Language (DSL), using C Programming language, on PC-DOS, x286+287, 640KB+384KB RAM, by Boris Jeremić, a staff engineer at (a) Energoprojekt-Hidroinžinjering Company in Belgrade, Yugoslavia, at (b) Bekhme Dam Project site in Iraq, and at (c) Gasser&Scepan Design Bureau in Baar, Switzerland.

1992-1997: Development of the program FEM, featuring small and large deformation (large strain, large displacements/rotations), elasto-plasticity, solids (bricks with 8, 20 and 27 nodes), solution advancement control (hyperspherical/arc length control), using C++ Programming language, on Sun-SparcStation 5, Solaris, 256MB RAM, and on PC-DOS x386, x486 and on PC-Linux-TurboRedHat, by Boris Jeremić, a graduate student at the University of Colorado at Boulder, as part of his Master Thesis (Jeremić, 1994) and PhD Dissertation (Jeremić, 1997).

1997-2000: Continued development of the program FEM, addition of dynamics from ESSI, structural elements from FRAME_and_GRID, Parallel version, MPI based, linking with FEI, using C++ Programming language, on PC-Linux, and PC-Linux cluster: NorthCountry, 4 nodes + master, 100based T network, by Professor Boris Jeremić, at Clarkson University and at the University of California at Davis.

2000-2006: Developments continued with introduction of all the previous and new developments from FEM into G3 Framework, later renamed OpenSEES. at PEER, using C++ Programming language, on PC-Linux, by Professor Boris Jeremić and co-workers at the University of California at Davis, CA, USA, see Final Report Presentation.

2006-Present: Development of the Real-ESSI Simulator System (aka Real-ESSI, MS-ESSI, NRC-ESSI), using C++, FORTRAN, FEI-DSL, Python Programming languages, on PC-Linux, by Professor Boris Jeremić and co-workers at UCD. For details see main Real-ESSI Simulator web site or/and real-essi.us or/and real-essi.info (they all point to the same URL),

Appendix 709

Computer Programs for ESSI Analysis

(2019-)

This section lists a number of available computer programs, commercial, Open Source, Public Domain and Open Use, that can be used and are used for performing Earthquake Soil-Structure Interaction (ESSI) analysis. Focus is on presenting information about programs without much critical assessment of programs capabilities for ESSI analysis.

709.1 Overview of Available ESSI Analysis Programs

This section is based in part on material from Pecker et al. (2022).

709.1.1 Program Distribution Methods

Briefly described here are method for distribution of programs, in source code form or in executable form

- Commercial programs (CP): Distributed, sold, made available by commercial companies. It is very important to note that these companies need to earn funds to support company, staff, etc. Commercial programs usually have features and capabilities that are defined by a commercial license. Commercial license content is usually controlled and written by company lawyers. Commercial programs usually guaranty good accuracy of examples provided in the manual. These example usually show good, nice comparison or results with some, carefully chosen analytic solution. Publicly available, accessible Verification and Validation (V&V) for commercial programs is usually not available. One of the reasons for this, as privately noted by one of principal engineers from one of big software companies, is that verification will document level of error for approximate, numerical methods, however these errors are small, for elements, algorithms. These errors of implemented numerical approximation methods are not deemed good for business. It is reasonable to assume that commercial programs do have a significant V&V effort and documentation...

- Open Source programs (OSP): Distributed online by developers, covered by one of the open source licenses (OSL): (a) General Public License (GPL), (b) Lesser General Public License (LGPL), (c) Creative Commons (CC)) The OSL guarantees that software source code and derivative source code will be always available through similar OSL. The OSL does not even attempt to provide any quality assurance for the quality of program due to legal reasons, liability. The quality assurance (QA) for a given program, is usually a separate effort. It is noted that QA for OSL programs is almost impossible, as anyone can obtain a source code for a program, make changes to program sources, that can possibly destroy any previous QA and V&V effort and present results as using the same program...

- Restricted Source programs (RSP): Distributed to select developers, users, using a restricted version of an open source license. The difference is that developers and program owners can restrict source code distribution, mostly due to intellectual property reasons. A version of OSL is used, usually a revised version of CC license. Quality Assurance with restricted source programs is easier, as the main developer, program owner, quality assurance maintainer controls program sources distribution and can, therefor, main control of the QA process.
- Open Use programs (OUS): Distributed are executable versions of the program. The program owner can place limitations on use of the program. The quality assurance (QA) is controlled by the program owner, distributor. The QA, if it exists, is easily mainteined.
- Public Domain programs (PDP): Distributed are source code and/or executable without any restrictions for any future use. Original developer and owner of the program releases all the rights to the program sources and executables for any future use.

709.1.2 Available Programs

Provided is an incomplete list of programs that can be used and are used for ESSI analysis, or part of the ESSI analysis. These programs are available using one of the distribution methods as noted in previous section 709.1.1 on page 3080.

- Commercial Programs:
  - ABAQUS (http://www.3ds.com)
  - ADINA (http://www.adina.com)
  - ANSYS (http://www.ansys.com/)
  - CLASSI ()
  - GT STRUDL (https://hexagonppm.com/offerings/products/gt-strudl)
  - LS-DYNA (http://www.lstc.com)
  - NASTRAN (http://www.mscsoftware.com)
  - RIGID ()
  - SAP2000 (https://www.csiamerica.com)
  - SASSI 2010 (http://sassi2000.net)
  - ACS SASSI (http://www.ghiocel-tech.com)

- SMACS ()
- STARDYNE (ftp://ftp.cray.com)
- SOFISTIK (http://www.sofistik.com)
- PLAXIS (http://www.plaxis.nl/)
- FLAC (http://www.itascacg.com)
- DYNAFLOW (https://blogs.princeton.edu/prevost/dynaflow/)
- Zsoil (http://www.zsoil.com)
- Real-ESSI (http://real-essi.us/, http://essi-consultants.com)

- Open Source programs, Restricted Source programs, and Open Use programs:
  - FEAP (http://www.ce.berkeley.edu)
  - DEEPSOIL (http://deepsoil.cee.illinois.edu/)
  - SIMQKE1 (http://nisee.berkeley.edu/)
  - OpenSees (http://opensees.berkeley.edu/)
  - Code_ASTER (http://www.code_astair.org)
  - Real-ESSI (http://real-essi.us/)

- Public Domain programs:
  - SHAKE91 (http://nisee.berkeley.edu/)
  - EERA and NEERA (http://www.ce.memphis.edu/)
  - DESRA-2 ()
  - SUMDES ()
  - D-MOD ()
  - TESS ()
  - OpenSees (http://opensees.berkeley.edu/)

Appendix 710

Work Organization

(1989-)

This section describes in some detail work organization related to the development of FEI modeling and computational system.

710.1 Communication

Tablets, smart phones, laptops and computers, using https://zoom.us/ as it works on linux and all other OSs.

710.2 Writing (Notes, Code, &c.) Version Control

710.2.1 Source Code

Memory Leaks Memory leaks are best discovered by running Valgrind (http://valgrind.org/). There are a number of tools that can be used with Valgrind. Mentioned are some of the most important ones, with example commands[1]

use of `tcsh` is assumed, with a time stamp (used in commands below) set as: `set TIMESTAMP = `date +%h_%d_%Y_%Hh_%Mm_%Ss__%A``

- `(time valgrind --tool=cachegrind $argv[1] >! $argv[1].cachegrind.$TIMESTAMP.out)>&! $argv[1].cachegrind.$TIMESTAMP.err`
- `(time valgrind --tool=callgrind $argv[1] >! $argv[1].callgrind.$TIMESTAMP.out)>&! $argv[1].callgrind.$TIMESTAMP.err`
- `(time valgrind --tool=massif $argv[1] >! $argv[1].massif.$TIMESTAMP.out)>&! $argv[1].massif.$TIMESTAMP.err`
- `(time valgrind --tool=memcheck --leak-check=full --show-reachable=yes --freelist-vol=10000 $argv[1] >! $argv[1].memcheck.$TIMESTAMP.out)>&! $argv[1].memcheck.$TIMESTAMP.err`
- `valgrind -v --leak-check=yes --show-reachable=yes --num-callers=32 --trace-malloc=yes --error-limit=no --tool=massif $argv[1]`

[1] Examples use synthax from few years ago, so should be proper synthax should be verified using excellent Valgrind documentation.

710.2.2 Verification of Real-ESSI

The aim is to run the verification procedure for Real-ESSI as automatically as possible. The verification of Real-ESSI is based on the verification of C++ libraries by https://www.boost.org/.

The verification is divided into 3 parts:

1. verification of `essi.sequential`, run by calling bash script `ESSI_VERIFICATION_run_all_verification_SEQUENTIAL.sh`
2. verification of `essi.parallel`, run by calling bash script `ESSI_VERIFICATION_run_all_verification_PARALLEL.sh`
3. check of the code stability, run by calling bash script `ESSI_VERIFICATION_run_CODE_STABILITY.sh`.

710.2.2.1 Update of the verification procedure from 2019

The following was done in `.../oofep/Rad_na_cml04/GLOBAL_RELEASE/Real-ESSI-Examples`.

1. In `*.fei` files, variable `Gamma` was replaced by `GammaParam` because `Gamma` is a keyword. The following was used

   ```
   grep -rl --include \*.fei 'Gamma' * | xargs -i@ sed -i 's/Gamma/GammaParam/g' @
   ```

   and then

   ```
   grep -rl --include $\backslash$*.fei 'ShearStrainGammaParam' * $\vert$ xargs ↩
   -i@ sed -i 's/ShearStrainGammaParam/ShearStrainGamma/g' @
   ```

2. `Beta` was replaced by `BetaParam` using

   ```
   grep -rl --include \*.fei 'Beta' * | xargs -i@ sed -i 's/Beta/BetaParam/g' @
   ```

3. 2TO3 converter was used to convert the `*.py` files from PYTHON2 to PYTHON3 using

   ```
   cd .../oofep/Rad_na_cml04/GLOBAL_RELEASE/Real-ESSI-Examples/
   ```

   and then

   ```
   2to3 -w .
   ```

   Before that, 2TO3 was installed as follows

   ```
   sudo apt install 2to3
   sudo apt install python3-lib2to3
   sudo apt install python3-toolz
   ```

4. During the evaluation of dynamic examples in `../Real-ESSI-Examples/dynamic_test`, warning:

   `DeprecationWarning: Please use ‘fftfreq‘ from the ‘scipy.fftpack‘ namespace, the ‘scipy.fftpack.helper‘ namespace is deprecated.`

   was returned, so in `../Real-ESSI-Examples/dynamic_test`, the following was done:

   ```
   grep -rl --include \*.py 'scipy.fftpack.helper' * | xargs -i@ sed -i 's/scipy.fftpack.helper/scipy.fftpack/g' @
   ```

5. During the evaluation of dynamic examples in `../Real-ESSI-Examples/dynamic_test`, an error was returned:

   `xi, fs, Ys = measure_damping(f[0:N/2], abs(D[0:N/2]))`

   `TypeError: slice indices must be integers or None or have an __index__ method Solution`

   so in `../Real-ESSI-Examples/dynamic_test`, the following was done:

   ```
   grep -rl --include \*.py 'N/2]' * | xargs -i@ sed -i 's#N/2]#N//2]#g' @
   ```

6. During the evaluation of dynamic examples in `../Real-ESSI-Examples/dynamic_test`, an error was returned:

   `runall.sh: line 28: cd: */: No such file or directory`

   Examples in all subfolders are evaluated by `runall.sh`. The error pertains to the folder `__pycache__`. I added `__pycache__.fei` (with just `bye;` inside), in folder `__pycache__`.

7. `ESSI_VERIFICATION_run_all_verification_SEQUENTIAL.sh` and `ESSI_VERIFICATION_run_all_verification_PARALLEL.sh` were modified.

710.2.3 Lecture Notes

Maintain lecture notes using git on `https://github.com/`.

Checking all http links in lecture notes using script `ESSI_check_URLs_in_lecture_notes.sh` in bin.

710.2.4 Bibliography

Bibliography List.

Papers of interest are organized in bibtex files (managed through *git* version control.

A list of those paper is compiled and available at:

http://sokocalo.engr.ucdavis.edu/~jeremic/research/Jeremic_et_al_bibliography_mechanics.pdf

http://sokocalo.engr.ucdavis.edu/~jeremic/research/Jeremic_et_al_bibliography_computers.pdf

http://sokocalo.engr.ucdavis.edu/~jeremic/research/Jeremic_et_al_bibliography_education.pdf

Bibliography Repository.

Most listed papers are available at:
http://sokocalo.engr.ucdavis.edu/~jeremic/PAPERSlocalREPO/. This site is only accessible to members of the Computational Mechanics group at University of California at Davis, and few other collaborating entities.

710.3 Backup

710.4 Calendar

710.5 Useful Programs and Scripts

710.5.1 Backup Scripts

710.5.2 Domain Reduction Method Processing Programs and Scripts

DRM Node Extraction for fk.

fk Output Processing for DRM.

710.5.3 Pre Processing Programs and Scripts

710.5.4 Post Processing Programs and Scripts

710.5.5 Parallel Computer Architecture

http://www.open-mpi.org/projects/hwloc/

Appendix 711

Collected Bibliography

Compilation of all collected bibliography, over years, not necessarily cited in this book.

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by:

Jeremić CompMech Group

Department of Civil and Environmental Engineering

University of California, Davis

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