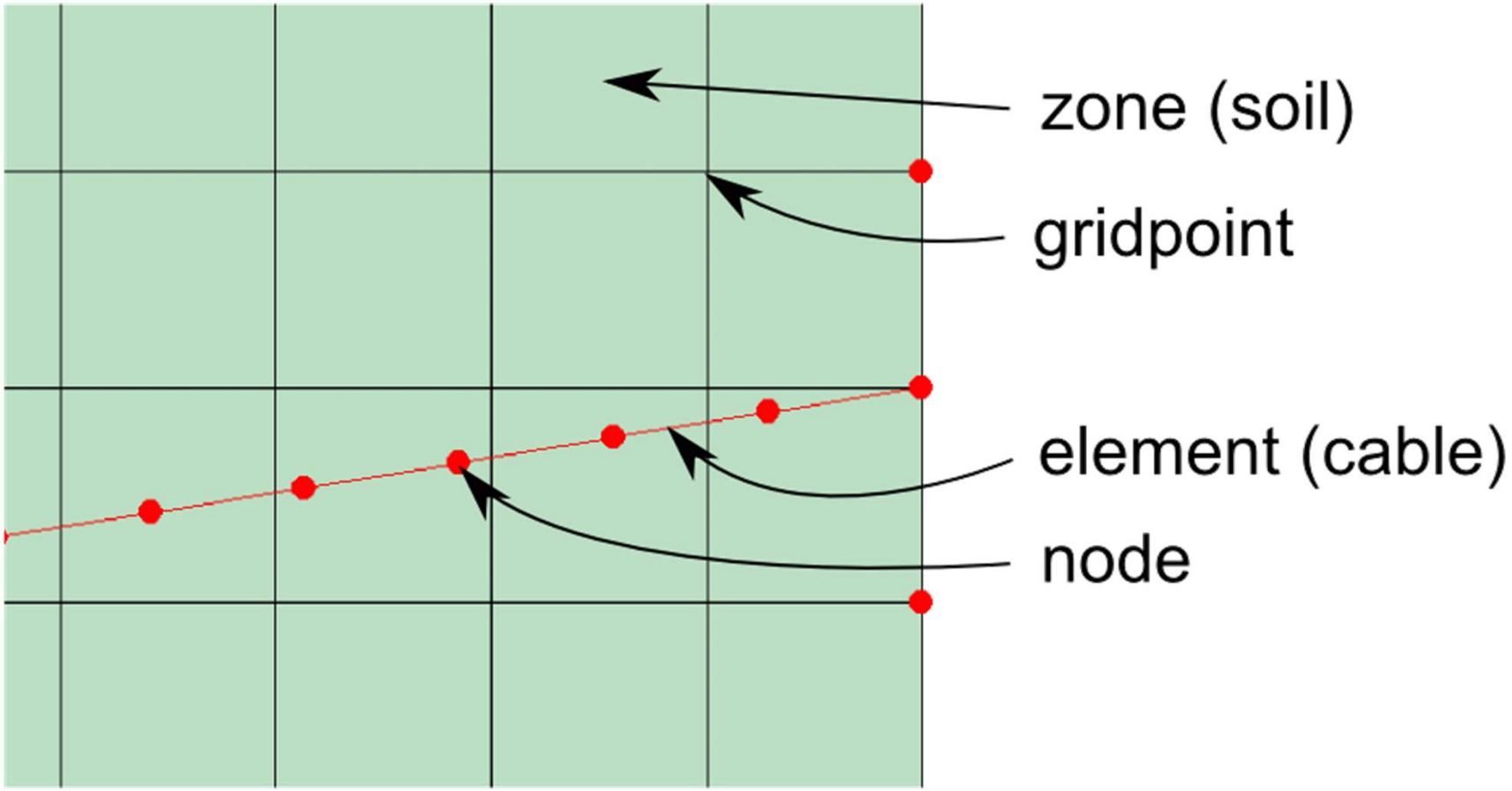
Support elements

Nomenclature



Structural elements in *FLAC3D*

There are seven types of structural element available in *FLAC3D*:

1D Elements

1. **Beam elements**. These allow bending, and are connected to the grid at nodes (rigid connection). Plastic moments can be specified.
2. **Cable elements**. No bending resistance. Cable nodes are slaved to grid motion in the normal direction, and via shear springs & slip elements in the shear direction. Yield may occur axially. Cable nodes may also be connected rigidly to gridpoints.
3. **Pile elements**. Bending resistance is included. Connection to the grid is via yielding springs in both the normal and shear directions.
4. **Rockbolt elements**. Similar to piles, and also can account for change in confining stress, strain-softening of grout, and tensile rupture of element.

Structural elements in *FLAC3D*

2D Elements

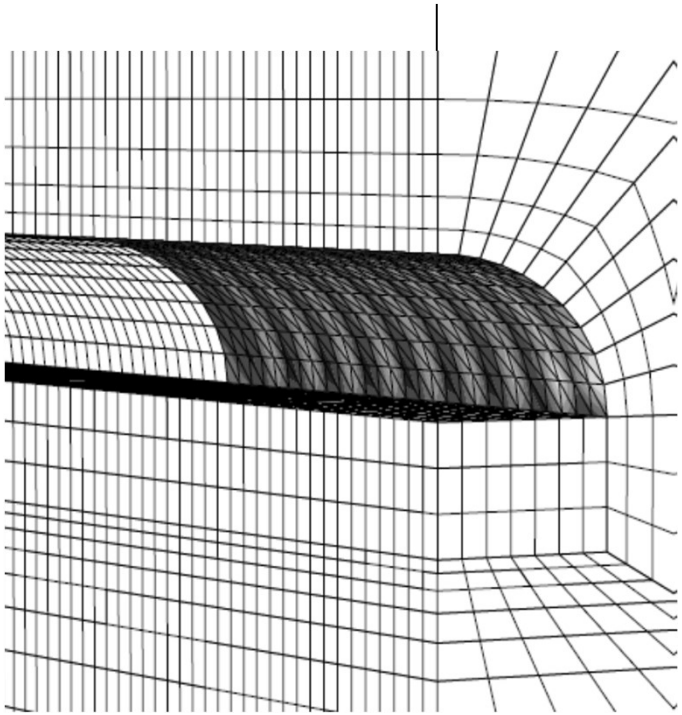
5. **Shell elements**. Behaves as an isotropic or orthotropic linearly elastic material with no failure limit; plastic hinge line can be introduced.
6. **Geogrid elements**. Same as shells except no bending resistance. A shear directed frictional interaction occurs between geogrid and FLAC3D grid.
7. **Liner elements**. Same as shells with bending resistance included. A shear directed frictional interaction occurs between liner and FLAC3D grid. Also, compressive and tensile forces can be carried in the normal direction, and the liner can break free (and re-attach) with the grid. An option is available to allow interaction with the grid on both sides of the liner. This is named an embedded liner.

Structural elements in *FLAC3D*

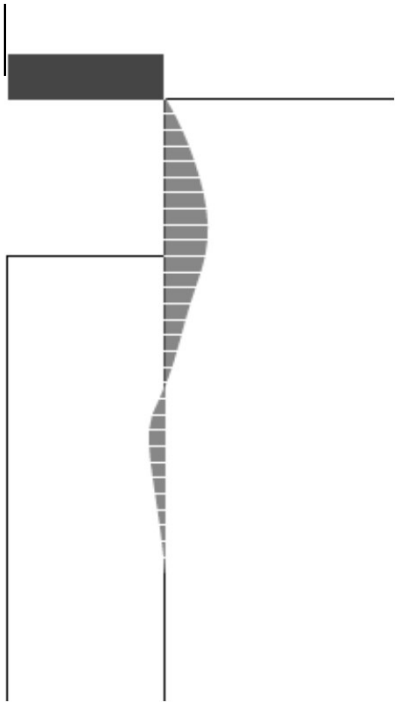
- Formulation:
  - Each element type is characterized by a combination of the
    a) structural behavior of the element segment, and
    b) medium/structure interaction at the node
  - The structural element logic is implemented in the framework of *FLAC(3D)*'s explicit finite-difference scheme.
  - Both static and dynamic analyses can be performed; a dynamic relaxation method is used to solve static problems.

Surface Support Elements

Lined tunnel



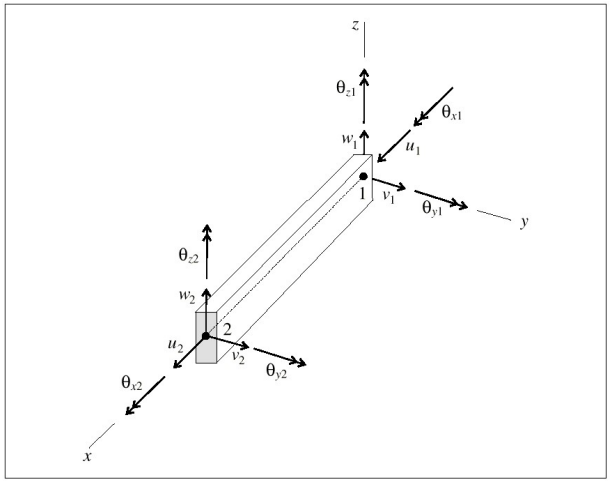
Retaining wall and strut

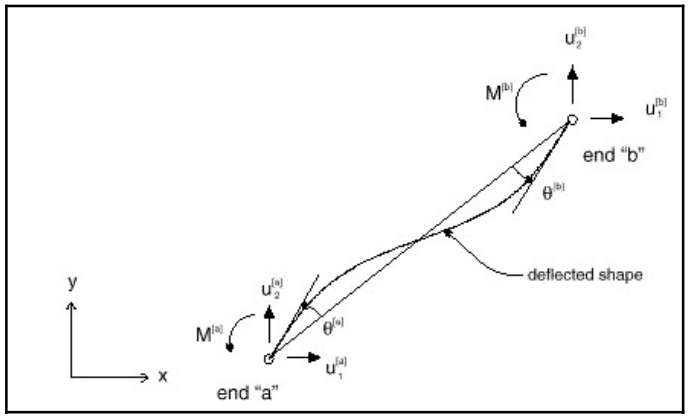


Beam Elements (beam)

Structural behavior:

- 3 degrees of freedom per node (2 translations + 1 rotation, FLAC), 3+3 FLAC3D
- Constant axial force, F; constant shear force, T; linear moment, M
- Linear axial displacement, cubic deflection.
- Axial peak and residual strengths (FLAC only)
- Can be joined together and/or to the grid
- Nodal behavior may also include plastic hinges.

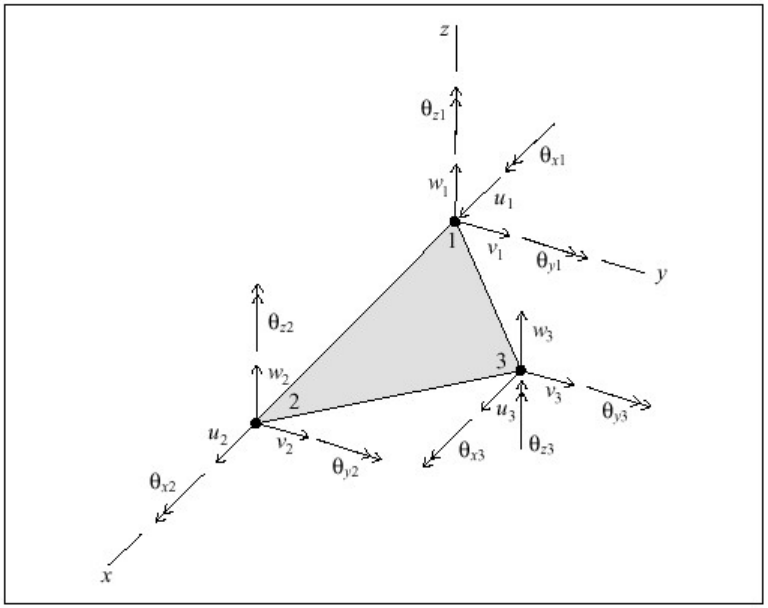




Applications:
Modeling of structural support in which bending resistance is important, including sheet piles, support struts in an open-cut excavation.

Shell Elements (`shell`)

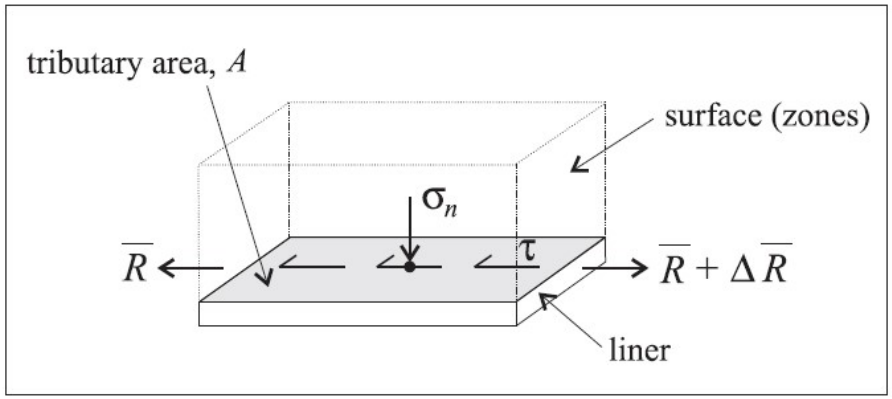
- Shell element is a triangle of given thickness
- Curved shells can be modelled as a collection of shell elements
- Shells are linearly elastic but a plastic hinge line may be introduced



Shell-type SEL coordinate system and 18 degrees-of-freedom available to the shell finite elements

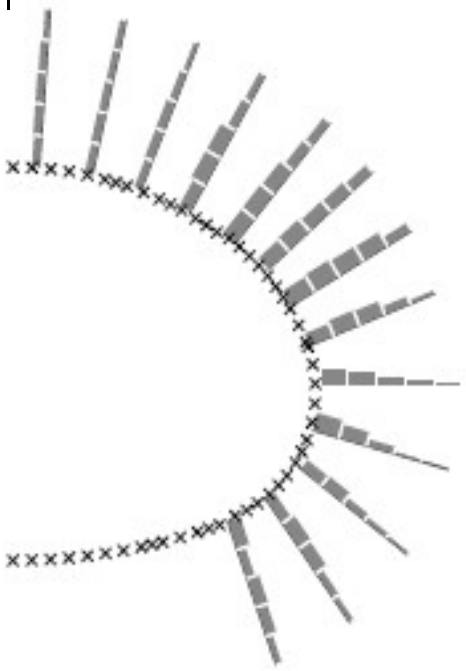
Liner Elements (`liner`)

- Shells that have frictional interaction between liner and FLAC3D grid
- Liner can break free from (and come back in contact with) the grid
- Used to model shotcrete-lined, tunnels, retaining walls, etc.

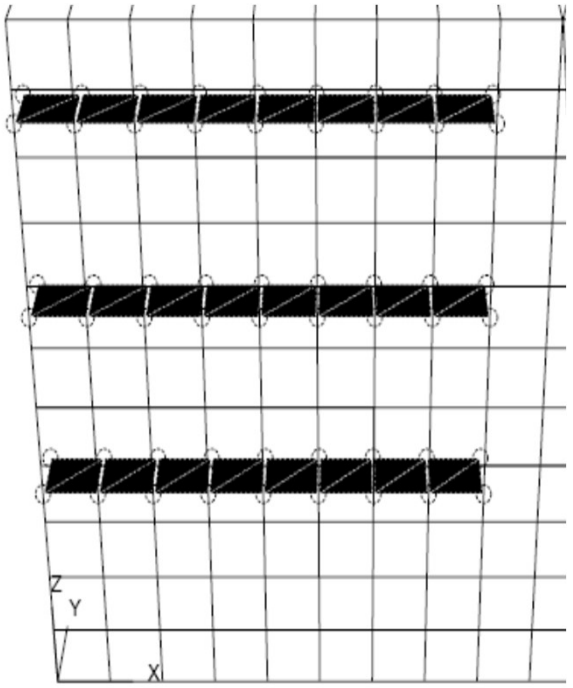


Shear Support Elements

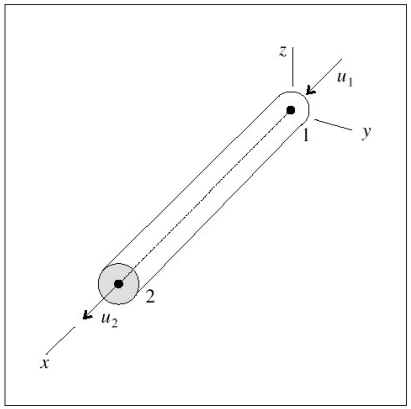
Tunnel with cable support



Geogrid reinforced embankment



Cable Elements (`cable`)

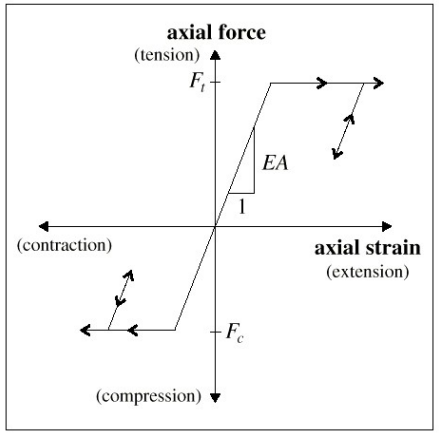


Structural behavior:

- One degree of freedom per node (axial translation).
- Can also fail in tension and compression, no flexural resistance.

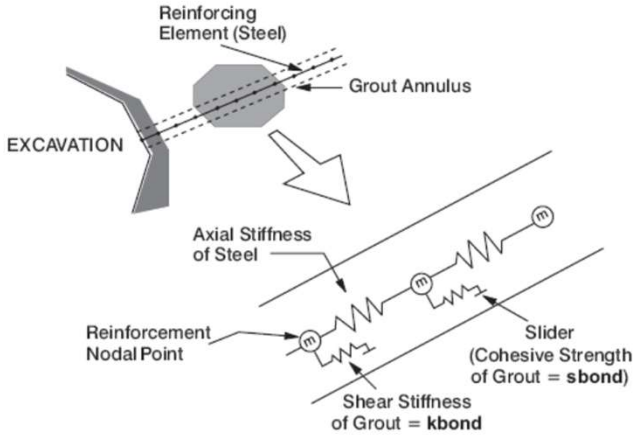
Medium/structure interaction:

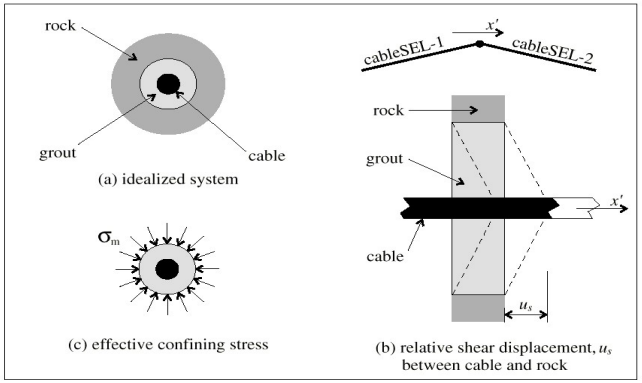
- Can be point-anchored or grouted so that the cable element develops forces along its length resisting relative motion between cable and grid.
- May be pre-tensioned, if desired.



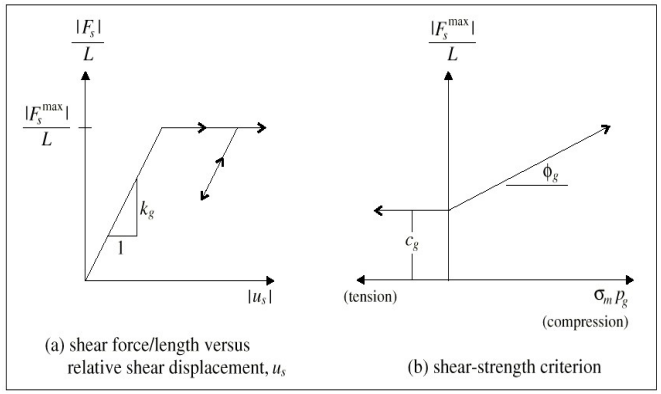
Applications: supports for which tensile capacity is important, including rock bolts, cable bolts and tie-backs.

Grout behavior accounted for in Cables





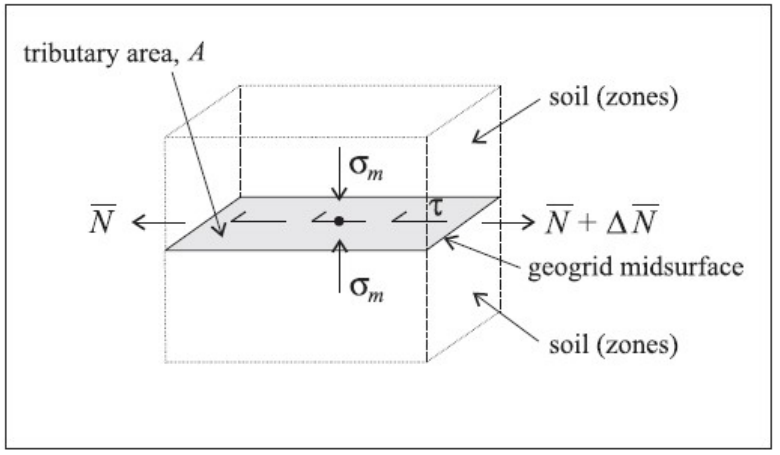
Conceptual Model



Constitutive Model

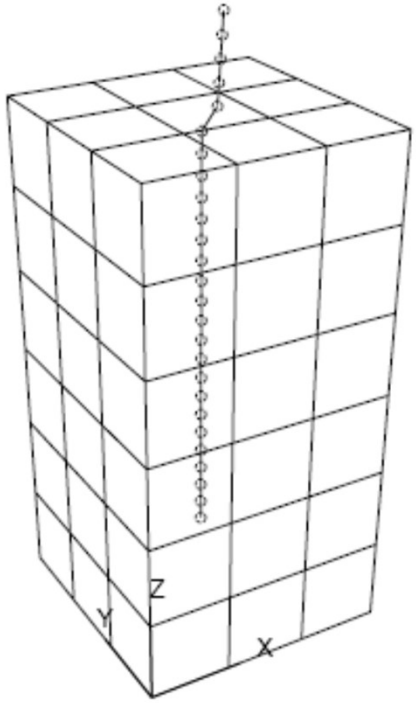
Geogrid Elements (`geogrid`)

- Shells that do not resist bending
- Frictional interaction occurs between the geogrid and the FLAC3D grid
- Like a 2D cable

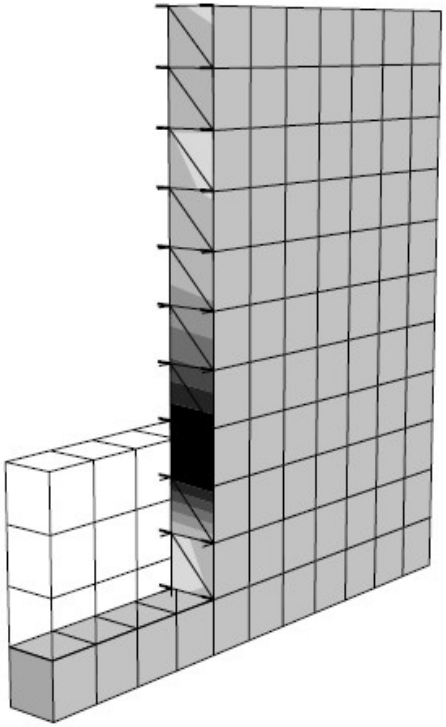


Shear and Normal Support Elements

Rockbolt rupture in shear test

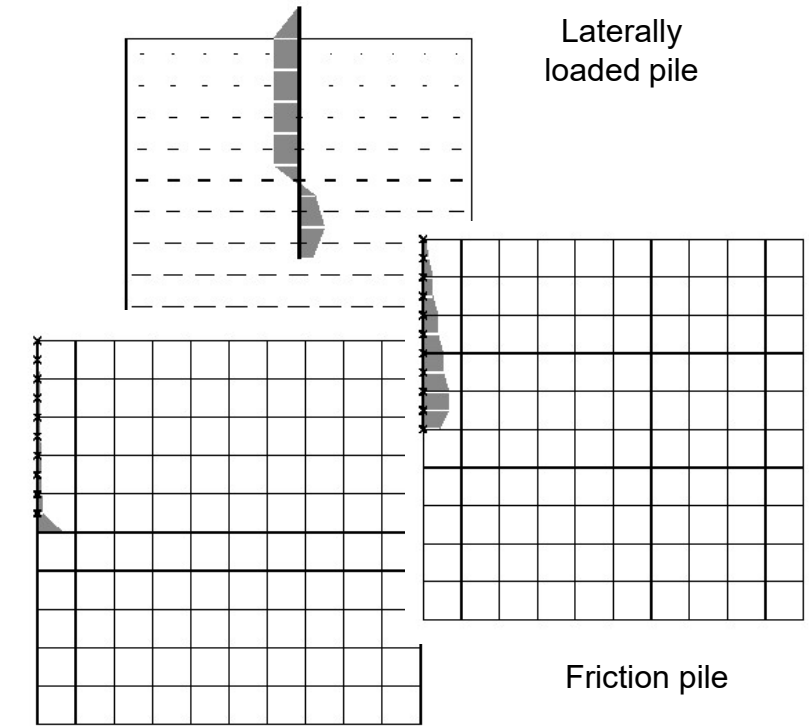


Bending stresses along embedded liner



Pile Elements (`pile`)

- **Piles**
  - Combines structural behavior of beams and medium/structure interaction of cables (can have plastic moment, but no axial yield).
  - Can also develop frictional forces along its length resisting relative *normal* motion between pile and grid. Used to model 3D effect of soil flowing through a row of piles.
  - Can be joined together and/or the grid
  - **Applications**:
    - Foundation piles
    - Stabilizing piles

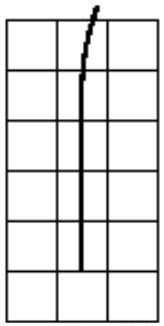


Rockbolt Elements
(pile prop rockbolt on)

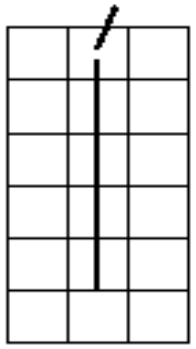
Structural behavior:

- Similar to pile elements
- Can also account for:
  - effect of changes in confining stress
  - strain-softening of grout
  - tensile rupture of element.

Applications: rock reinforcement in which nonlinear effects of confinement, grout bonding or tensile rupture are important.

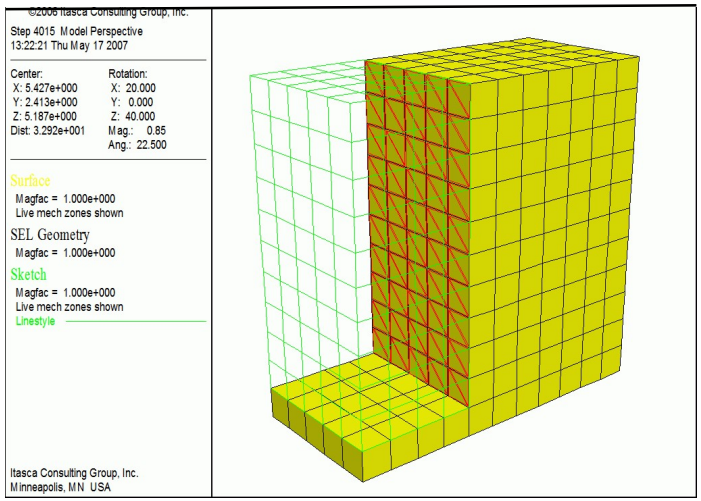


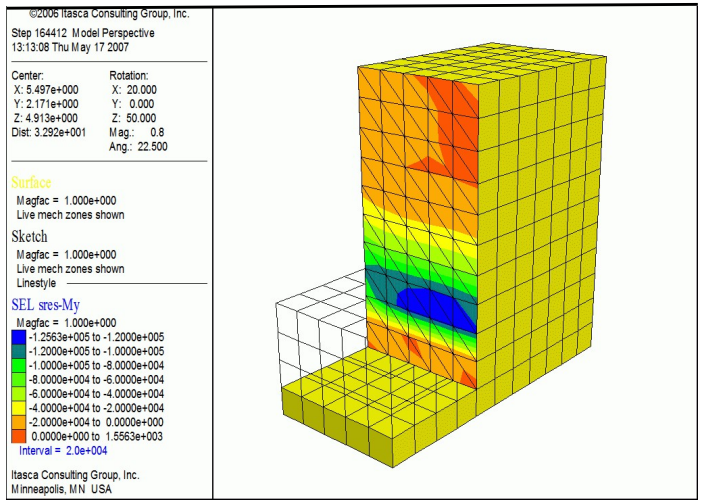
Deformed shape of 25 mm diameter rockbolt at end of shear test



Deformed shape of 25 mm diameter rockbolt following rupture at end of shear test

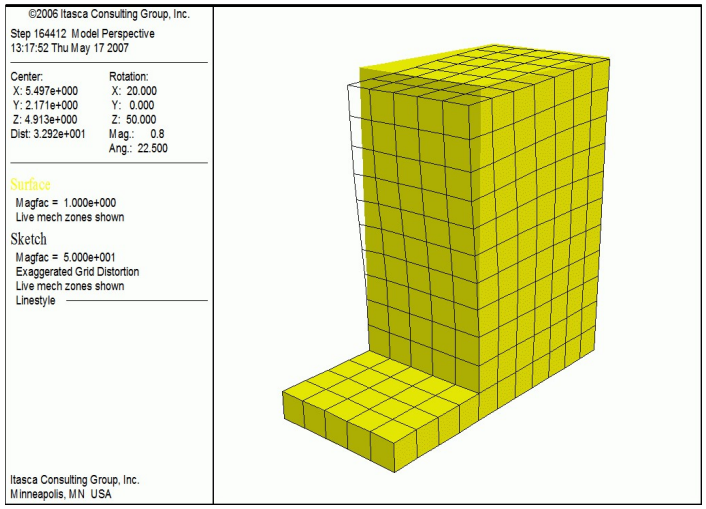
Embedded Liner Element

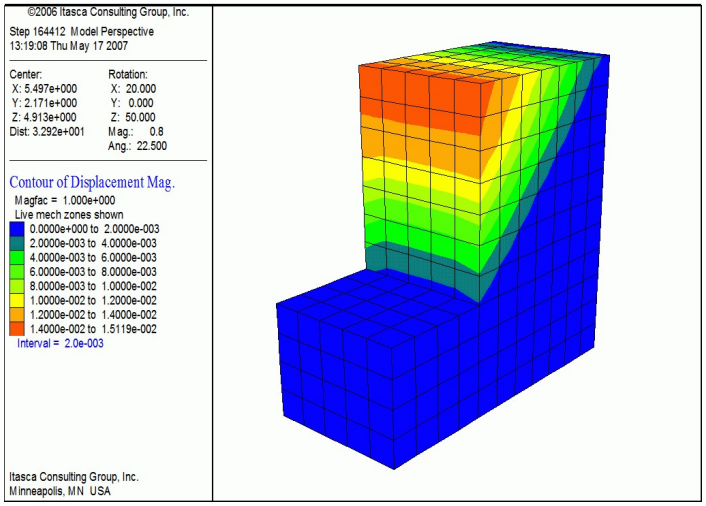




Liner interacts with grids on both sides of liner

Embedded Liner Element





Liner interacts with grids on both sides of liner

Structural Boundary Conditions

- Free/fixed velocities (translation and rotation)
- Applied forces and moments
- Pin connection