LinerCorner

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The retaining wall is modeled using zones --- they are too stiff in bending.
The retaining wall is modeled using liners --- strange behavior occurs at the corner. This behavior is as expected (see slide 25).
Before adding the embedded liner, we need to split the grid. The splitting operation at the corner is complex.

**THIS IS WHAT WE WANT**

![Diagram showing grid splitting](image-url)
Before adding the embedded liner, we need to split the grid. The splitting operation at the corner is complex. The split will work if it is done it for the entire liner (both horizontal and vertical sections) at once.

**THIS IS WHAT WE WANT**

- link A: (node-to-zone) liner-link conditions
- link B: (node-to-zone) liner-link conditions
- link C: (node-to-node) rigid in all 6 DOF

**DaveR suggested attachment**

Results in this slide set indicate that only a single corner node is okay.
The command \{struct liner create by-zone-face separate <range of four zone faces>\} splits the grid as shown here. Note that the grid points at the liner ends are not split. We have created a topological slit.

Results in this slide set indicate that only a single corner node is okay.
We build a simple model that puts a retaining wall that encloses a rectangular surface excavation. The model is run using FLAC3D 9.0.155.
All zones are one cubic meter. Pit is 3x3x3 cube centered at top of 11x11x11 soil block.

brick
p0: (0, 0, -11)
p1: (11, 0, -11)
p2: (0, 11, -11)
p3: (0, 0, 0)
The pit is in sandy clay that will remain elastic (density=1300 kg/m$^3$, E=100 MPa, nu=0.25). The retaining wall is concrete (density=2400 kg/m$^3$, E=40 GPa, nu=0.15) with thickness of 0.3 m.

What is the density of soil in kg m$^3$?

The typical bulk density of a fine sandy soil under natural conditions is about 1,5 gram/cm$^3$ or 1 500 kg/m$^3$. A fine and well-structured clay soil has a typical gross density of 1,3 gram/cm$^3$ or 1 300 kg/m$^3$.

Concrete generally have an elastic modulus varying between 30 to 50 GPa. Jan 22, 2017

Poisson’s ratio is the ratio of lateral strain to longitudinal strain in a material subjected to loading. Poisson’s ratio varies between 0.1 for high strength concrete and 0.2 for weak mixes. It is normally taken as 0.15 for strength design and 0.2 for serviceability criteria.

https://engineeringdiscoveries.com/what-is-poissons-ratio-of-concrete/
Typically, we want the liner-zone interface to be stiff compared to the surrounding material, but able to slip and perhaps open in response to the anticipated loading. For this situation, we simply need to provide a means by which the liner elements can slide and/or open relative to the zone surfaces. The strength properties are important, but the elastic stiffnesses are not. It is recommended that the lowest stiffness consistent with small interface deformation be used. A good rule-of-thumb is that $k_n$ and $k_s$ be set to ten times the equivalent stiffness of the stiffest neighboring zone. The apparent stiffness (expressed in stress-per-distance units) of a zone in the direction normal to the surface is

$$
\max \left[ \frac{(K + \frac{4}{3} G)}{\Delta z_{\text{min}}} \right] \tag{1}
$$

where: $K$ and $G$ = the bulk and shear modulus, respectively; and $\Delta z_{\text{min}}$ = the smallest dimension of an adjoining zone in the normal direction.

$k_n = k_s = \max \left[ \frac{K + \frac{4}{3} G}{\Delta z_{\text{min}}} \right], \quad \Delta z_{\text{min}} = 1 \text{ m}

K + \frac{4}{3} G = 6.7 \times 10^7 \text{ N/m}^2 + \frac{4}{3} 4.0 \times 10^7 \text{ N/m}^2 = 1.2 \times 10^8 \text{ N/m}^2

k_n = k_s = 1.2 \times 10^9 \text{ N/m}^3
Soil is sandy clay (behaves as an isotropic elastic material)
Liner is concrete with 0.3-m thickness
Liner is bonded to pit surface with infinite strength (it cannot separate or slip)

directory LinerCorner-TwoSidesThroughThickness

**Two-sided through liner (case A)**
(pit and liner extend through entire model depth)

Initial stresses are installed in the soil.
The pit is excavated, and the liner is installed on the pit side surfaces before allowing the model to relax to equilibrium. The liner is unloaded before excavation; excavation deforms and loads the liner.
All zones are one cubic meter
Soil block is an 11-m cube
Pit goes through model and has square cross section of 3-m width
Liner covers the two back surfaces
All zones are one cubic meter
Soil block is an 11-m cube
Pit goes through model and has square cross section of 3-m width
Liner covers the two back surfaces
After Excavation

Results show displacement and stress produced by excavation
initial shape
bottom edges pinch inwards and bend
Why? Soil stress increases with depth and is max at bottom.
The soil pushes inwards more at the bottom.

dehomed (x 2000) shape
bottom edges pinch inwards and bend
Why? Soil stress increases with depth and is max at bottom.
The soil pushes inwards more at the bottom.
Surface System
(x is directed along pit axis, y is directed along pit circumference, z is normal to liner surface)

$xyz \rightarrow \{\text{red, green, blue}\}$
Increasing membrane compression with depth, zero at top
Increasing bending with depth
(as the bottom edges pinch inwards and the liner bulges wrt an axial line)
Normal stress on liner
note the compression near the bottom that induces the bulging
Normal stress on liner: pulling upwards along side edges (more near bottom)
Soil is sandy clay (behaves as an isotropic elastic material)
Liner is concrete with 0.3-m thickness
Liner is bonded to pit surface with infinite strength (it cannot separate or slip)

Two-sided through liner (case B)
(pit and liner extend through entire model depth)

The liner is installed as an embedded liner before excavation. Initial stresses are installed in the soil, and these stresses also load the liner. Then the pit is excavated; excavation deforms and loads the liner.

The results for this case are approximately the same as for Case A. Therefore, the embedded liner is behaving correctly.
liner create by-zone-face separate \{range of internal faces\}

Splits the grid of the five internal grid points but not the grid points at the ends

Also splits the grid points at the top and bottom of the model.
The normal stress acting on the liner before excavation. This stress is produced by the initial stress in the soil at the time of liner installation, with the soil stress being higher near the bottom. If we draw a horizontal line across the liner, we find that the normal stress becomes less at the corner, because the link at the corner is directed at a 45-degree angle to each side, and thus, the stress acts in this direction. The stress is less when it is mapped onto each side (as shown in the sketch below).
The normal stress acting on the liner after excavation. This stress is produced by the inward bulging of each side, with more bulging near the bottom because of the increased soil stress near the bottom.

CASE B
Normal stress on liner
note the compression near the bottom that induces the bulging

CASE B
The model has been rerun (directory LinerCorner-TwoSidesDepthOf6m), but this time the pit goes only to a 6-m depth. Again, there is a liner on the two back sides. The response is reasonable, and it is approximately the same for the two cases as it should be.

The model is again rerun (directory LinerCorner-FourSidesDepthOf6m), but this time the pit goes to a 6-m depth and the liner is on all four sides. The response is reasonable, and it is approximately the same for the two cases as it should be.

There is no need to create the complex attachment conditions shown on slide 5. The problem can be done in a straightforward fashion via the \{struct liner create by-zone-face separate\} command.