Underground Modelling by Zsoil:
A Practical Experience over the Software's Strengths and Development Requirements

Tohid Kazerani
Mohammad Monfared, Ettiene Garin, Nima Nilipour

Presented on the 28th of August of 2015 at Lausanne

www.bg-21.com
Projects to be briefed

1. An underground junction for the EOLE (Paris underground extension project)

2. A linking point among two parallel tubes (the existing Swiss Ligerz tunnel and its new emergency tunnel)

3. A tube driven in an inclined-layered ground (Swiss CEVA project)

4. A pipe anchor support
EOLE
Extension of RER E toward west
Model mesh for support and girder reinforcement

Homogenised support material

Separate modelling of shotcrete and girder
Plasticity around the intersectional zone
Ground subsidence over the point of interest and some benchmarks
Deformed mesh
Internal axial forces in girders
Strength of ZSoil

1. Constitutive law
2. Element variety enabling user to incorporate girder and support explicitly.

Issues if enhanced will help us so much
1. Model discretization for intersection problems
2. A 3D-based mesh generator instead of the current 2D-based
Issues subject to further development

- Minimum:
  1. Incorporate tetrahedral elements into code
  2. Possibility to import them from a mesh file provided by a stronger mesh generator
Issues subject to further development

• Optimum:
  1. Volume-based unstructured mesh generation in 3D
     ▪ E.g.: 3D Delaunay triangulation
Issues subject to further development

- Optimum:
  2. Interface with Spaceclaim to create 3D macro model
Issues subject to further development

• Load functions for material property
  1. Young's modules to increase with LF to model e.g. ground treatment

Please add following lines to ZSOIL.CFG ("c:\Users\All Users\Zsoil v2014\Full\CFG\ZSOIL.CFG") file:
E_MODULUS_DEGRADATION
1
PLAS_MC_V
Linking for the emergency tunnel of existing Ligerz tunnel

- Stability analysis for the rock around the excavation zone
- Change in the tunnel support force
hypotheses

• Constitutive rule
  • Concrete  Linear elastic
  • Rock  Hoek-Brown
    • Young's module  50 GPa
    • Compressive strength  120 MPa
    • Tensile strength  11.4 MPa

• Lateral pressure coefficient of rock at rest ($K_0$)
  • Sensibility analysis with $K_0$ equal to 0.6, 1.0, 2.0 verified no significant change in model response $\uparrow K_0 = 1.0$
Before-excavation mesh
After-excavation mesh
Change in total displacements due to the implementation of the emergency tunnel and the linking (t = 12 - 5)
Required enhancement

Shell principal stresses change with local axes rotation while for both the cases **ALL the stress data are retrieved**.

\[
\sigma_{\text{max}} = 2.0 \text{ MPa} \quad \sigma_{\text{max}} = 1.9 \text{ MPa}
\]
### Required enhancement

![Image of software interface](image)

<table>
<thead>
<tr>
<th>Bending moment-2 [kN]</th>
<th>Shear Force-X [kN/m]</th>
<th>Shear Force-Y [kN/m]</th>
<th>Stress-XX [kN/m²]</th>
<th>Wood-Armer M-bot-XX [kN]</th>
<th>Wood-Armer M-top-XX [kN]</th>
<th>Wood-Armer [kN/m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>-3.45E+00</td>
<td>-6.53E+00</td>
<td>4.58E+00</td>
<td>-5.68E+02</td>
<td>-1.58E+00</td>
<td>1.75E+00</td>
<td>1.92E+01</td>
</tr>
<tr>
<td>-3.17E+00</td>
<td>-3.72E+00</td>
<td>1.31E+01</td>
<td>-7.39E+02</td>
<td>-2.80E+00</td>
<td>1.00E+00</td>
<td>3.89E+00</td>
</tr>
<tr>
<td>-1.73E+00</td>
<td>-6.65E+00</td>
<td>9.18E+01</td>
<td>-5.44E+02</td>
<td>-1.75E+00</td>
<td>4.62E-02</td>
<td>0.00E+00</td>
</tr>
<tr>
<td>-9.46E-01</td>
<td>-1.01E+01</td>
<td>3.92E+00</td>
<td>-1.26E+02</td>
<td>-9.86E-01</td>
<td>9.29E-02</td>
<td>0.00E+00</td>
</tr>
<tr>
<td>-1.07E+00</td>
<td>-6.65E+00</td>
<td>-3.68E+00</td>
<td>-3.85E+02</td>
<td>-7.51E-01</td>
<td>8.81E-01</td>
<td>0.00E+00</td>
</tr>
</tbody>
</table>
CEVA: Linking tunnel

- 3D model of tunnelling progression in an inclined-layered ground
- Constitutive rule: Hardening Soil Model (HSS)
Mesh geometry in excavation

Elements for convergence-confinement curve

Section B

Section A

Top heading

Invert

20m

10m

Excavation direction
Section A – Top heading elements No. 13654 to 13661

Change in radial stress vs excavation progression for 8 elements on the top heading at section A
Deformation of hinged shells

Invert is hinged to wall to free moment but fix displacements.
Pipe anchor support

Strength of ZSoil in explicit representation of (micro)piles, interfaces etc.
Mesh problem
Mesh problem
Conflict between material change and interface activation
Still happens for non-drained driver
Conflict between material change and interface activation
Still happens for non-drained driver

As soon as new material replaces the previous one, the elements get detached while no interface is placed.
Thanks for your patience