A User-Friendly Interface for Pile Analysis Using OpenSees

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Single Pile in a Layered Half-Space

Circular pile in level ground: filled view of ½ mesh due to symmetry
Problems could be Studies by the GUI

- **Seismic Excitation**: Linear and nonlinear (incremental plasticity based) 3D ground seismic response with capabilities for 3 dimensional excitation, and multi-layered soil strata.

- **Pushover Analysis**: Inclusion of a pile or shaft in the 3D ground mesh (circular or square pile in a soil island).

- **Ground Modification**: Various ground modification scenarios may be studied by appropriate specification of the material within the pile zone.
Seismic Excitation

Build-in Library of Input Motions

User-Defined Input Motion

Full Mesh for 3D Seismic Response
Pushover Analysis

- Force Based or Displacement Based
- Monotonic or Cyclic
Pile Element Types

- Linear pile element (elasticBeamColumn)
- Nonlinear pile elements (nonlinearBeamColumn)
  - Aggregator section
  - Fiber section
Soil Materials

- **Elements:** `brickUP, 20_8_BrickUP`
- **Soil materials:**
  - `PressureDependMultiYield`
  - `PressureIndependMultiYield`

**Build-in Library of Soil Materials**

- 8. Cohesionless medium, sand permeability
- 1. Cohesionless very loose, silt permeability
- 2. Cohesionless very loose, sand permeability
- 3. Cohesionless very loose, gravel permeability
- 4. Cohesionless loose, silt permeability
- 5. Cohesionless loose, sand permeability
- 6. Cohesionless loose, gravel permeability
- 7. Cohesionless medium, silt permeability
- 9. Cohesionless medium, gravel permeability
- 10. Cohesionless medium-dense, silt permeability
- 11. Cohesionless medium-dense, sand permeability
- 12. Cohesionless medium-dense, gravel permeability
- 13. Cohesionless dense, silt permeability
- 14. Cohesionless dense, sand permeability
- 15. Cohesionless dense, gravel permeability
- 16. Cohesive soft
- 17. Cohesive medium
- 18. Cohesive stiff
- 13. U-Sand1...
- 20. U-Sand2...
- 21. U-Clay1...
- 22. U-Clay2...

**User-Defined Sand2**

**User-Defined Clay1**

**U-Clay1 for Soil Layer #1**

- **Soil Elastic Properties**
  - Saturation Mass Density
  - Reference Pressure
  - Pressure Dependence Coefficient
  - Friction Angle
  - Cohesion
  - Bmax

- **Soil Nonlinear Properties**
  - Peak Shear Strain (%)
  - Friction Angle (degrees)
  - Cohesion

- **Fluid Properties**
  - Fluid Mass Density
  - Combined Bulk Modulus
  - Horizontal Permeability
  - Vertical Permeability
Ground Modification Scenarios

- Material within the pile zone (e.g., gravel permeability)
- Materials outside the pile zone (e.g., multi-layered soil strata with sand or silt permeability)
Other Features

Bridge Deck

Pile in Sloping Ground

Straightforward and fast mesh definition/refinement
Output: Deformed Mesh
Output: Excess Pore Pressure Contour
Output: Pile Response Profiles

- Displacement Profile
- Rotation Profile
- Bending Moment Profile
- Shear Force Profile
Output: Pile Response Histories

- Displacement History
- Rotation History
- Bending Moment History
- Shear Force History
Output: Pile Response Relationships

Moment-Curvature Relationship (at Different Locations of Pile)

Load-Displacement Relationship
Output: Soil Acceleration Time Histories
Output: Excess Pore Pressure Time Histories
Output: Shear Stress vs. Strain & Effective Confinement

The two graphs below are evaluated at 5.58m depth.

Longitudinal Shear Stress (kPa) vs. Longitudinal Shear Strain (File: ss_5.58m.txt)

Longitudinal Shear Stress (kPa) vs. Effective Confinement (kPa) (File: sp_5.58m.txt)
Comparison with PLAXIS

<table>
<thead>
<tr>
<th>Soil, linear elastic</th>
<th>E</th>
<th>ν</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100 MPa</td>
<td>0.35</td>
</tr>
<tr>
<td></td>
<td>(K/G=3)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Compact elastic concrete pile</th>
<th>E</th>
<th>ν</th>
<th>Diameter</th>
<th>I</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20 GPa</td>
<td>0.25</td>
<td>1 m</td>
<td>0.049 m^4</td>
</tr>
</tbody>
</table>

The pile is 6m above terrain, 6m into soil. The soil layer is 10m thick. The load is 100kN at pile head.

PLAXIS Mesh (S. Nordal, 2006)  
OpenSees Mesh
# Deflection Comparison

<table>
<thead>
<tr>
<th>Deflection (mm)</th>
<th>PLAXIS</th>
<th>OpenSees</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pile head</td>
<td>19.47</td>
<td>18.13</td>
<td>7%</td>
</tr>
<tr>
<td>Ground surface</td>
<td>1.99</td>
<td>1.97</td>
<td>1%</td>
</tr>
</tbody>
</table>
## Bending Moment Comparison

<table>
<thead>
<tr>
<th></th>
<th>PLAXIS</th>
<th>OpenSees</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. Moment (kN-m)</td>
<td>685</td>
<td>600</td>
<td>12%</td>
</tr>
<tr>
<td>Location for Max</td>
<td>0.5 m below surface</td>
<td>Near surface</td>
<td></td>
</tr>
</tbody>
</table>
Summary

- A user interface for pile analysis using OpenSees was developed.
- Analysis options available include seismic excitation, pushover analysis and ground modification.
- Features include automatic meshing of soil and pile configurations, available libraries of already calibrated soil models, and structural models for seismic response.
- Future work includes option for pile group.
- OpenSeesPL can be downloaded from:
  http://cyclic.ucsd.edu/OpenSeesPL/