

OpenSeesPL

3D Lateral Pile-Ground Interaction

OpenSeesPL Quick Guide

(Updated 4/11/2018)

([Click here](#) for a PDF version of this quick guide)

OpenSeesPL is a Windows-based graphical pre- and post-processor (user-interface) for three dimensional (3D) ground and ground-structure response (Lu et al. 2006; Elgamal and Lu 2009). Finite Element (FE) computations in OpenSeesPL are conducted using OpenSees (Mazzoni et al. 2009; McKenna et al. 2010), an open source software framework developed by the Pacific Earthquake Engineering Research (PEER) Center since 1998.

OpenSeesPL main window:

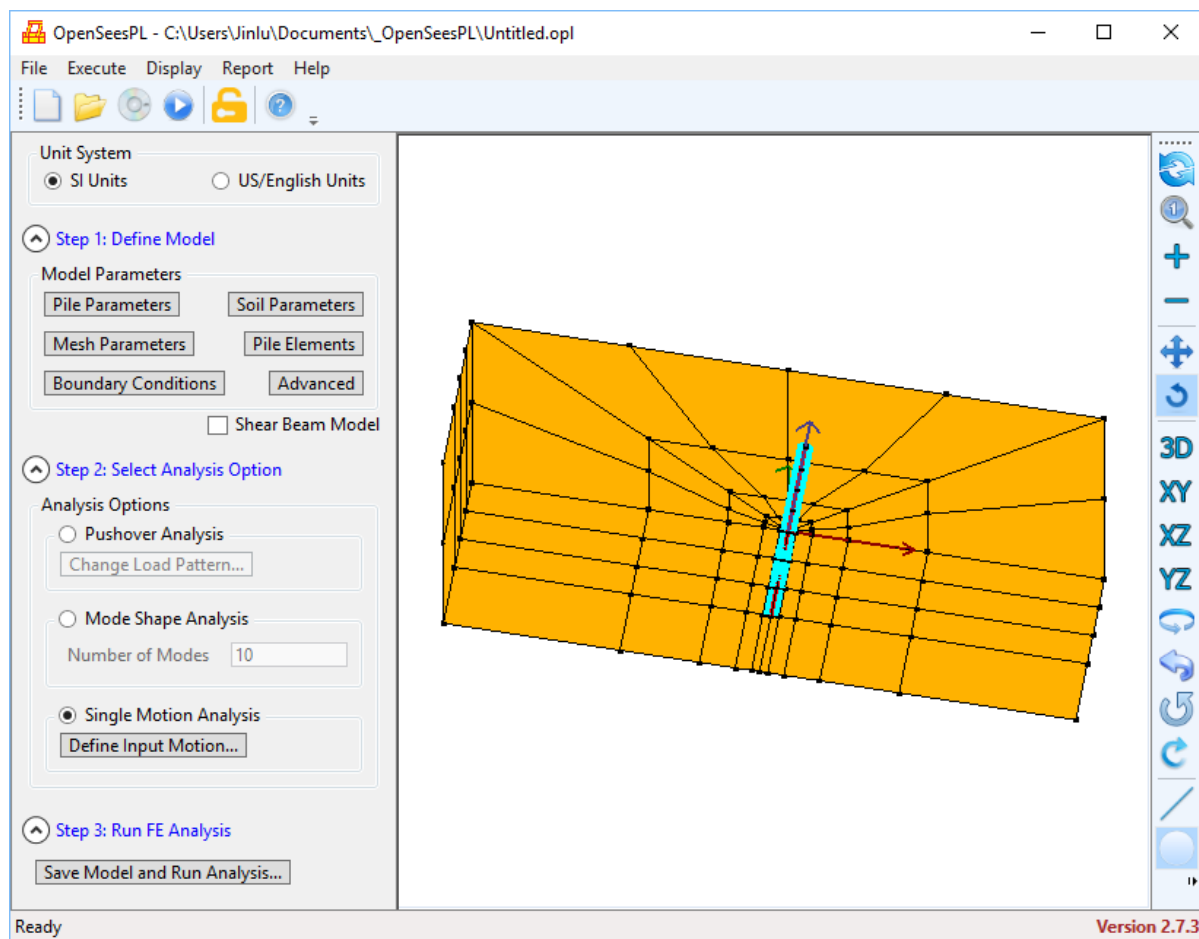


Image buttons in the main window (also available in the deformed mesh window):



: To recreate FE mesh if there is a change in input parameters.



: To redraw the FE mesh based on the original zoom settings.



: To zoom in on the FE mesh.



: To zoom out on the FE mesh.



: To pan the view on the FE mesh. This is a toggle button which means it can be turned on or off.



: To rotate the FE mesh. This is a toggle button which means it can be turned on or off. However, this button and the above toggle button (i.e., the one to pan the view) cannot be both ON at the same time. When the user turns on either of them, the other one will be changed to OFF automatically.



: To display the 3D view of the FE mesh.



: To display the XY-plane view of the FE mesh.



: To display the XZ-elevation view of the FE mesh.



: To display the YZ-elevation view of the FE mesh.



: To rotate the FE mesh about the vertical axis (Z) counter-clockwise (if viewed from the positive Z-axis).



: To rotate the FE mesh about the vertical axis (Z) clockwise (if viewed from the positive Z-axis).



: To rotate the FE mesh about the longitudinal axis (X) clockwise (if viewed from the positive X-axis).



: To rotate the FE mesh about the longitudinal axis (X) counter-clockwise (if viewed from the positive X-axis).



: To show the pile(s) only if the button is "ON" status (this is also a toggle button).



: To show the pile size/dimensions (in Cyan color) if the button is "ON" status (this is a toggle button).



: To show the X, Y and Z axes of the global coordinate system if the button is "ON" status (this is a toggle button)

1. Menu

(Go to [2. Model Parameters](#) [3. Analysis Types](#) [4. Miscellaneous](#))

Menu File

New Model: To create a new OpenSeesPL model. All input parameters will be reset to the default values (and FE mesh will be recreated).

Open Model...: To open an existing OpenSeesPL model file (an OpenSeesPL model file must have an .opl extension).

Save Model: To save the current OpenSeesPL model to file (if there is any change). If the model has not been saved yet, a window will pop

up to ask the folder and filename to save the current model. The model filename will be suffixed with the “.opl” extension if not provided.

Save Model As...: To save the current OpenSeesPL model as a different filename (with the .opl extension). The model filename will be suffixed with the “.opl” extension if not provided.

OpenSeesPL allows to conveniently save and open a model file. The model filename must have the .opl extension. No space is allowed in an OpenSeesPL model filename.

When a model file is saved and analysis is about to start, a folder suffixed with “_pfiles” will be created. For example, if the model file is saved as “Untitled.opl”, a folder named “Untitled_pfiles” is created (under the same folder as the model file) and will contain all files associated with the model including OpenSees Tcl and output files, some of which include (Taking “Untitled.opl” model filename as an example):

Untitled.tcl: OpenSees Tcl input file for the OpenSeesPL model.

Untitled.log: OpenSees analysis log file for the model.

Untitled.dsp: OpenSees displacement output file for all nodes.

Untitled.acc: OpenSees acceleration output file for all nodes.

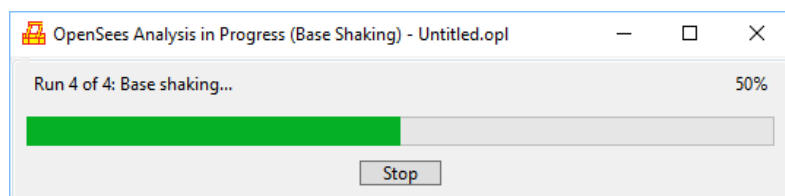
Untitled.piledisp: OpenSees displacement output file for all pile nodes.

Untitled.pileforce: Internal force output file for all pile elements.

Exit: To exit OpenSeesPL.

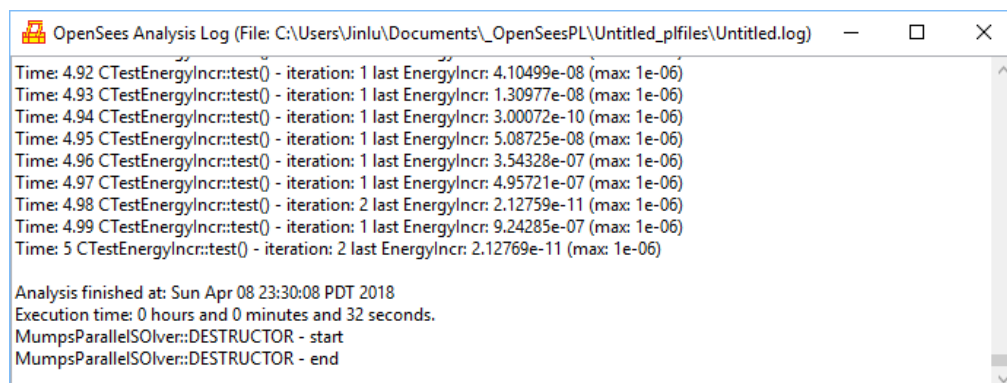
Menu Execute

Save Model and Run Analysis: To save the current model and run OpenSees analysis. A popup will be displayed to show the analysis progress.



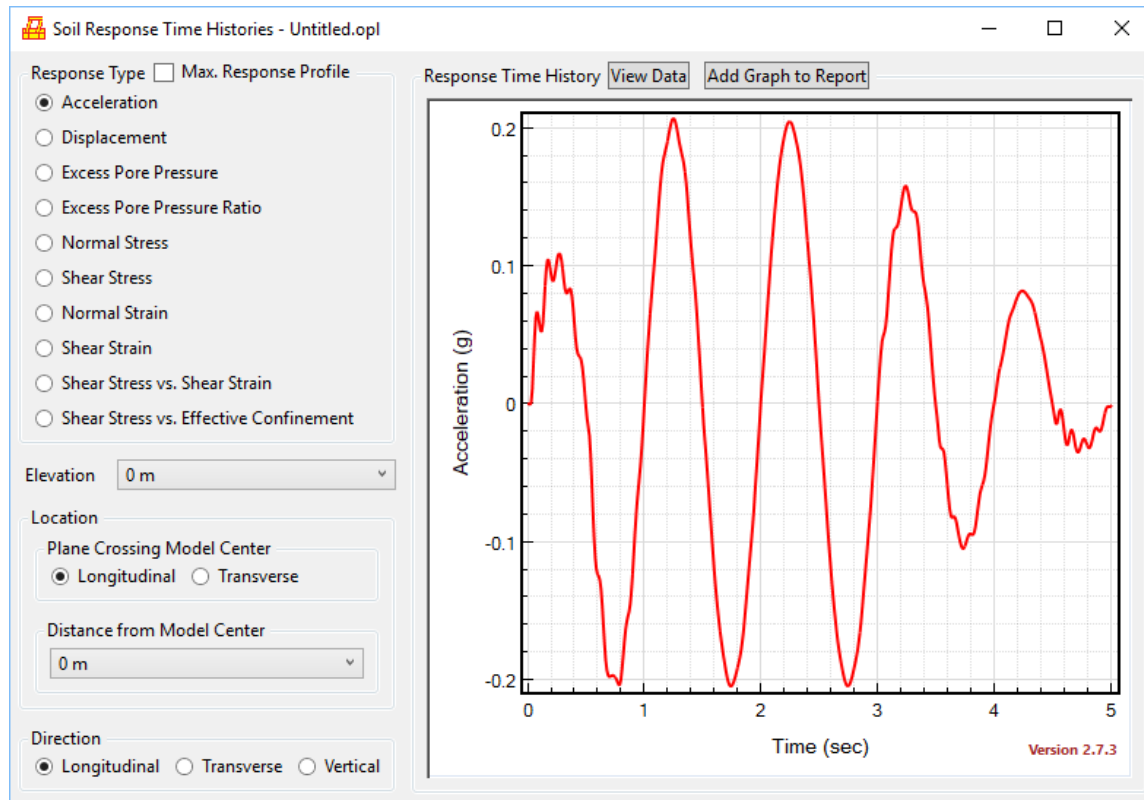
If the analysis fails (typically due to convergence problems) in the final run (i.e., after application of own weight), OpenSeesPL should be able to view the results up to the step where the analysis fails.

OpenSees Analysis Log: To view OpenSees analysis log (if any) for the current model. If the model file is named “Untitled.opl”, the OpenSees log file will be “Untitled.log” (located under the folder of “Untitled_pfiles”).

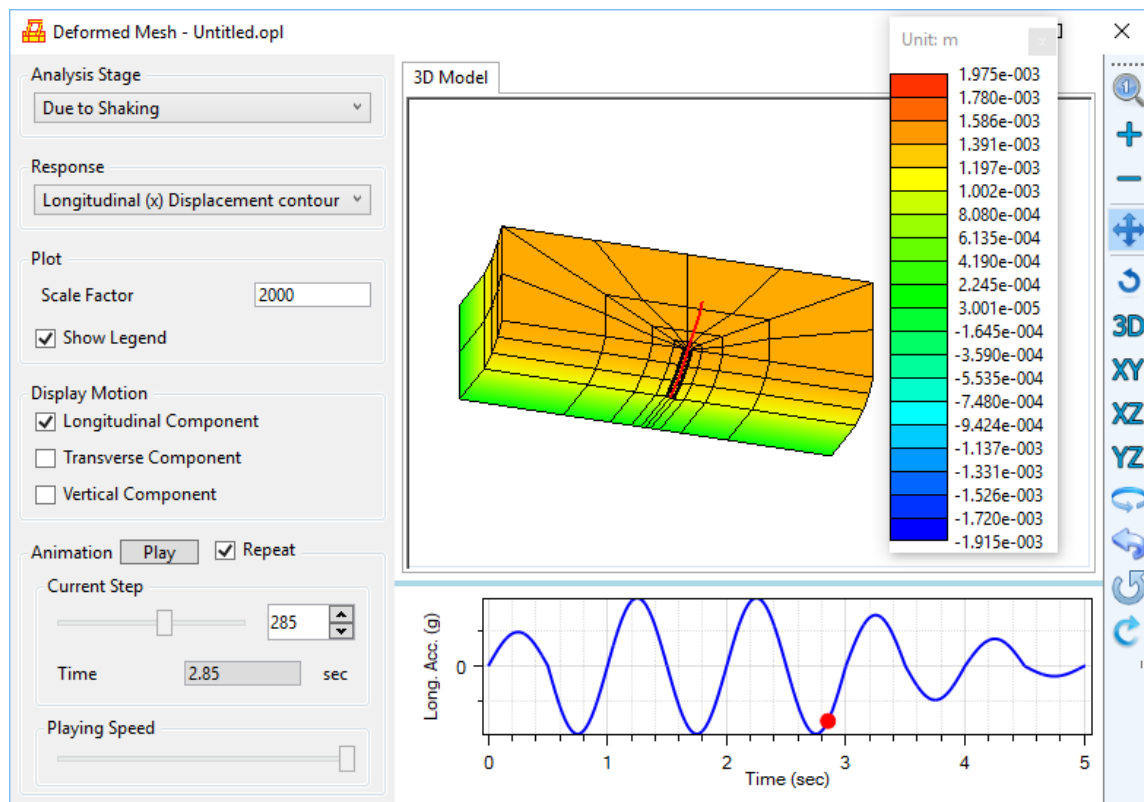


Menu **Display**

Soil Response Time Histories: To view the response time histories of the soil. A zero-depth/elevation means the ground surface. If **Max. Response Profile** is checked, the absolute maximum values of the response along the depth/elevation will be displayed.



Deformed Mesh: To view the deformed mesh.



List of the response items available in the deformed mesh window (may not be all available depending on the problem/model being analyzed):

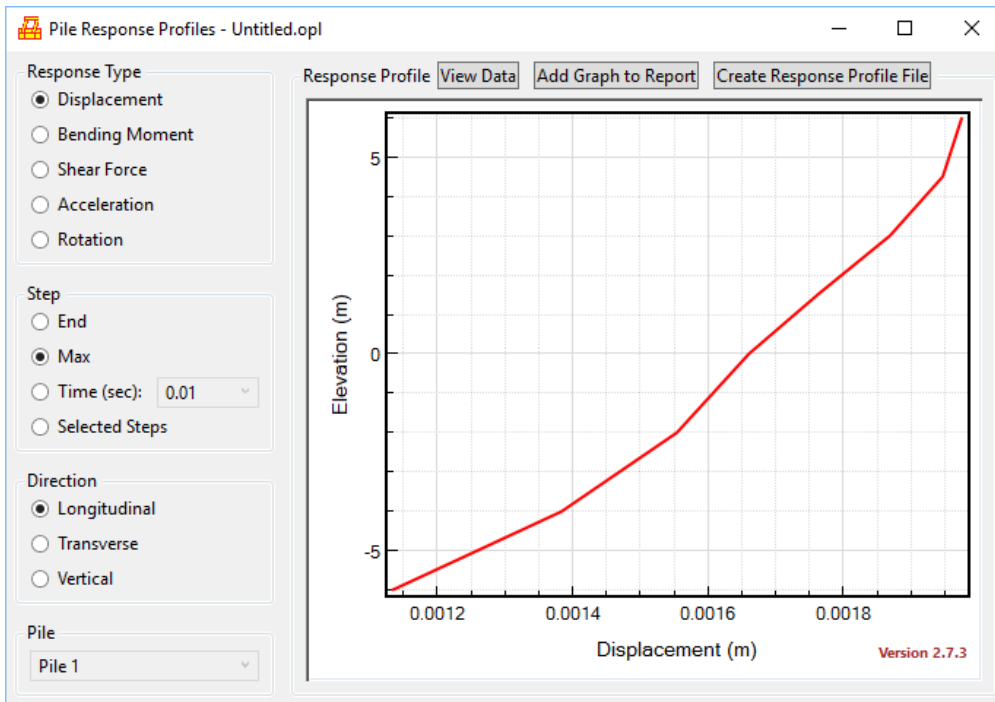
- Deformed mesh
- Displacement contour fill
- Longitudinal (x) Displacement contour
- Transverse (y) Displacement contour
- Vertical (z) Displacement contour
- Pore pressure (PP) contour
- Excess PP (EPP) contour
- EPP ratio contour
- Longitudinal stress contour
- Transverse stress contour
- Vertical stress contour
- Shear stress (xy) contour
- Shear stress (yz) contour
- Shear stress (zx) contour
- Stress ratio contour
- Eff. confinement contour
- Longitudinal strain contour
- Transverse strain contour
- Vertical strain contour
- Shear strain (xy) contour
- Shear strain (yz) contour
- Shear strain (zx) contour

Pile Response Profiles: To view the response profiles of the pile (or a given pile for a pile group case). A zero-elevation is the elevation at the ground surface. If **End** is selected, the response profile at the end of analysis will be displayed. If **Max** is selected, the response profile at the time when the absolute maximum of the response (across the entire given pile) is reached, will be displayed. If **Selected Steps** is chosen, response profiles for about 20 steps including step 0, step 1 and the final step will be displayed.

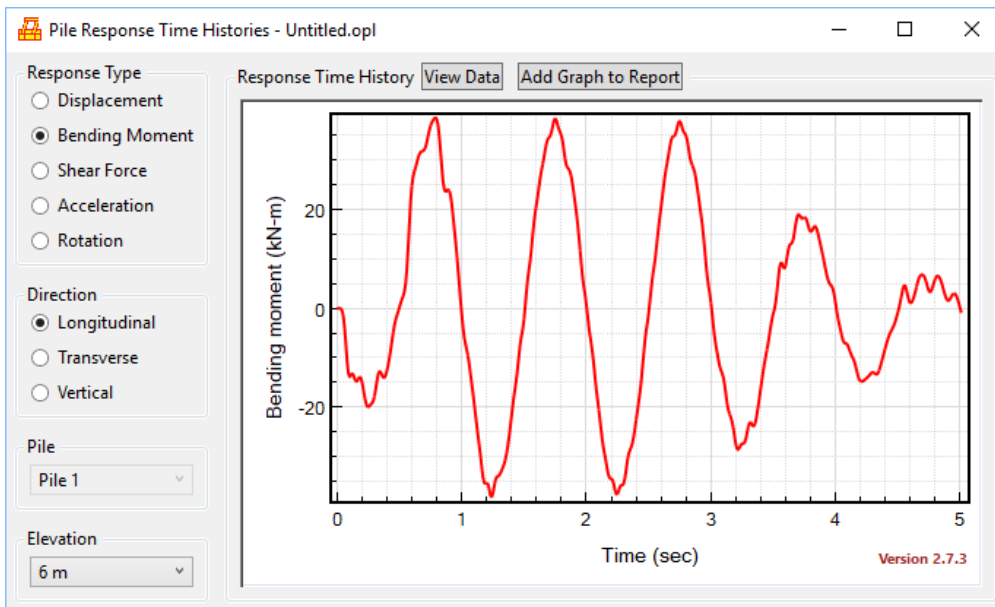
Notes:

If **Bending Moment** and **Longitudinal** are chosen, the bending moment displayed is the one about the Y-Transverse axis (Myy).

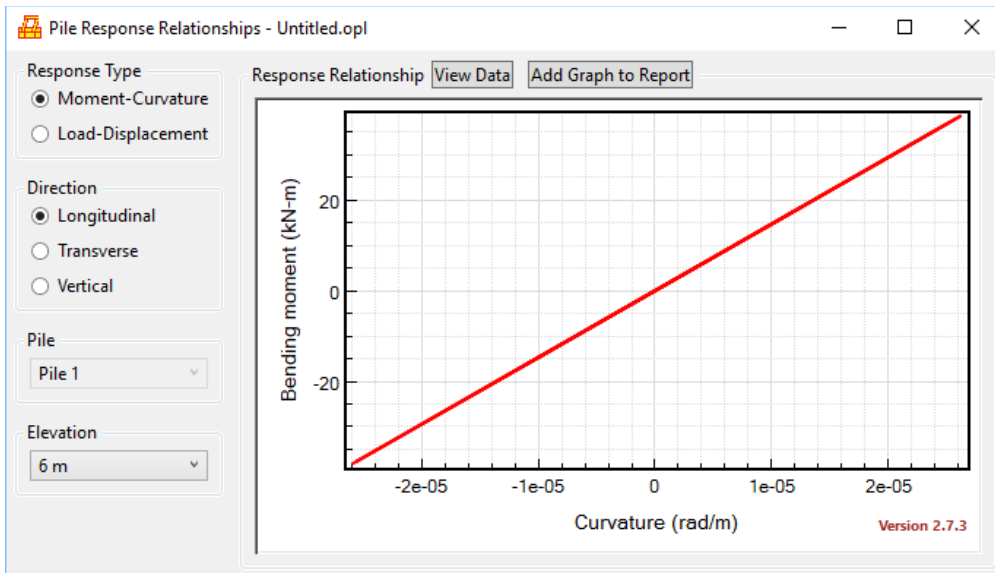
If **Bending Moment** and **Transverse** are chosen, the bending moment displayed is the one about the X-Longitudinal axis (Mxx).



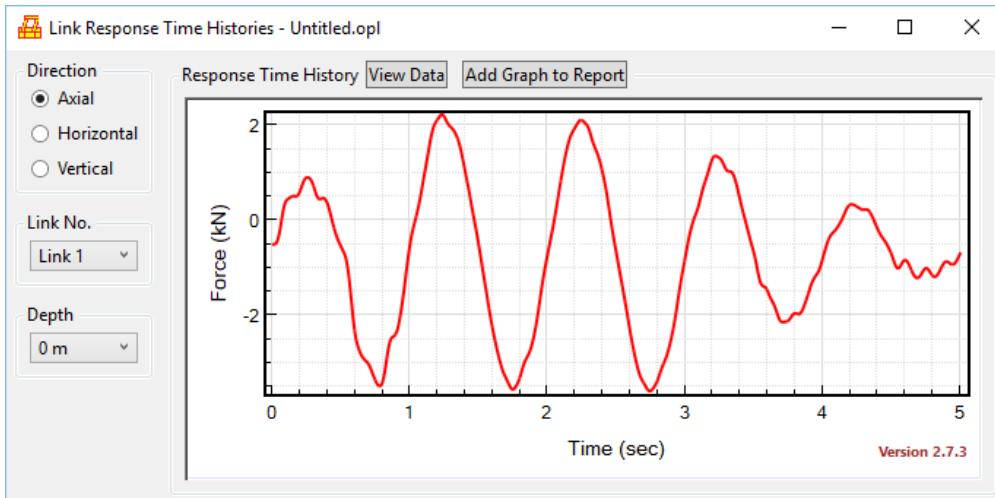
Pile Response Time Histories: To view the response time histories for the pile (or a given pile for a pile group case).



Pile Response Relationships: To view the bending moment-curvature and force-displacement curves for the pile (or a given pile for a pile group case) at a given elevation. Note that a zero-elevation is the elevation at the ground surface.



Link Response Time Histories: To view the response time histories of a given rigid link (connecting between soil and pile elements).



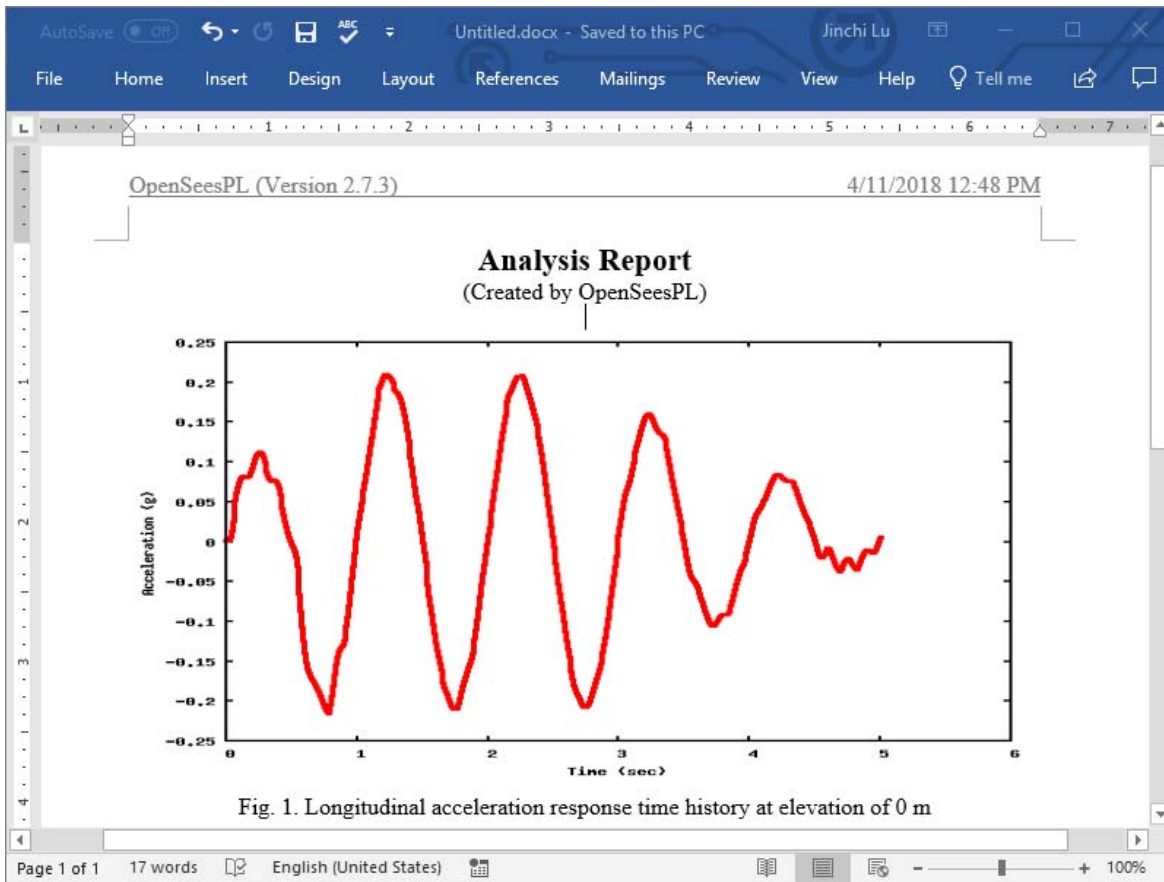
Postprocessing Settings: To change postprocessing settings.

Menu Report

(Microsoft Word is required for this menu to be functional)

Open Report Session: To open a report session. When a report session is open, a .docx Word file is created (e.g., Untitled.docx under folder "Untitled_pfiles" if the model file is named "Untitled.opl") and the user can add figures (which will be converted to PNG images) to the Word file until the report session is closed (see the menu item to be described next). The Word file will be overwritten (if exists) when a new report session is open.

Close Session and Open Report: To close session and Open the report file (in Microsoft Word).



Menu **Help**

OpenSeesPL Website: To go to OpenSeesPL website (<http://soilquake.net/openseespl/>).

About OpenSeesPL: To view OpenSeesPL copyright and other information.

2. Model Parameters

(Go to [1. Menu](#) [3. Analysis Types](#) [4. Miscellaneous](#))

Pile Parameters:

Pile Parameters

Pile

Pile Type: Circular

Diameter/Side Length (D): [m]

Total Pile Length: [m]

Pile Length above Surface: [m]

Mass Density: [Mg/m³]

Pile Head

Pile Head Connection

Fixed Head Free/Pinned Head

Pile/Pier Head Mass: [Mg]

Axial Load (Positive for Compression): [kN]

Pile Group

Group Layout

	Longitudinal	Transverse
Number of Piles	<input type="text" value="3"/>	<input type="text" value="3"/>
Spacing [xD]	<input type="text" value="3"/>	<input type="text" value="3"/>

Pier Height: [m]

Pier Head Connection

No Rotation @ Longitudinal Axis

No Rotation @ Transverse Axis

OK Cancel Apply

Soil Parameters:

Soil Parameters

Soil Strata

Layer #	Height [m]	Soil Type	Properties
1	<input type="text" value="10"/>	22: U-Clay2 (PressureIndependentMultiYield)	Material Properties
2	<input type="text" value="0"/>	22: U-Clay2 (PressureIndependentMultiYield)	Material Properties
3	<input type="text" value="0"/>	22: U-Clay2 (PressureIndependentMultiYield)	Material Properties
4	<input type="text" value="0"/>	22: U-Clay2 (PressureIndependentMultiYield)	Material Properties
5	<input type="text" value="0"/>	22: U-Clay2 (PressureIndependentMultiYield)	Material Properties
6	<input type="text" value="0"/>	22: U-Clay2 (PressureIndependentMultiYield)	Material Properties
7	<input type="text" value="0"/>	22: U-Clay2 (PressureIndependentMultiYield)	Material Properties
8	<input type="text" value="0"/>	22: U-Clay2 (PressureIndependentMultiYield)	Material Properties
9	<input type="text" value="0"/>	22: U-Clay2 (PressureIndependentMultiYield)	Material Properties

Saturated Soil Analysis

Water Table Depth (Below Ground Surface if Positive; Above Surface if Negative): [m]

Interfacing Layer

Modify Properties... Top Layer Same as Soil

Thickness (xD):

Piled Raft

Modify Properties... Modify Extents...

Pile Zone

Modify Properties... Top Layer Same as Soil

Outermost Zone

Modify Properties... Top Layer Same as Soil

Thickness: [m]

Tension Cut-off for Cohesive Soils

OK Cancel Apply

Built-in materials (Yang and Elgamal 2002; Elgamal et al. 2003; Yang et al. 2003):

- 1: Sat. cohesionless very loose, silt permeability
- 2: Sat. cohesionless very loose, sand permeability
- 3: Sat. cohesionless very loose, gravel permeability
- 4: Sat. cohesionless loose, silt permeability
- 5: Sat. cohesionless loose, sand permeability
- 6: Sat. cohesionless loose, gravel permeability
- 7: Sat. cohesionless medium, silt permeability
- 8: Sat. cohesionless medium, sand permeability
- 9: Sat. cohesionless medium, gravel permeability
- 10: Sat. cohesionless medium-dense, silt permeability
- 11: Sat. cohesionless medium-dense, sand permeability
- 12: Sat. cohesionless medium-dense, gravel permeability
- 13: Sat. cohesionless dense, silt permeability
- 14: Sat. cohesionless dense, sand permeability
- 15: Sat. cohesionless dense, gravel permeability
- 16: Cohesive soft
- 17: Cohesive medium
- 18: Cohesive stiff

User-defined soil materials (Yang and Elgamal 2002; Elgamal et al. 2003; Yang et al. 2003):

- 19: U-Sand1A (PressureDependMultiYield)
- 20: U-Sand1B (PressureDependMultiYield)
- 21: U-Clay1 (PressureIndependMultiYield)
- 22: U-Clay2 (PressureIndependMultiYield)
- 23: U-Sand2A (PressureDependMultiYield02)
- 24: U-Sand2B (PressureDependMultiYield02)
- 25: U-Sand3 (PressureDependMultiYield03)

USand1A:

U-Sand1A (PressureDependMultiYield) for Soil Layer 1

Material Properties | Stress-strain Response | Reset Based on a Built-in Cohesionless Material (Click to Choose One...)

Soil Elastic Properties

Saturated Mass Density: 1.9 [Mg/m³]
 Reference Pressure: 80 [kPa]
 Pressure Dependence Coeff.: 0.5
 Gmax: 75000 [kPa]
 Bmax: 200000 [kPa]

Soil Nonlinear Properties

Peak Shear Strain Multiplied by (Sqrt(2/3)): 10 [%]
 Friction Angle: 33 [deg]
 Cohesion (c) Multiplied by ((Sqrt(3))/2): 0.3 [kPa]

Fluid Properties

Fluid Mass Density: 1 [Mg/m³]
 Combined Bulk Modulus: 2200000 [kPa]
 Horizontal Permeability: 6.6E-05 [m/s]
 Vertical Permeability: 6.6E-05 [m/s]

Miscellaneous

Number of Yield Surfaces: 20

Dilatancy/Liquefaction Properties

Phase Transformation Angle: 27 [deg]
 Contraction Parameter c1: 0.07
 Dilation Parameter d1: 0.4
 Dilation Parameter d2: 2
 Liquefaction Parameter 1: 10 [kPa]
 Liquefaction Parameter 2: 0.01
 Liquefaction Parameter 3: 1

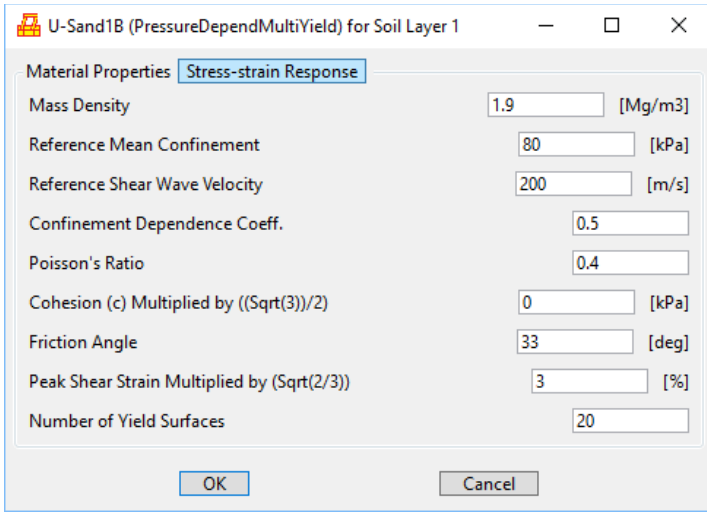
User-defined Backbone Curve | Modify Curve...

Strain [%] and G/Gmax in pairs:

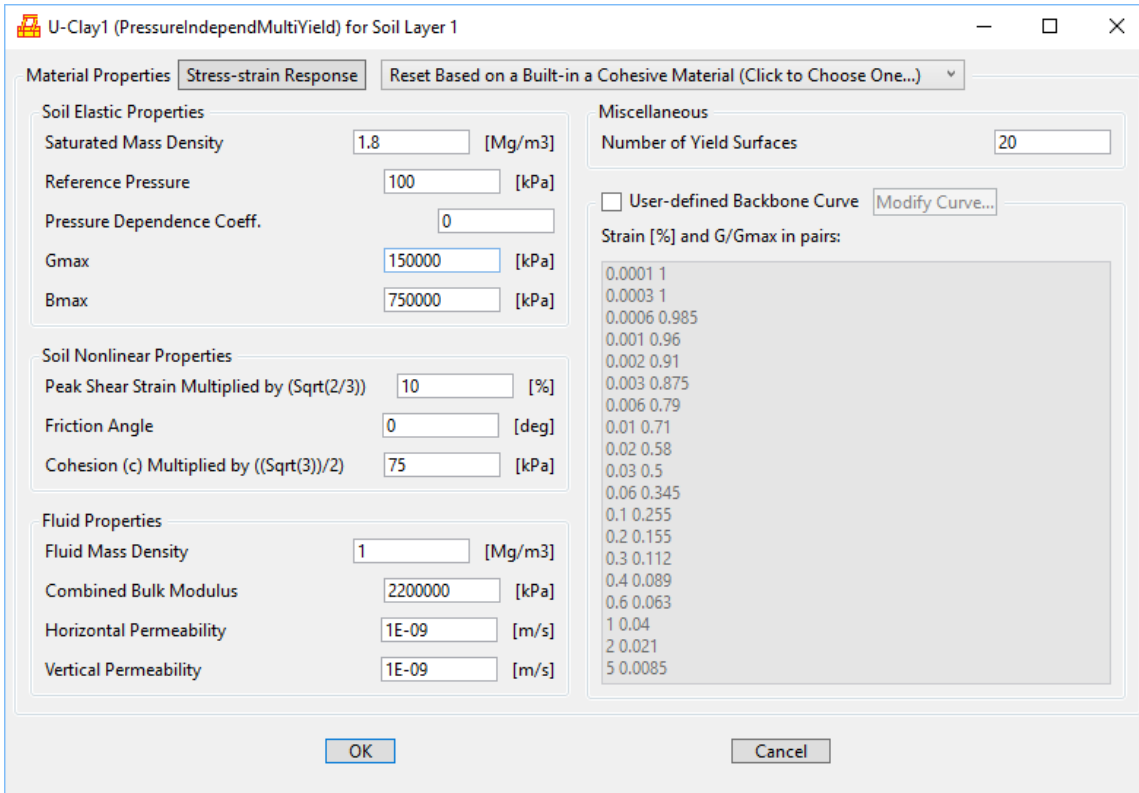
0.0001	1
0.0003	1
0.0006	0.985
0.001	0.96
0.002	0.91
0.003	0.875
0.006	0.79
0.01	0.71
0.02	0.58
0.03	0.5
0.06	0.345
0.1	0.255
0.2	0.155

OK | Cancel

USand1B:



UClay1:



UClay2:

U-Clay2 (PressureIndependentMultiYield) for Soil Layer 1

Material Properties **Stress-strain Response**

Mass Density [Mg/m3]

Shear Wave Velocity [m/s]

Poisson's Ratio

Cohesion (c) Multiplied by ((Sqrt(3))/2) [kPa]

Peak Shear Strain Multiplied by (Sqrt(2/3)) [%]

Number of Yield Surfaces

USand2A:

U-Sand2A (PressureDependMultiYield) for Soil Layer 1

Material Properties **Stress-strain Response** ▾

Soil Elastic Properties

Saturated Mass Density [Mg/m3]

Reference Pressure [kPa]

Pressure Dependence Coeff.

Gmax [kPa]

Bmax [kPa]

Soil Nonlinear Properties

Peak Shear Strain Multiplied by (Sqrt(2/3)) [%]

Friction Angle [deg]

Cohesion (c) Multiplied by ((Sqrt(3))/2) [kPa]

Fluid Properties

Fluid Mass Density [Mg/m3]

Combined Bulk Modulus [kPa]

Horizontal Permeability [m/s]

Vertical Permeability [m/s]

Miscellaneous

Number of Yield Surfaces

Dilatancy/Liquefaction Properties

Phase Transformation Angle [deg]

Contraction Parameter c1

Contraction Parameter c2 (Default: 5)

Contraction Parameter c3

Dilation Parameter d1

Dilation Parameter d2 (Default: 3)

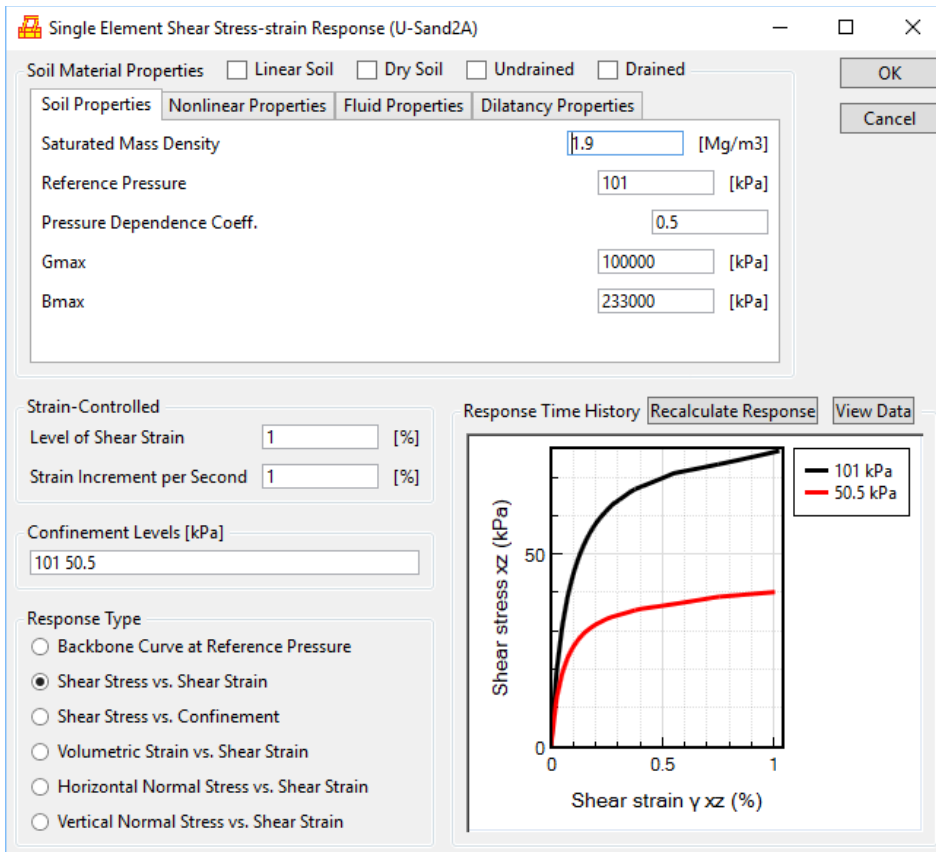
Dilation Parameter d3

User-defined Backbone Curve

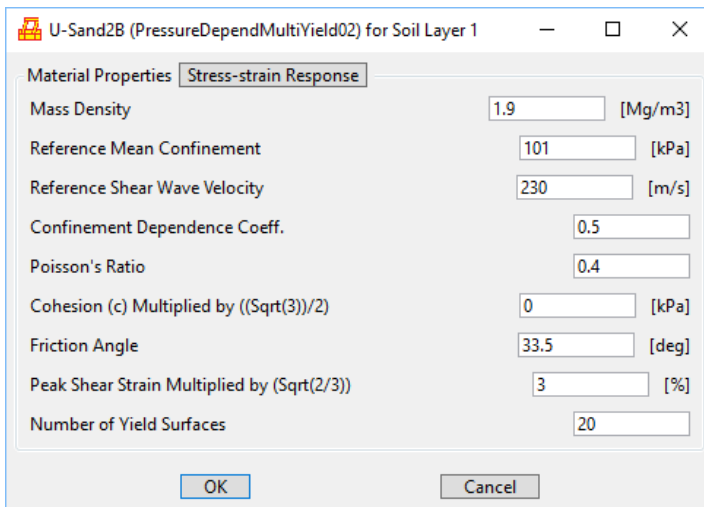
Strain [%] and G/Gmax in pairs:

```
0.0001 1
0.0003 1
0.0006 0.985
0.001 0.96
0.002 0.91
0.003 0.875
0.006 0.79
0.01 0.71
0.02 0.58
0.03 0.5
0.06 0.345
```

Shear-stress strain response of single element:



USand2B:



Mesh Parameters:

Mesh Parameters

General Meshing | **Horizontal Meshing (Single Pile)** | Vertical Meshing | Mesh Scaling

Mesh Scale: **Half Mesh**

Pile

Number of Slices: **16**

Number of Beam Column Elements above Surface: **4**

Pier

Number of Beam Column Elements for Pier: **4**

Mesh Info

Soil Domain: 39 m (Longitudinal) x 19.5 m (Transverse) x 10 m (Vertical).

Number of Elements: 144 (Soil) and 43 (Pile & Links). Number of Nodes: 230 (Soil) and 44 (Pile & Links).

OK Cancel Apply

Horizontal meshing parameters for the single pile case:

Mesh Layer #	Length [m]	Number of Mesh Layers	Uniform Meshing	Element Size Increasing Ratio
1 (Pile Radius)	0.5	1	<input checked="" type="checkbox"/>	1
2	1	1	<input checked="" type="checkbox"/>	1
3	18	3	<input type="checkbox"/>	0.45
4	0	1	<input checked="" type="checkbox"/>	1
5	0	1	<input checked="" type="checkbox"/>	1

Horizontal meshing parameters for a pile group case:

Pile Group

Longitudinal Transverse

Number of Mesh Layers between Piles: **2** **2**

Element Size Increasing Ratio: **1** **1**

Longitudinal

Mesh Layer #	Length [m]	Number of Mesh Layers	Uniform Meshing	Element Size Increasing Ratio
1	1	2	<input checked="" type="checkbox"/>	1
2	10	2	<input type="checkbox"/>	0.5

Use Longitudinal Parameters for Transverse Direction

Transverse

Mesh Layer #	Length [m]	Number of Mesh Layers	Uniform Meshing	Element Size Increasing Ratio
1	1	2	<input checked="" type="checkbox"/>	1
2	10	2	<input type="checkbox"/>	0.5

Vertical meshing parameters:

Mesh Layer #	Height [m]	Number of Mesh Layers	Uniform Meshing	Element Size Increasing Ratio
1	6	3	<input checked="" type="checkbox"/>	1
2	4	1	<input checked="" type="checkbox"/>	1

Mesh scaling:

Scale Soil Domain in Horizontal Directions

Model Size (In term of Full Mesh)

Model Length (Longitudinal Direction)

Model Width (Transverse Direction)

Pile Elements:

Pile Elements

Beam Column Element Type

Linear

Bilinear

Advanced

Notes

1. Same pile properties will be used for all piles if "Linear" or "Bilinear" is chosen. Pier (if any) will be assumed rigid in this case.
2. The global pile mass density (defined in "Pile Parameters" window) will be used if "Linear" or "Bilinear" is chosen.
3. If "Advanced" is chosen, the Unit Weight for the Sections will be used.

Bilinear pile model:

Bilinear Model

Bilinear Model Parameters

Flexural Rigidity E^*I [kN-m²]

Plastic Moment [kN-m]

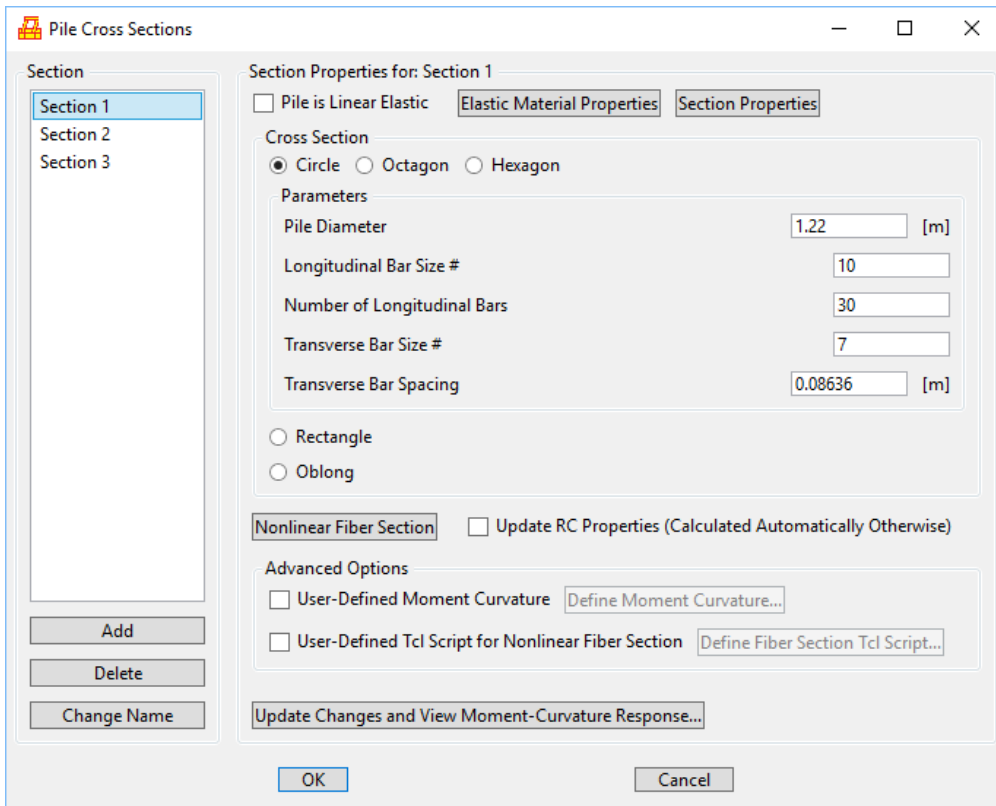
Additional Parameters

Shear Rigidity G^*A [kN]

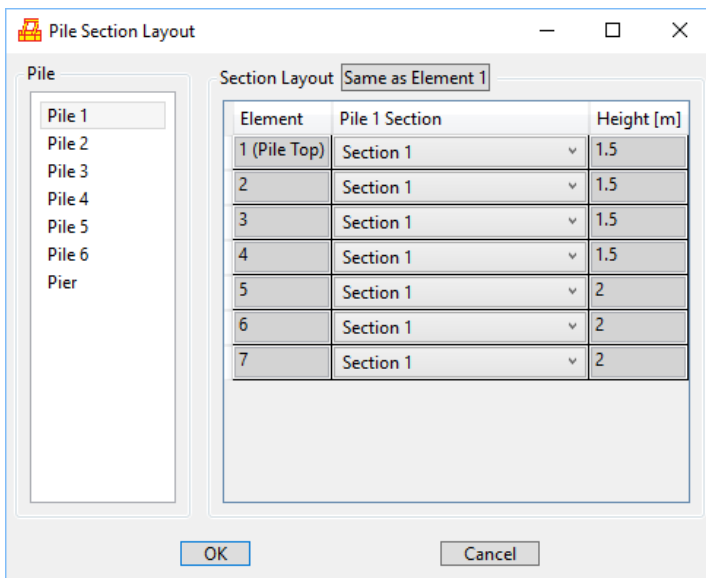
Torsional Rigidity G^*J [kN-m²]

Axial Rigidity E^*A [kN]

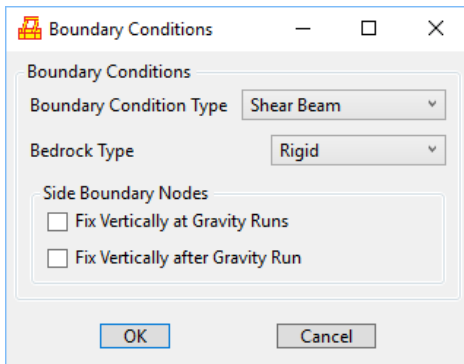
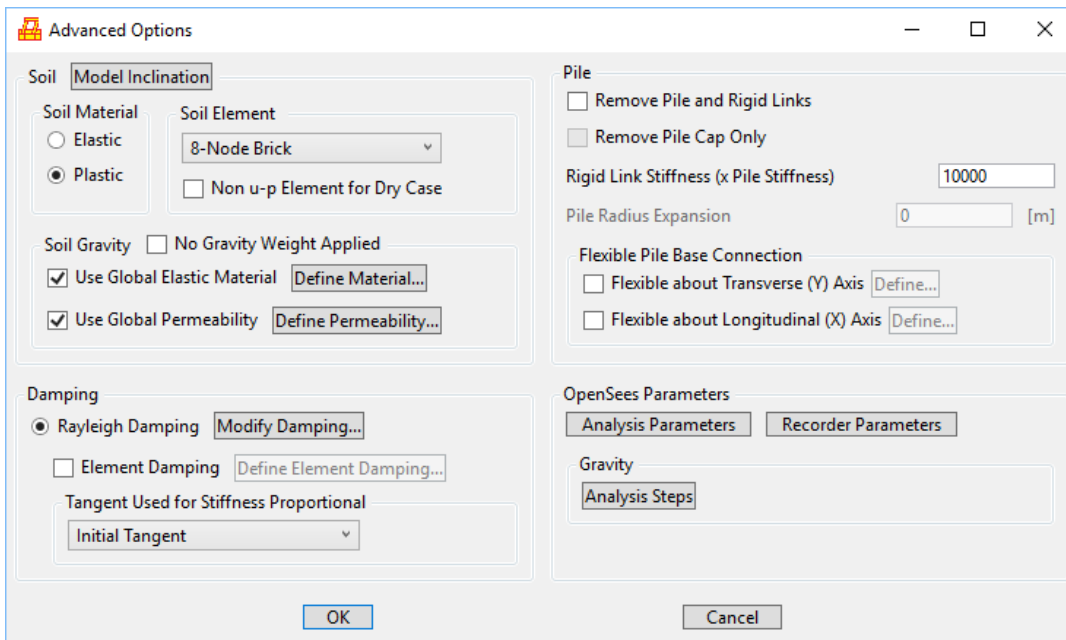
Nonlinear Fiber section (Scott and Fenves 2006; Scott and Ryan 2013):



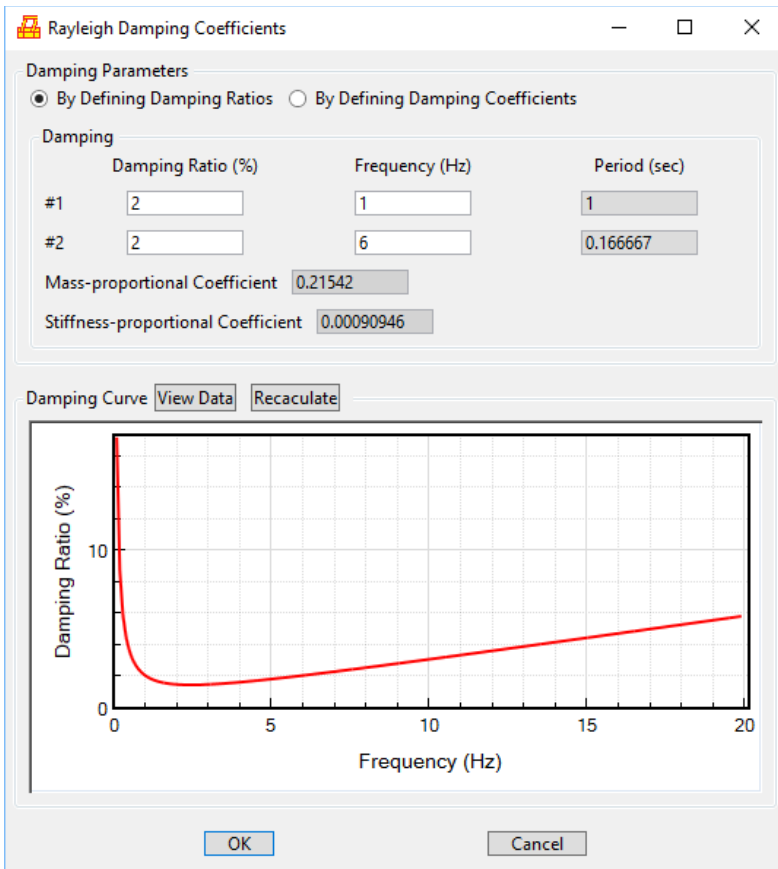
Assigning sections to pile(s):



Boundary Conditions:

**Advanced:**

Rayleigh damping:



Element damping:

Element Damping

Element Damping Parameters

Layer #	Height [m]	Element Damping	Mass-proportional Am	Stiffness-proportional Ak
Layer 1	2	<input type="checkbox"/>	0	0
Layer 2	2	<input type="checkbox"/>	0	0
Layer 3	2	<input type="checkbox"/>	0	0
Layer 4	2	<input type="checkbox"/>	0	0
Layer 5	2	<input type="checkbox"/>	0	0

Analysis parameters:

Command	Option	Parameters
constraints	Penalty	
system	Mumps	
test	EnergyIncr	
algorithm	KrylovNewton	
integrator	TRBDF2	

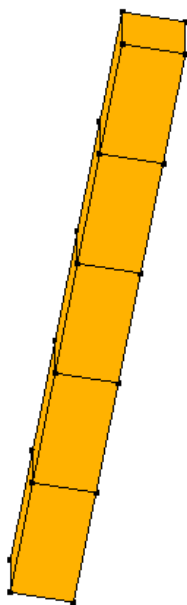
Note: Please make sure you enter the correct parameters (or leave blank) for each command that you choose, otherwise OpenSees may crash.

Parameters for Integrator Newmark		Convergence Tolerance	
Gamma	0.6	Tolerance	1E-06
Beta	0.3025		

OK Cancel

Shear-beam type site response analysis:

Shear-beam model can be obtained by checking "Shear Beam Model" in the OpenSeesPL main window:



3. Analysis Types

(Go to [1. Menu](#) [2. Model Parameters](#) [4. Miscellaneous](#))

Pushover Loading (Pushover Analysis is available only when pile is included)

Pushover

Type

Static Pushover Total Number of Steps

Dynamic Pushover

Computation Time [sec] Time Step [sec]

Method

Forced-Based Method

Displacement-Based Method

Pattern

Monotonic Pushover

Loading Duration [sec]

Cyclic Pushover Define Cyclic...

U-Push Define U-Push...

Pushover Location

Pile Head

Shear Beam

Loading Height [m]

Profile Pushover Define Profile...

Force Increment (per Step)

Longitudinal (X) Force [kN]

Transverse (Y) Force [kN]

Vertical (Z) Force [kN]

Moment of X [kN-m]

Moment of Y [kN-m]

Moment of Z [kN-m]

Displacement Increment (per Step)

Longitudinal (X) Displacement [m]

Transverse (Y) Displacement [m]

Vertical (Z) Displacement [m]

Rotation around X [rad]

Rotation around Y [rad]

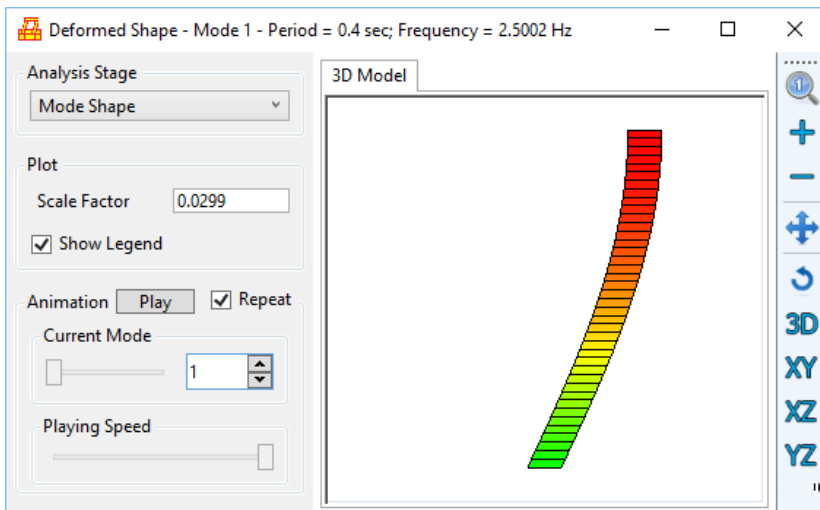
Rotation around Z [rad]

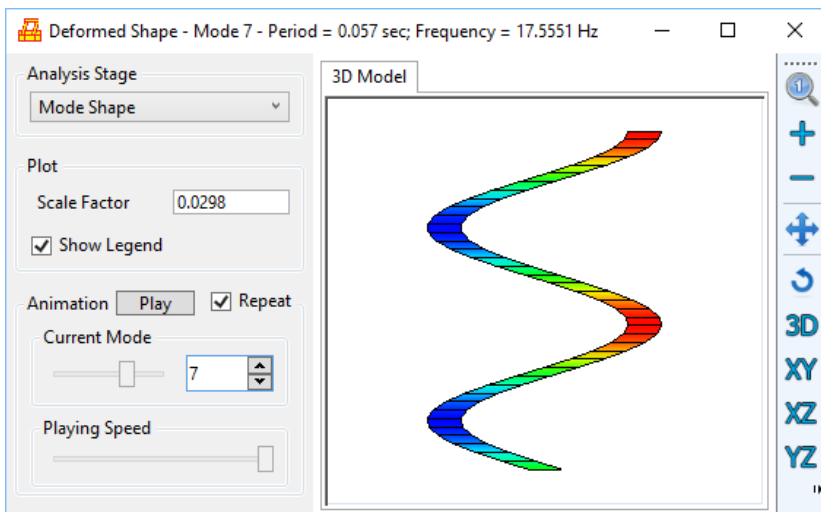
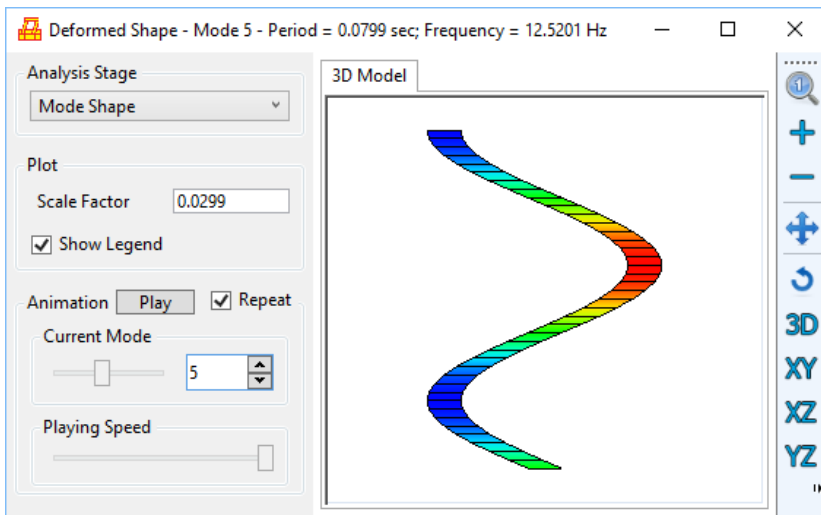
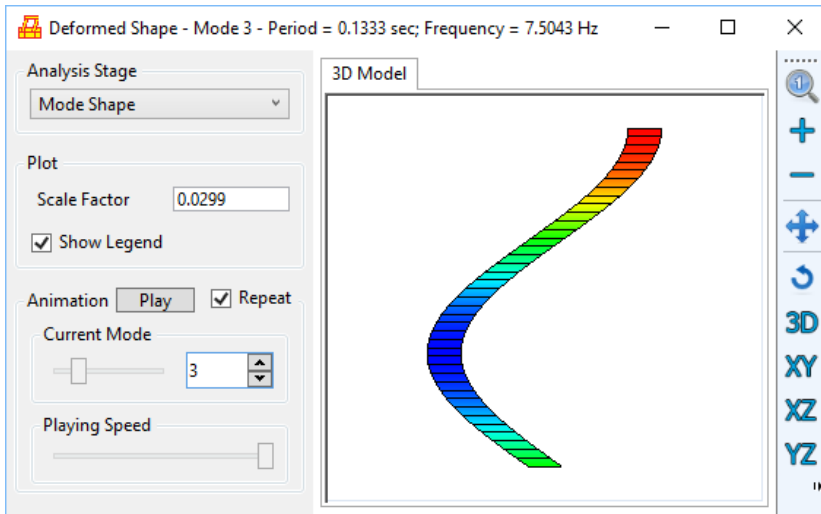
Surface Load (per Step; Applied at the Ground Surface of the Pile Zone)

Longitudinal (X) [kPa] Transverse (Y) [kPa] Vertical (Z) [kPa]

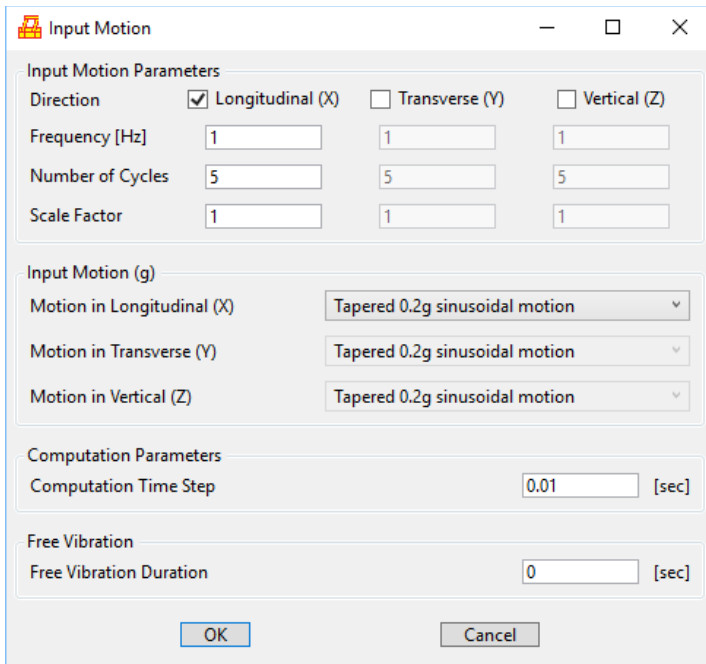
Mode Shape Analysis:

First few modes for a shear beam model (the mode shapes are displayed in the deformed mesh window):

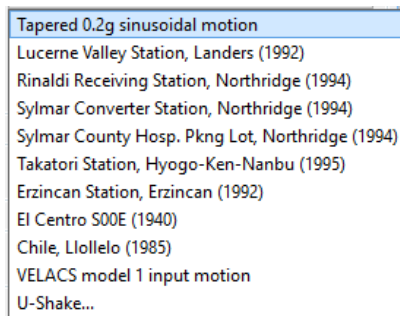




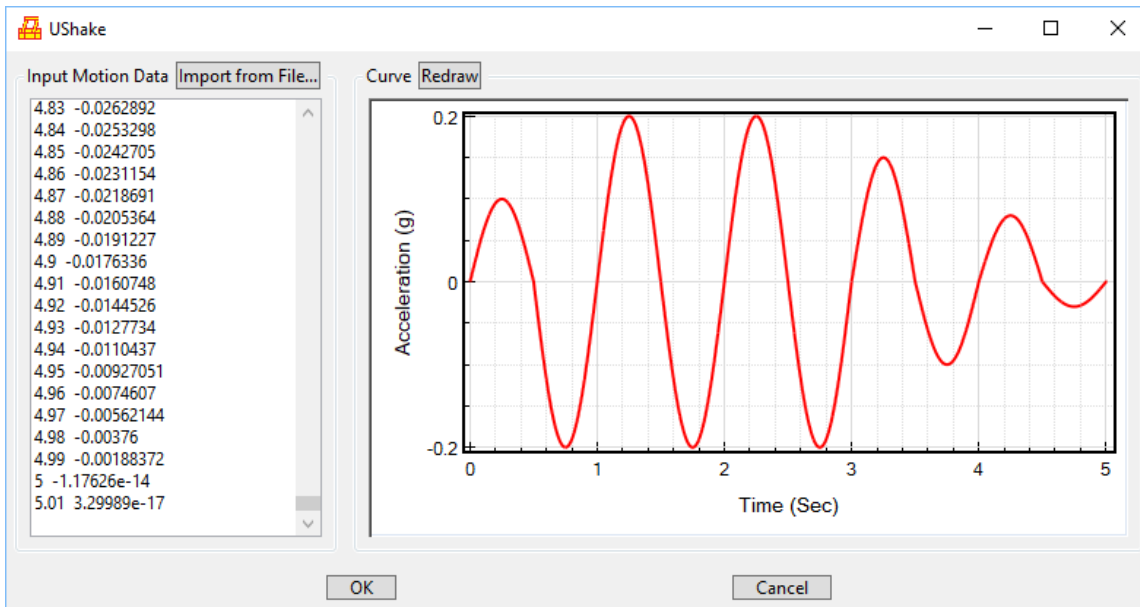
Base Shaking:



List of built-in input motions and also option to define user input motion:



User-defined input motion (time and acceleration in g):



4. Miscellaneous

(Go to [1. Menu](#) [2. Model Parameters](#) [3. Analysis Types](#))

(i) Regarding Modifying OpenSees Tcl Files

It is possible that OpenSeesPL is still able to do post-processing if the user modifies the OpenSees Tcl files manually (in this case, analysis cannot be performed through the user interface but instead has to be done in the OpenSees command window). However, care must be taken if the user plans to make changes to the Tcl input files. Only minor modifications of the Tcl files are suggested and change of the mesh information (e.g., adding/removing nodes/elements) is discouraged.

(ii) Regarding Unit Systems

OpenSeesPL operates in SI and English units. The SI unit system in OpenSeesPL uses m, kN, kPa, Mg, etc. The English one uses inches (or feet), kips, psi, pcf, and so on.

Note that in OpenSeesPL, the output recorded in the OpenSees recorder files (e.g., Untitled.dsp) are in SI units (even the English unit system is selected). Conversion is done internally in OpenSeesPL for the post-processing, if the English unit system is being used.

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OpenSeesPL

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