Training document

Enhancements to pile/soil modelling and analysis

GeniE V7.3

9 February 2016

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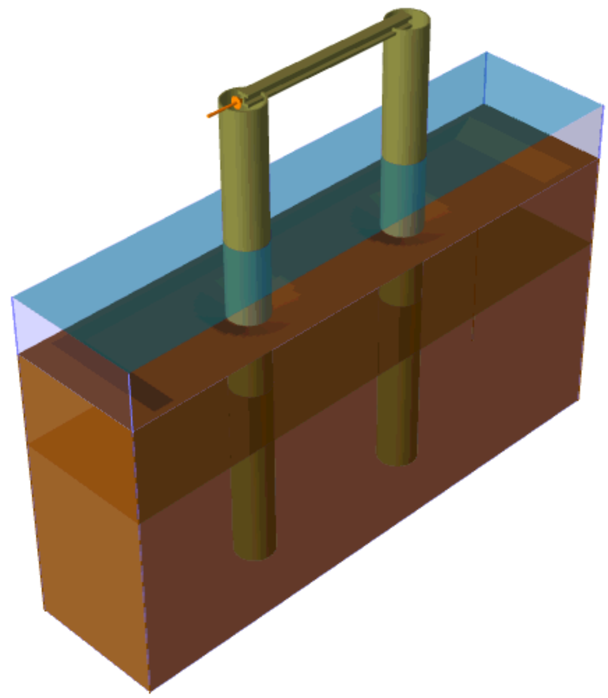
Introduction

- The main goal of this training example is to describe what is needed to perform a Pile Soil Analysis. The values used, e.g. soil characteristics or layer definitions, are not necessarily realistic. However, the example illustrates how to set up this kind of analysis and many important concepts are explained. Reference is made to the Gensod user documentation for further details.

- A *Pile* in GeniE is considered to be a straight beam, supplied with a set of specific additional properties called Pile Characteristics, which is joined and aligned with an existing beam.



A picture of the model used in this example

- The usage of piles inside GeniE is restrained to model the interaction of this specific type of beam with the *Soil*. This in turn implies that a natural choice of the coordinate system is to set the xy-plane parallel to the ground or seabed or calm sea-water surface and the z-axis to have an upwards direction. In this sense, the layers/levels are defined only by their z-coordinate. This convention is satisfied in what follows.

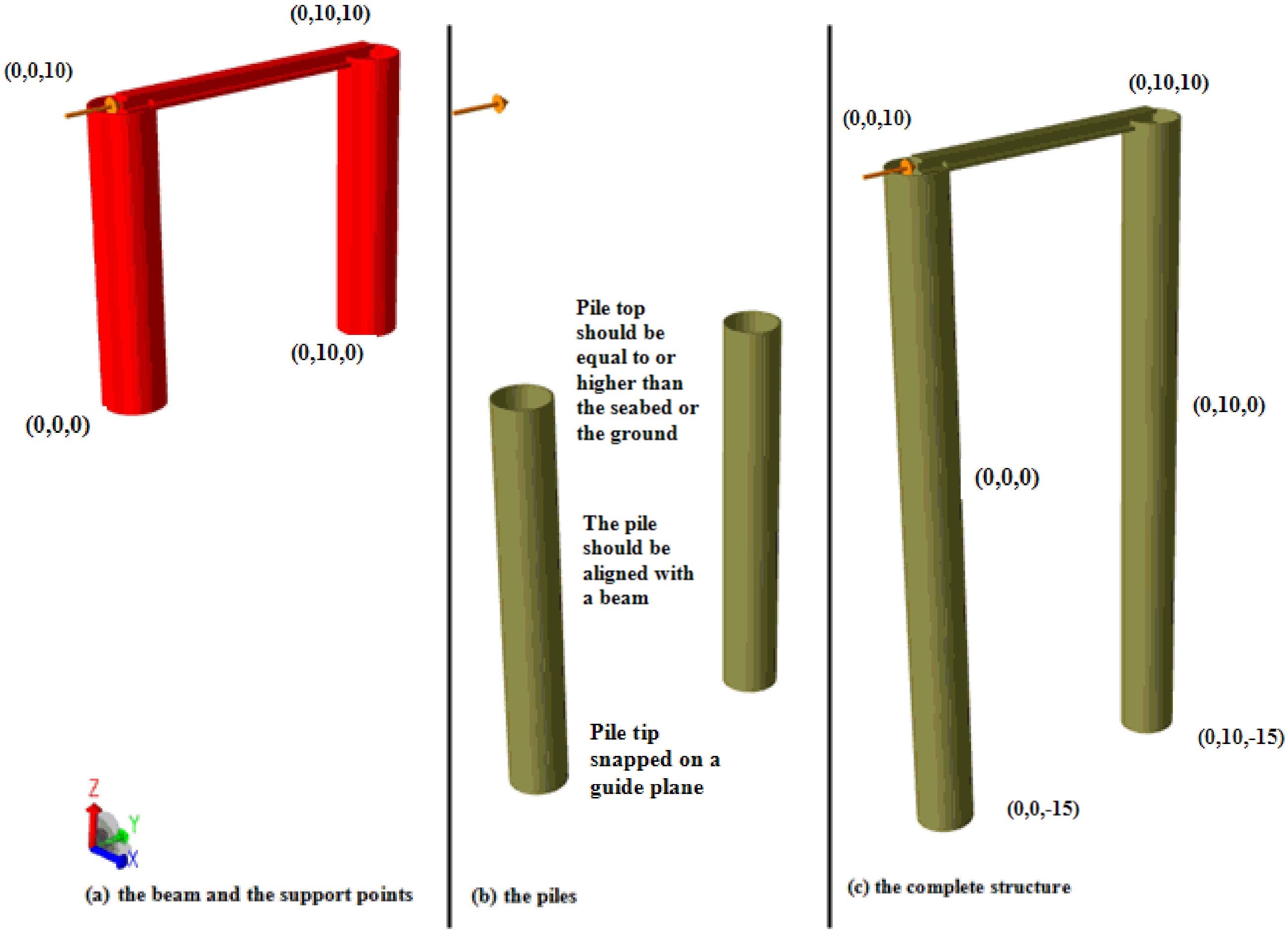
- When running GeniE the user is encouraged to move the curser above the dialog light bulbs to get specific information of an input field or of the dialog in general.

- If you want to do the example yourself in GeniE, you may have this document open on your computer so that you can copy and paste the javascript code snippets into the command window in GeniE. The complete command input file is appended at the end of the document.

The Pile Modeling

This chapter shows how to create a simple two-pile structure in GeniE.

First we create three beams arranged as in the figure below.



The structural pile model

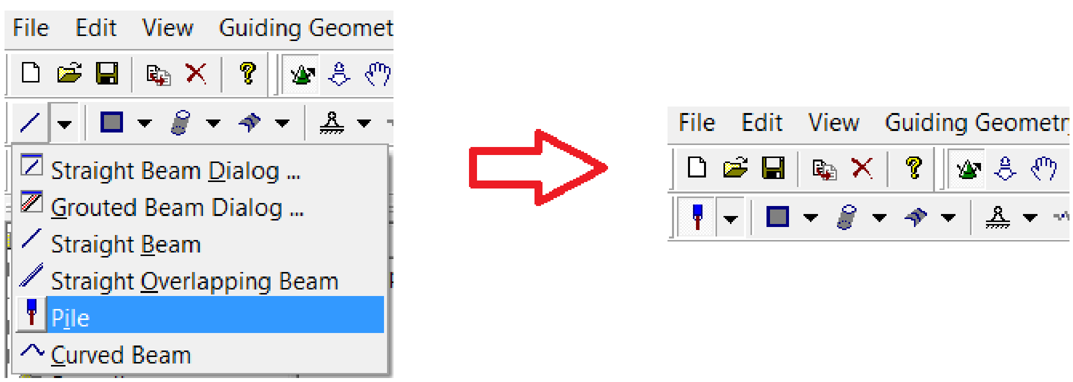
The javascript code is:

```
//Sections and material
Pipe21 = PipeSection(2.1, 0.08);
I600 = ISection(0.6, 0.6, 0.15, 0.15);
Steel = MaterialLinear(255000000 Pa, 7.850 tonne/m^3, 2.1e+011
Pa, 0.3, 1.2e-005 delC^-1, 0.03 kN*s/m);

//Top horizontal beam
Bm1 = Beam(Point(0 m,0 m,10 m), Point(0 m,10 m,10 m));
Bm1.material = Steel;
```

```
Bm1.section = I600;
//Beams connecting piles
Bm2 = Beam(Point(0 m,0 m,10 m), Point(0 m,0 m,0 m));
Bm3 = Beam(Point(0 m,10 m,10 m), Point(0 m,10 m,0 m));
Bm2.material = Steel;
Bm3.material = Steel;
Bm2.section = Pipe21;
Bm3.section = Pipe21;
```

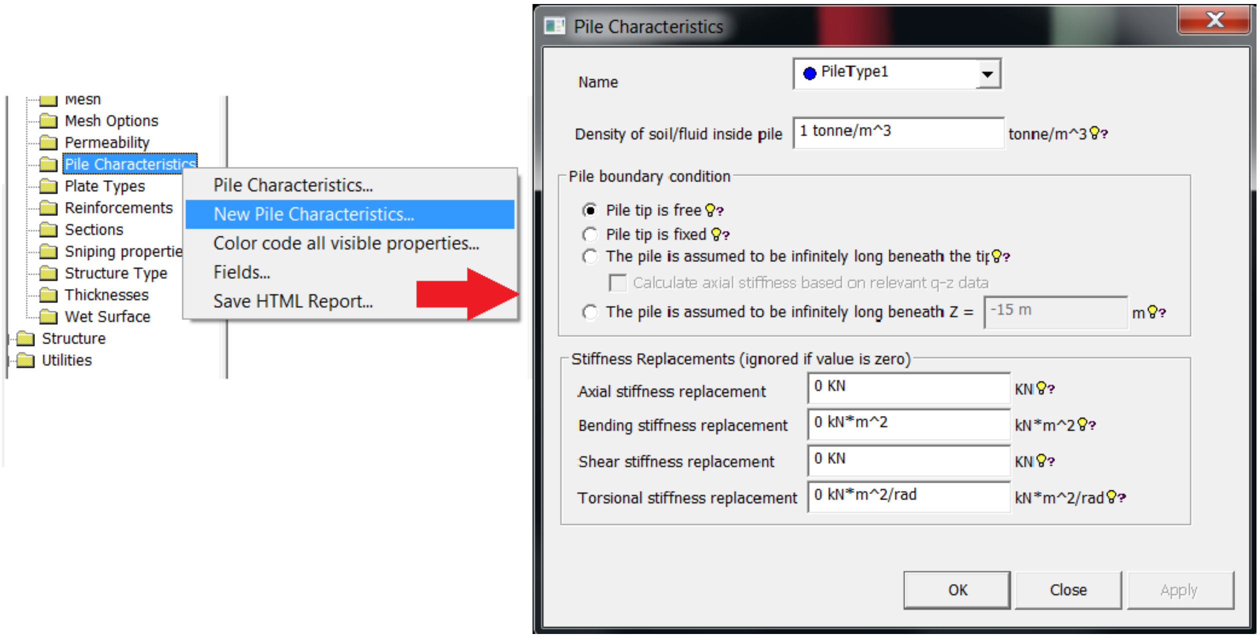
Then, we switch the Straight Beam button into a Pile button by clicking the down arrow next to the button. When the Pile button is pressed you are ready to insert piles (see next figure).



Select Pile in Beam menu

A pile is easily modeled by the following three step procedure (see figure above):
a. Select the pile top (snap to the end beam points)
b. Specify the Z-level of the pile tip in the dialog showing up (do not click anywhere in the model)
c. Align the pile by selecting the alignment beam in the structure.

Since piles are beams, they should have a section and a material assigned to them. The *pile characteristics* allow section stiffness values to be overruled (as compared to ungrouted Pipe section properties) and where special pile tip boundary conditions may be specified. Create the property by right-clicking the Properties > Pile Characteristic folder and selecting New Pile Characteristics (see next figure). Thereafter assign this property to all piles.



Dialog for creating Pile Characteristics

The javascript code is:

```
//Piles
Pile1 = Pile(Point(0 m,0 m,0 m), Point(0 m,0 m,-15 m));
Pile2 = Pile(Point(0 m,10 m,0 m), Point(0 m,10 m,-15 m));
PileType1 = PileCharacteristics(1 tonne/m^3, tcFree);
Pile2.pileCharacteristics = PileType1;
Pile1.pileCharacteristics = PileType1;
Pile1.section = Pipe21;
Pile2.section = Pipe21;
Pile1.material = Steel;
Pile2.material = Steel;
```

<u>Note abut pile boundary conditions</u>
For long flexible piles option 3 and 4, in the picture above, is recommended for long flexible piles in order to avoid numerical problems. Please consult Splice User Manual Section 6.2.6 and Splice Engineering Descriptions for more details.

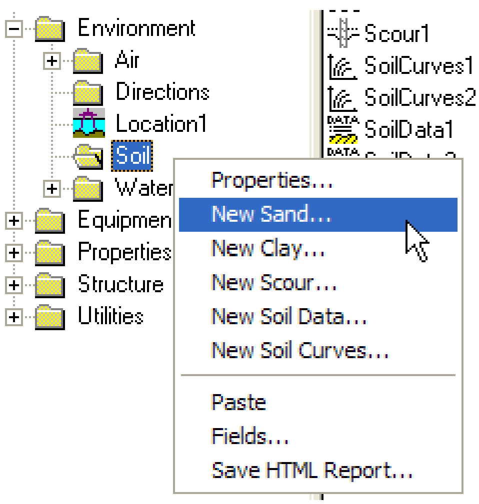
<u>Create loads</u>

In this example a point load and a gravity load is created. Since this is not specific for a Pile Soil analysis it is not described in further detail.

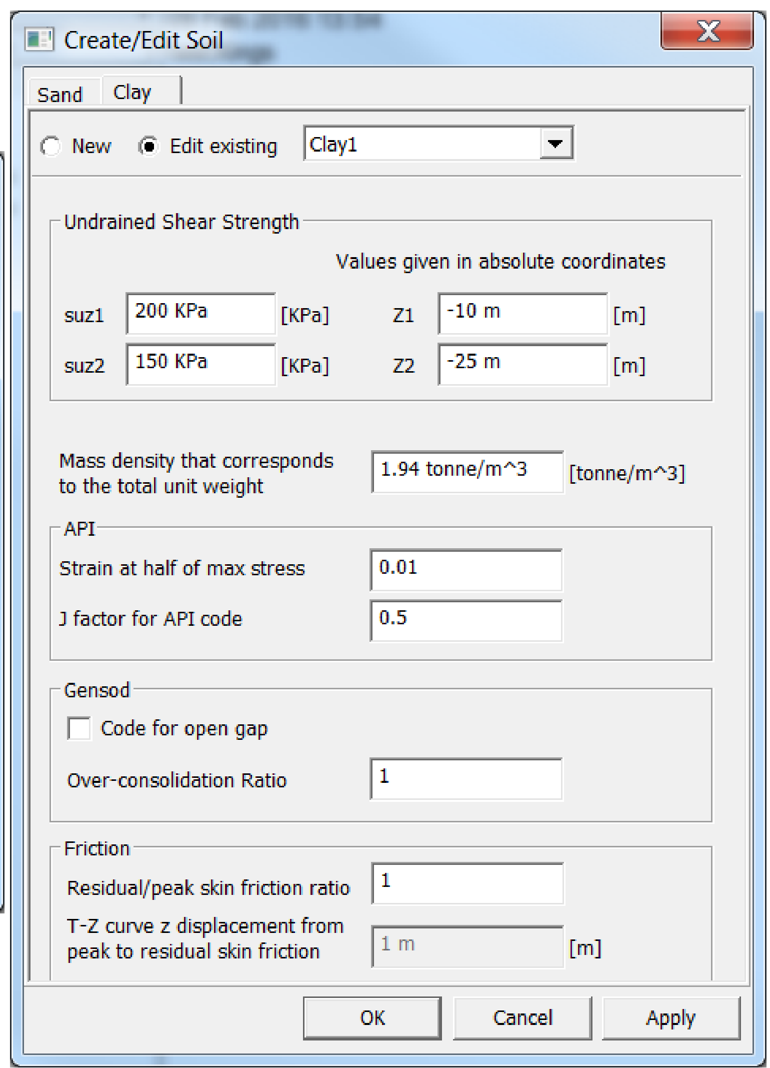
```
//Loadcase one: sideforce
sideForce = LoadCase();
PLoad1 = PointLoad(sideForce, Point(0 m,0 m,10 m), 0, 100 kN, 0
N, 0 N*m, 0 N*m, 0 N*m);
```

```
//Load case two: Gravity
Gravity = LoadCase();
Gravity.setAcceleration(Vector3d(0 m/s^2,0 m/s^2,-9.80665
m/s^2));
Gravity.includeSelfWeight();
Gravity.includeStructureMassWithRotationField();
```

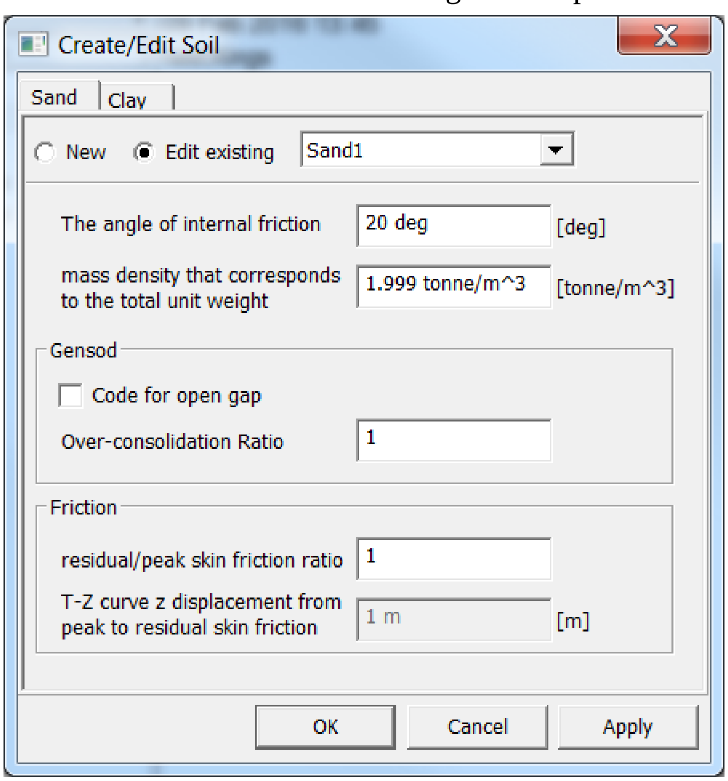
Definition of the "Soil Types"



The soil types are based on the models of Sand and Clay. They can be defined by selecting "New Clay…" and "New Sand…" on the RMB on the browser node "Soil".



The create/edit soil dialog shows up:

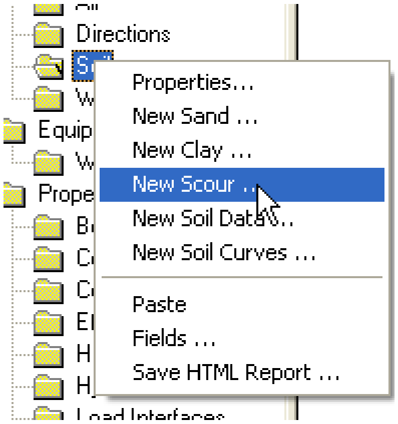


Dialogs for creating Sand and Clay

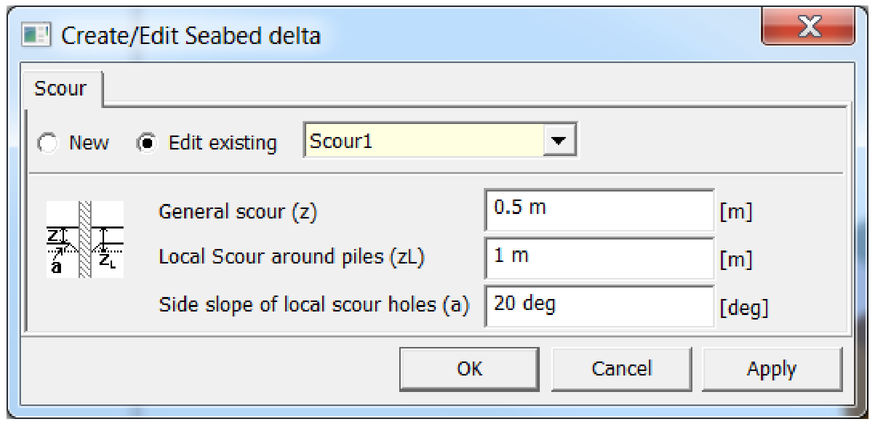
Applying the settings from this dialog, the following js-commands are executed:

```
Sand1 = Sand(false, 1, 1.99 tonne/m^3, 20 deg);
Clay1 = Clay(false, 1, 1.94 tonne/m^3, 0.01, 200 KPa, -10 m, 150
KPa, -25 m);
Clay1.apiJFactor = 0.5;
```

Definition of the “Scour”



Working analogously, by selecting “New Scour…” on the RMB on the browser node “Soil”, we can define the scour. The dialog below appears.



Dialog for creating Scour

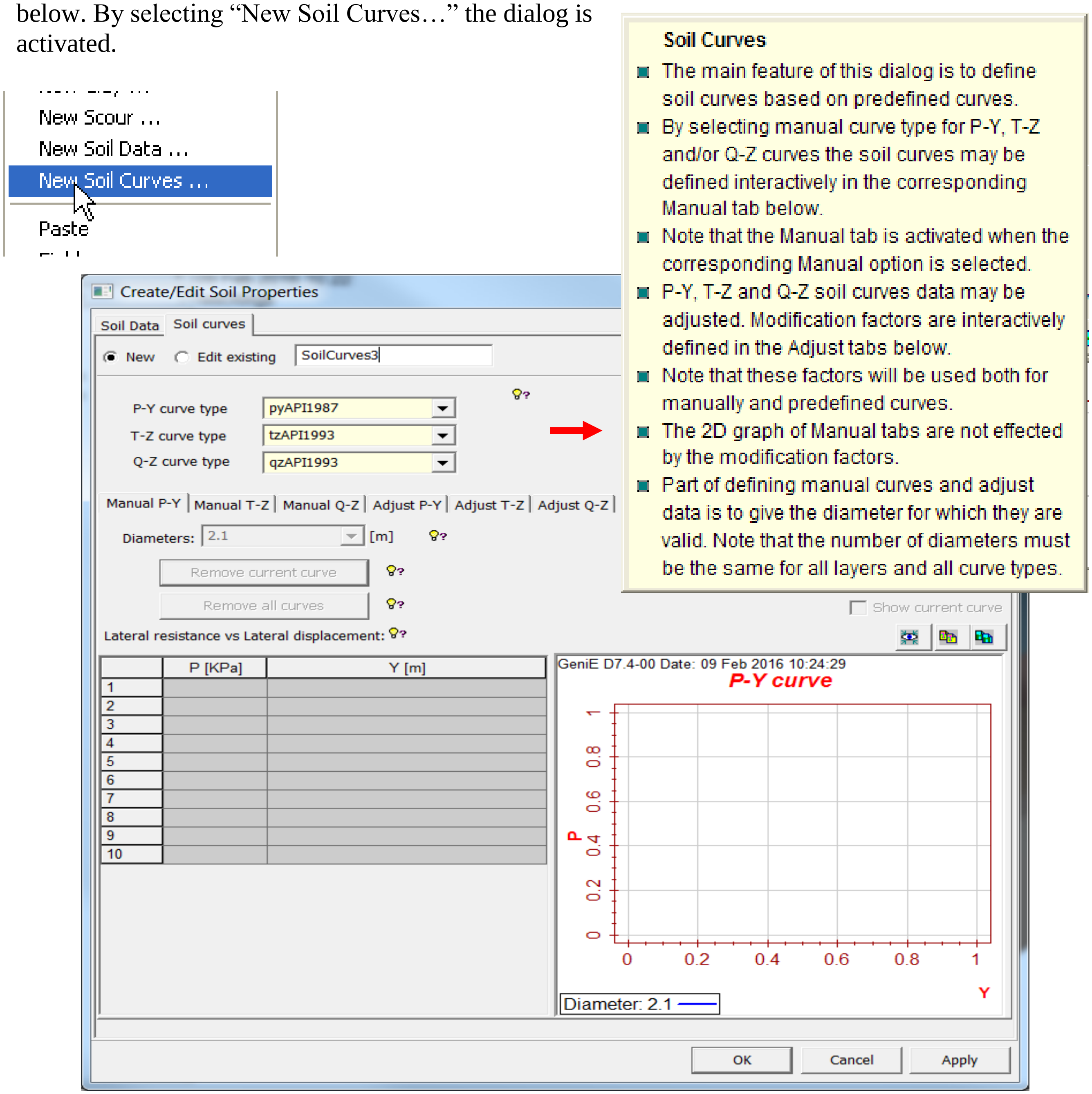
Applying the settings of the above dialog, the following js-command is executed:

```
Scour1 = Scour(0.5,1.0,20);
```

Note that the seabed level is the top most horizontal line shown in the figure of the dialog. See also figures on page 16.

Definition of the “Soil Curves”

The Soil Curves are defined in the Soil curves tab of the Soil Properties dialog as shown in figure below. By selecting “New Soil Curves…” the dialog is activated.



Dialog for creating soil curves

This is an example of the scripting command creating a soil curve defined only by predefined soil curves:

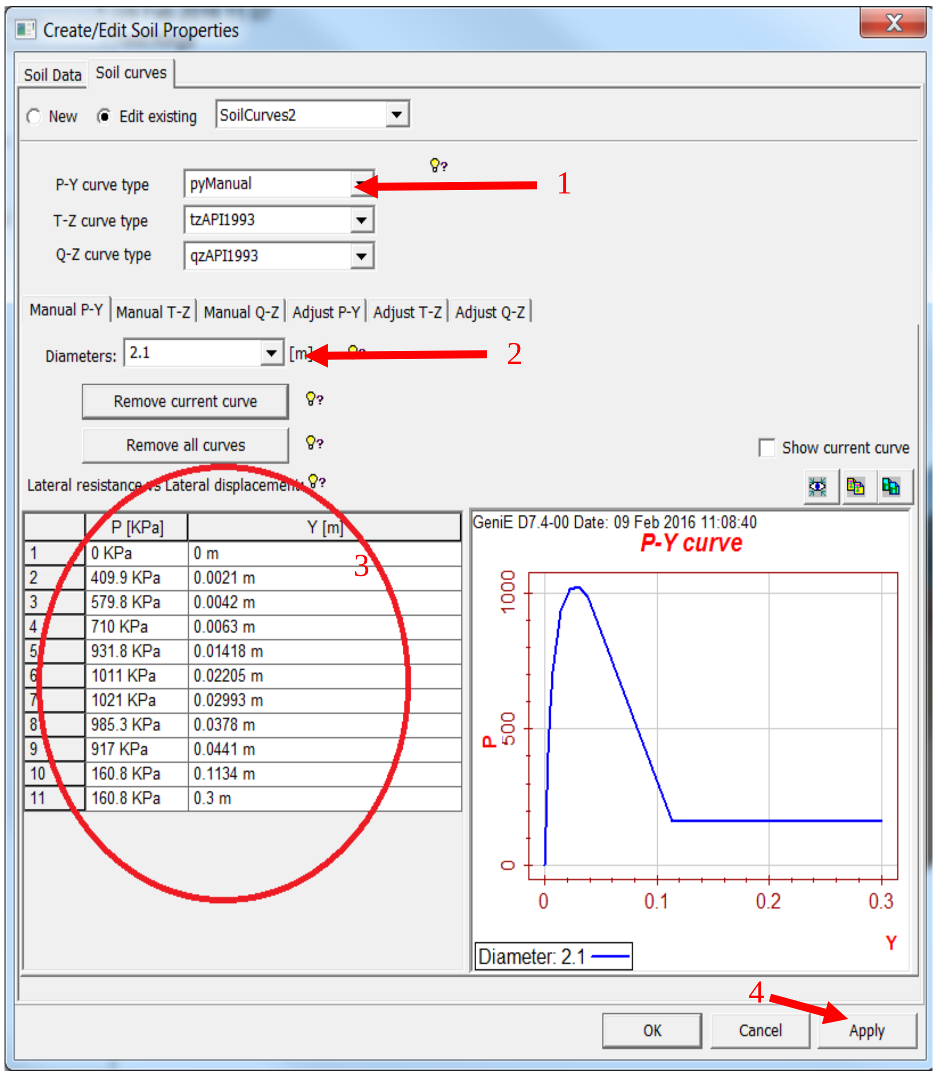
```
SoilCurves1 = SoilCurves(pyAPI1987,tzAPI1993,qzAPI1993);
```

Manual Soil Curves

GeniE gives the opportunity to define P-Y, T-Z and Q-Z soil curves manually. These curves are defined in the Manual tabs or directly by scripting commands. By selecting the Manual option of the relevant curve type combo box, the corresponding Manual tab is activated. A description of how to define a P-Y manual curve is given in the sequel, in conjunction with the following figure.

<u>Defining P-Y curves</u>

1. Select *pyManual* from the ‘P-Y curve type’ combo box. The Manual P-Y tab is activated.
2. From the ‘Diameters’ combo box either select an existing diameter or enter a new value. The combo box is automatically populated with all diameters used by all soil curves of the active *Location* (see page 14).
3. Enter P- and Y-values in the table. Note that the first pair must equal (0,0), all remaining values must be larger than 0 and the Y-values must be in increasing order. Values can be copied from a spreadsheet and pasted into the table.



The Manual P-Y tab used for defining the manual curve

4. Press ‘Apply’ when all values are entered. Data will be lost if a new diameter is selected before pressing ‘Apply’.

When ‘Apply’ is pressed in the figure above the following js-commands is executed:

```
SoilCurves2 = SoilCurves(pyManual, tzAPI1993, qzAPI1993);
```

```
SoilCurves2.addManualPY(2.1 m, Array(0 m, 0.0021 m, 0.0042 m,
0.0063 m, 0.01418 m, 0.02205 m, 0.02993 m, 0.0378 m, 0.0441 m,
0.1134 m, 0.3 m), Array(0 KPa, 409.9 KPa, 579.8 KPa, 710 KPa,
931.8 KPa, 1011 KPa, 1021 KPa, 985.3 KPa, 917 KPa, 160.8 KPa,
160.8 KPa));
```

The first parameter is the diameter of the pile, the next is the array of Y-values (lateral displacements) and the last is the array of P-values (lateral resistance).

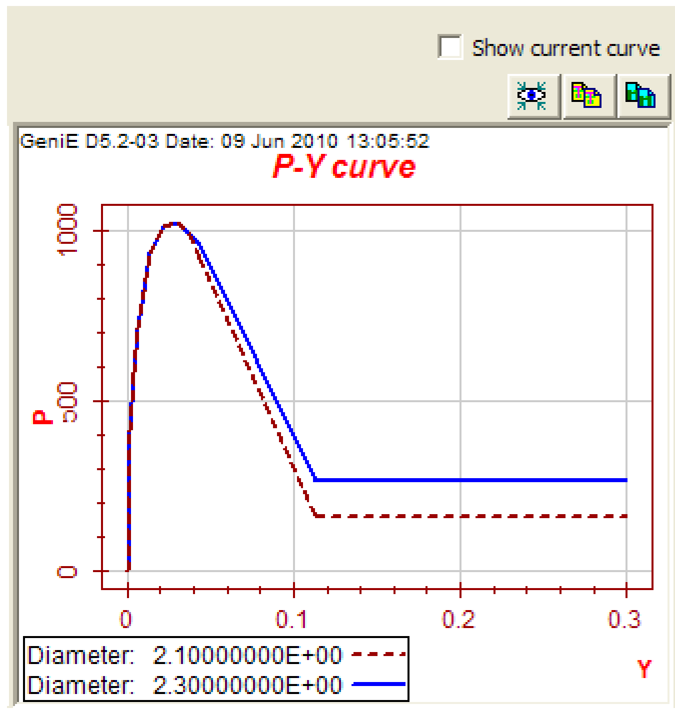
<u>The 2D graph</u>

In the GUI you get a 2D graphical visualization of the soil curves. The 2D graphs are dynamically updated when values are entered into the table.

By checking the 'Show current curve' check box only the current manual soil curve will be visualized.

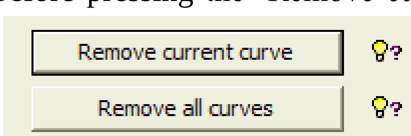
Between the 'Show current curve' check box and the graph there are three buttons. From left their roles are:
- Zoom All
- Copy Bitmap
- Copy Metafile

You can get more information by moving the cursor above each button.



<u>Removing curves</u>

Before pressing the 'Remove current curve'/'Remove all curves' button be sure that you have selected the correct diameter, i.e. have the correct curve in the table. These buttons have two functions. They remove the curve both from the table/graph and from the database. Thus pressing 'Apply' is not needed. If necessary, use the Undo functionality to restore the curves.



When pressing the 'Remove current curve' button the scripting command activated will look like this:

```
SoilCurves2.removeManualPY(2.3);
```

When pressing the 'Remove all curves' button the scripting command activated will look like this:

```
SoilCurves2.removeAllManualPY();
```

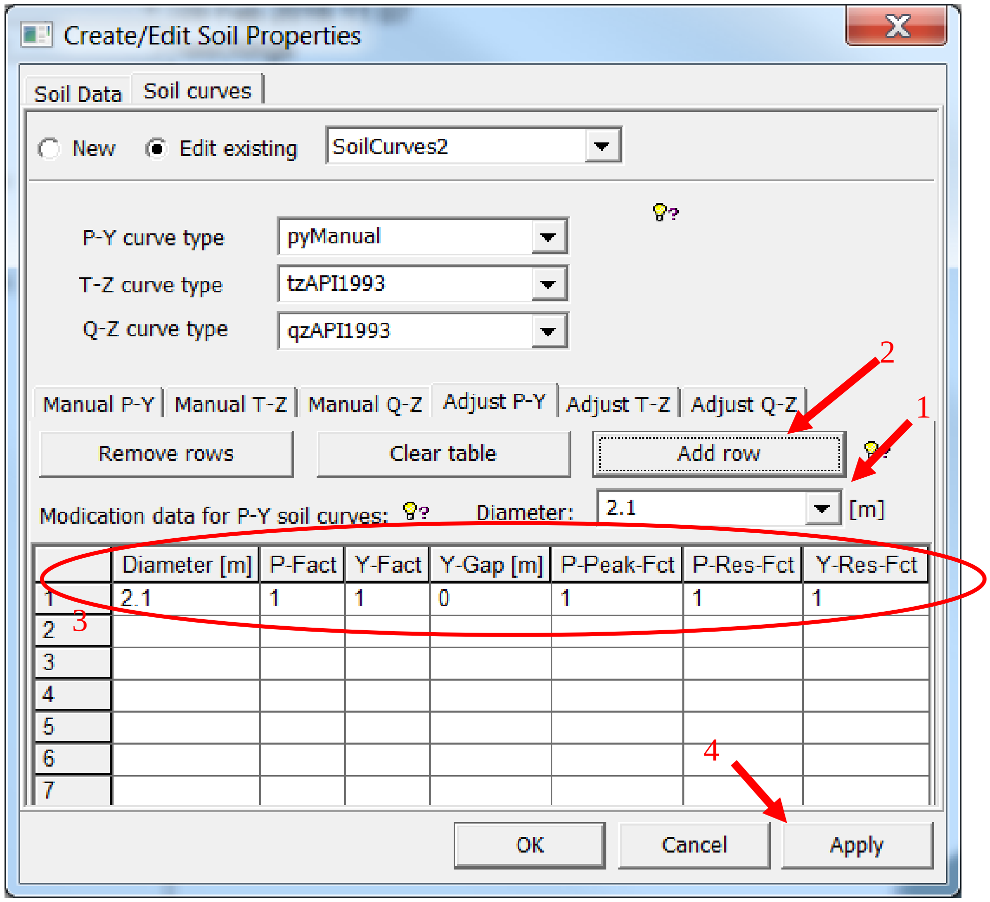
Adjust Soil Curves Data

The P-Y, T-Z and Q-Z soil curves may be modified by factors. These factors are defined in the Adjust tabs or directly by scripting commands. Note that these factors will modify all soil curve types, not only those manually defined, by the Gensod program. Moreover, these factors will not influence the 2D graph of the Manual tabs.

<u>Defining factors</u>

The simplest way of defining modification factors is by using the ‘Add row’ button. For defining P-Y adjust data these are the steps:

1. From the ‘Diameters’ combo box either select an existing diameter or give a new value. The combo box is automatically populated with all diameters used by all soil curves of the active *Location* (see page 14).
2. Push the ‘Add row’ button. A row will be appended to the table and filled with default values.



The Adjust P-Y tab used for defining the modification factors

3. Modify factors where necessary.
4. Press ‘Apply’ when all values are entered.

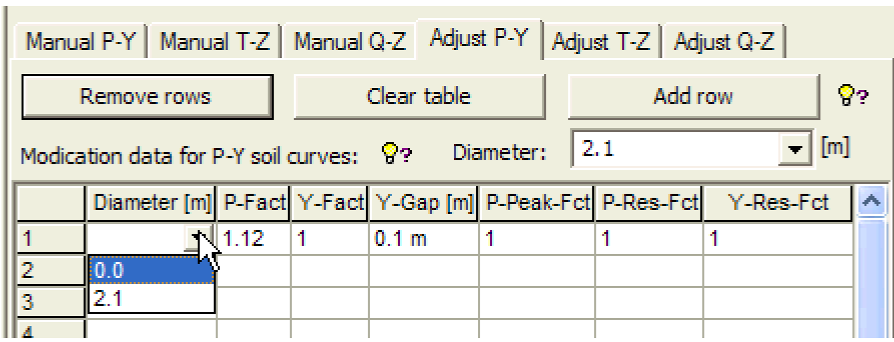
Note that a diameter equal to 0.0 is interpreted to mean that all diameters shall be included. If a diameter equal to 0.0 is given values for no other diameters shall be defined, i.e. the table shall contain one row, only.

When ‘Apply’ is pressed for the data in the figure above the scripting commands will look like this:

```
SoilCurves2.addAdjustPY(2.1 m, 1, 1, 0.0 m, 1, 1, 1);
```

Manual definition

As an alternative to using the ‘Add row’ button the complete row may be manually defined. The Diameter field of each row is a combo box populated with the same diameters as the separate Diameter combo box, plus the value ‘0.0’. New values cannot be entered into the Diameter cells. Values for all the factors must be entered manually. Alternatively, the values can be copied from a spreadsheet and pasted into the table.

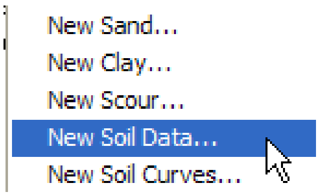


Remove rows/Clear table

The ‘Remove rows’/’Clear table’ button remove selected/all rows from the table. To store the changes in the database the ‘Apply’ button must be pushed.

Definition of the “Soil Data”

The Soil Data are defined in the Soil Data tab of the Soil Properties dialog. By selecting “New Soil Data…” the dialog is activated. The ‘Peak skin friction’ can either be Constant or Linear Varying with respect to Z. This is described in detail below.



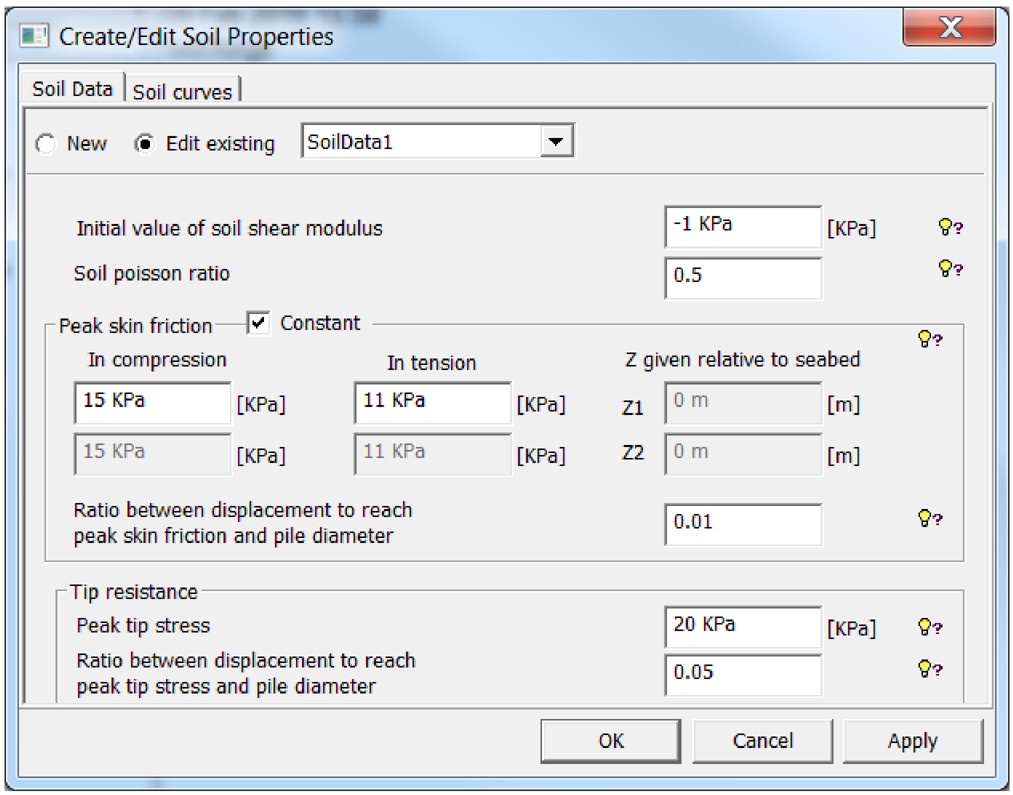
<u>Constant skin friction</u>

The figure shows the definition of soil data with a constant peak skin friction.

To define a constant peak skin friction the ‘Constant’ check box must be checked.

This option is also compatible with the old Soil Data definition.

The settings in the dialog lead to the following js-command:



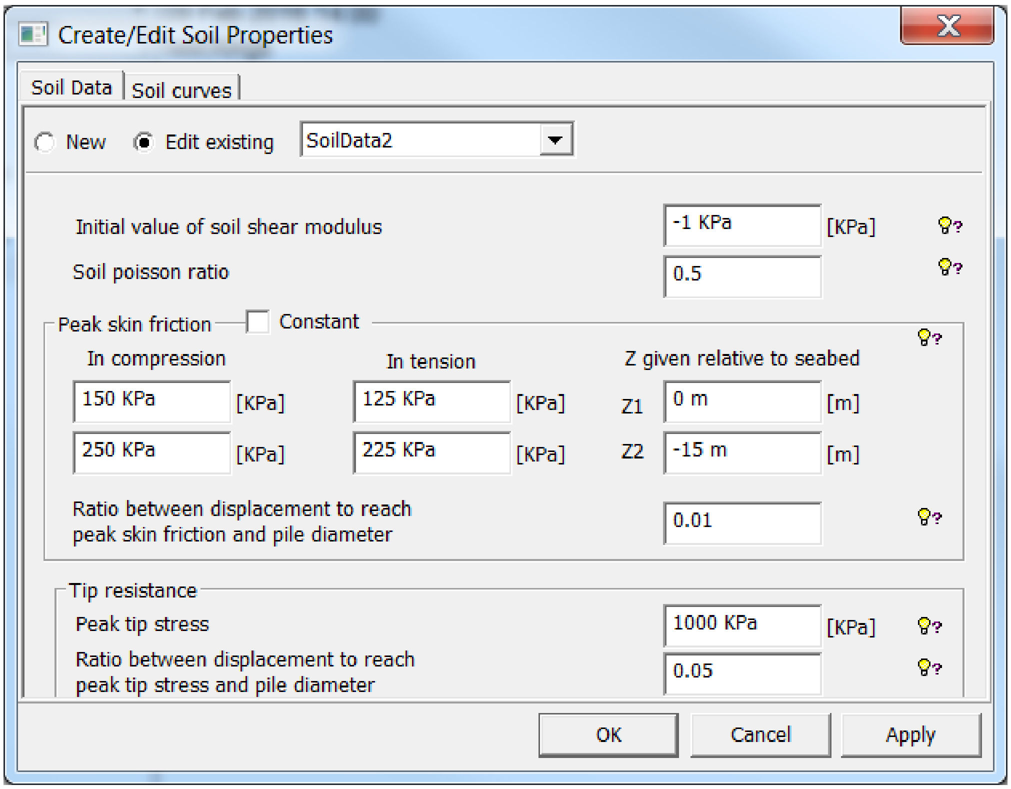
Dialog for creating soil data with constant skin friction

```
SoilData1 = SoilData(-1 KPa, 0.5, 15 KPa, 11 KPa, 0.01, 20 KPa,
0.05);
```

Linearly varying skin friction

The next figure shows the definition of a linearly varying peak skin friction, which is the default option of the dialog. Note that the Z-values are relative to the seabed and that the orientation of the Z-axis equals that of the global coordinate system in GeniE.

It is assumed that Z1 is greater than Z2.



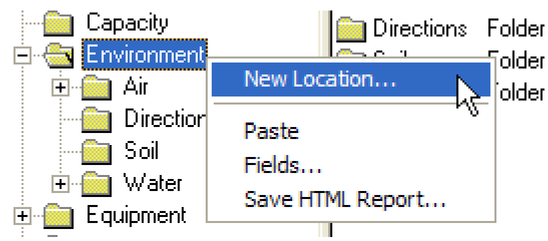
Dialog for creating soil data with linear varying skin friction

The above settings lead to the following js-command:

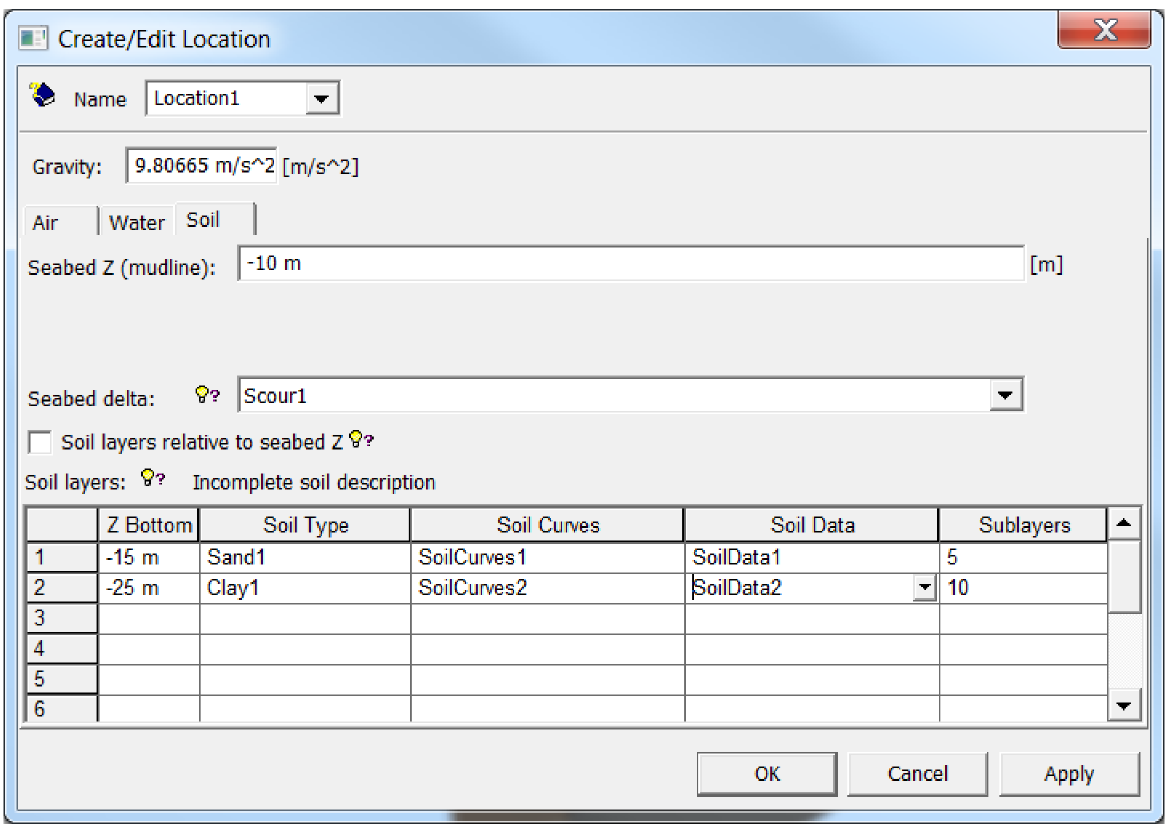
```
SoilData2 = SoilData(-1 KPa, 0.5, 150 KPa, 250 KPa, 125 KPa, 225
KPa, 0 m, -15 m, 0.01, 1000 KPa, 0.05);
```

Definition of the "Location"

Select the "New Location…" entry on the RMB menu, over the browser node "Environment".



The dialog below shows up. Here you can define the parameters for the *Air*, the *Water* and the *Soil* of the "Environment".



The 'Z Bottom' values, i.e. the Z-coordinate of each layer, are expressed with respect to the global coordinate system, or with respect to the seabed layer if the 'Soil layers relative to seabed Z' is checked. Inversely, by checking 'Soil layers relative to seabed Z' the existing values will automatically be transformed so as to be relative to the seabed Z.

Sublayers

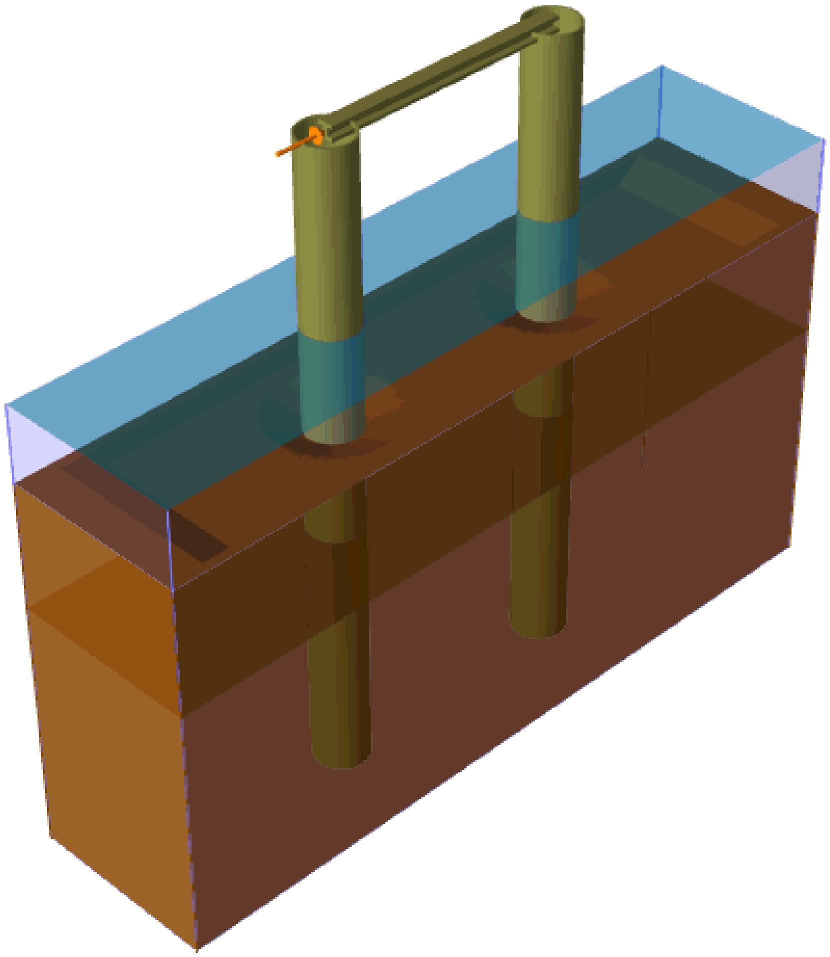
The sublayers row determine how many elements that will be used within each soil layer. The pile element height will be equal to the soil layer height divided by the number of sublayers. The method used in Splice to find the stiffness of a pile element embedded in soil is based on the assumption that the contact stresses (axial, torsional and lateral) between pile and soil vary linearly over the element length. For too long elements this may not be valid and this may make the pile-soil analysis fail to converge and or very poor accuracy of the results. Consult Splice User Manual Section 6.3.1 for further details. The following is recommended (L is element length and D is pile diameter):

- For clay L/D < 1.0
- For sand L/D < 0.7

Applying the settings shown in the above figure we get the following js-commands:

```
Location1 = Location(3 m, 0 m);
Location1.gravity = 9.80665 m/s^2;
Location1.air().density = 0.001226 tonne/m^3;
Location1.air().kinematicViscosity = 1.462e-005 m^2/s;
Location1.water().density = 1.025 tonne/m^3;
Location1.water().kinematicViscosity = 1.19e-006 m^2/s;
Location1.seabed().normaldirection = Vector3d(0 m,0 m,1 m);
Location1.seabed().seabedDelta = Scour1;
Location1.insertSoilBorder(-15 m);
Location1.insertSoilBorder(-25 m);
Location1.soil(1).soilCurves = SoilCurves1;
Location1.soil(1).soilData = SoilData1;
Location1.soil(1).soilType = Sand1;
Location1.soil(1).numberOfSublayers = 5;
Location1.soil(2).soilCurves = SoilCurves2;
Location1.soil(2).soilData = SoilData2;
Location1.soil(2).soilType = Clay1;
Location1.soil(2).numberOfSublayers = 10;
```

The result is shown in the next figure.



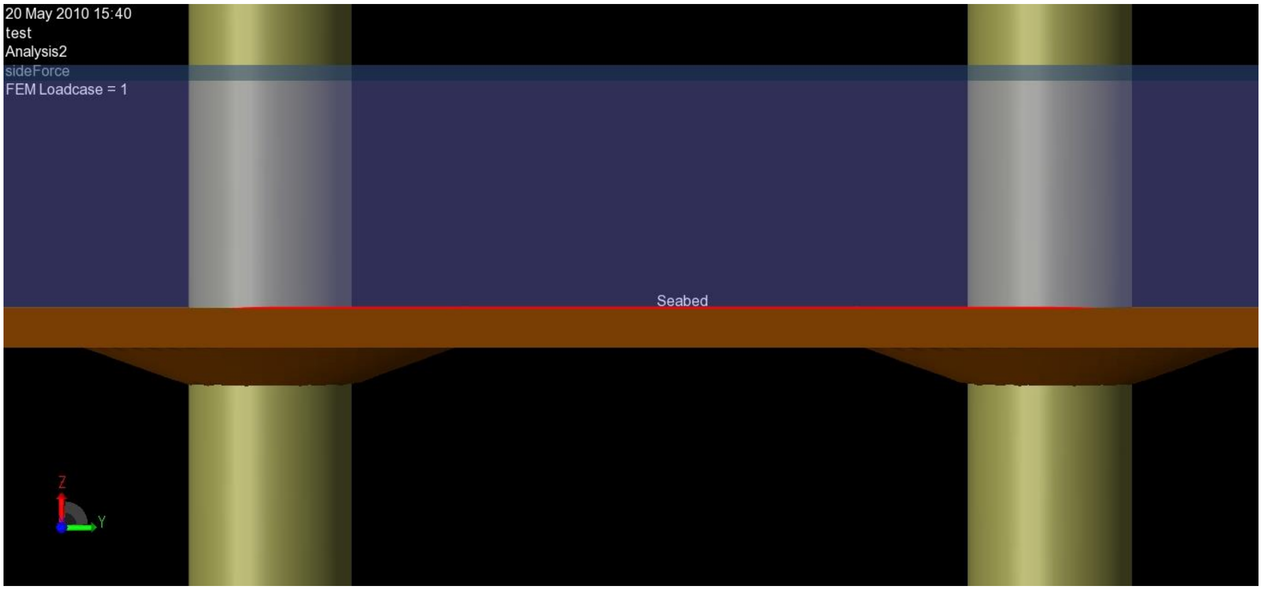
the water surface at z=3 m

the scour at z=0 m

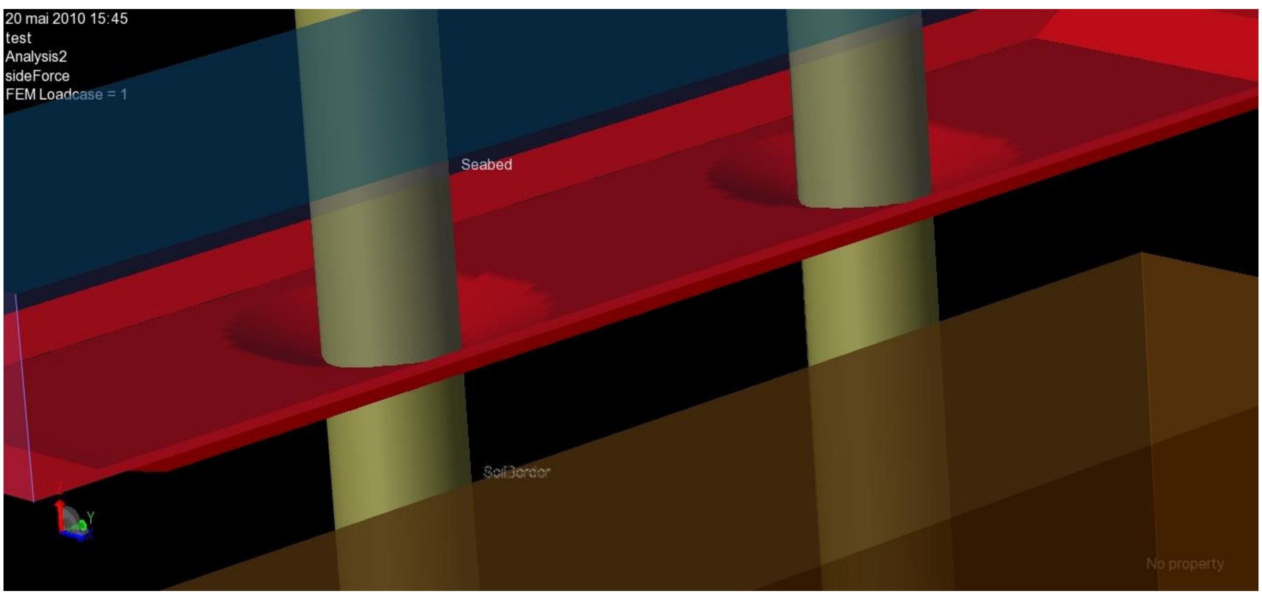
the layer Sand1,SoilCurves1,SoilData1 is From z=-10 m to z=-15 m and has 5 sublayers

the layer Clay1,SoilCurves2,SoilData2 is From z=-15 m to z=-25 m and has 10 sublayers

The following figures show exactly where the scour is with respect to the seabed and its 3D geometry.



The scour in the lateral view (viewed from X)



The scour in the isometric view

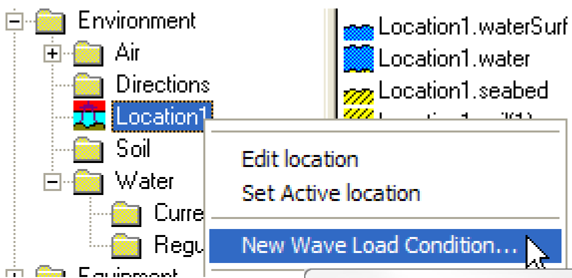
Definition of the “Condition”

A Condition must exist before a Pile Soil Analysis can be created. In this example a CalmSea Condition is created.

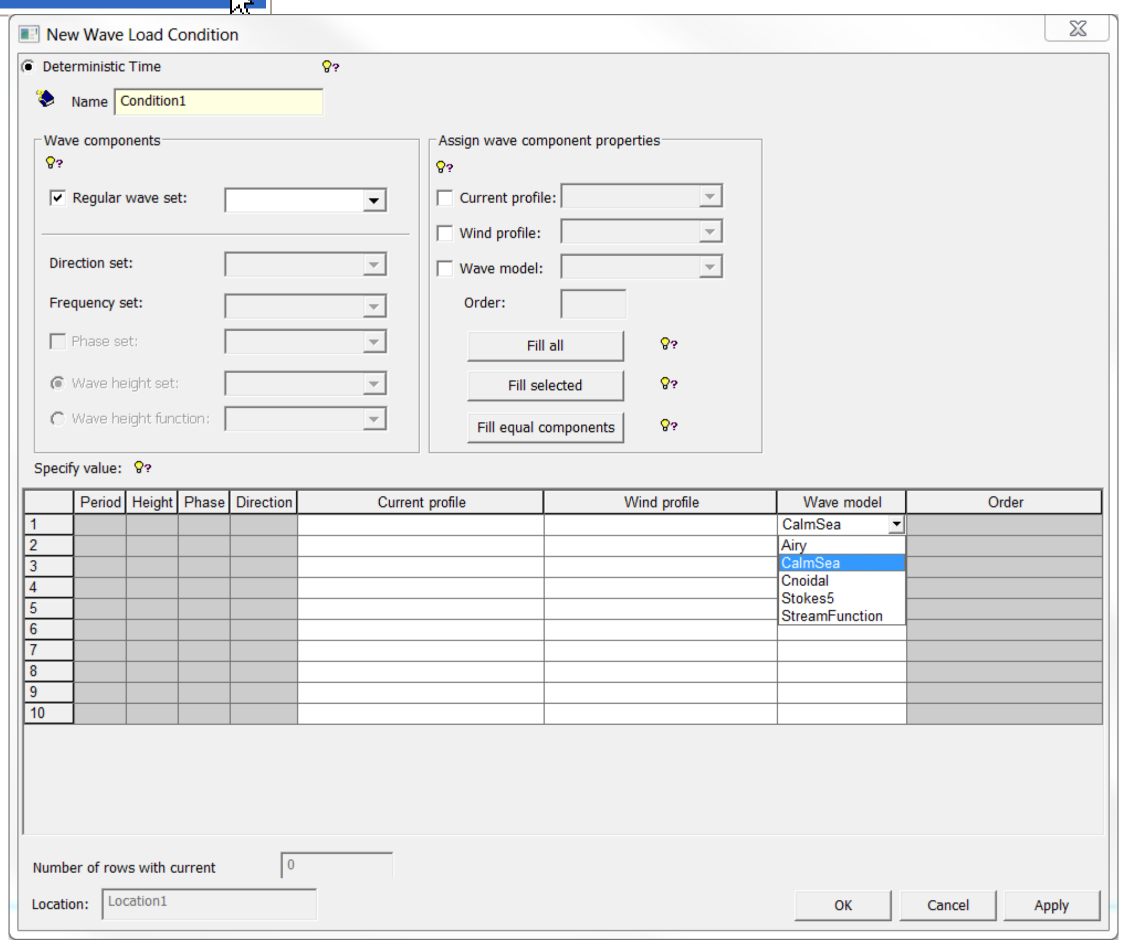
Select ‘New Wave Load Condition…’ to activate the dialog. When the dialog appears you must select ‘WaveSet1’ in the ‘Regular wave set’ combo box. The first row of the table is automatically filled in. Clear the first row by

- select the row (in the first column)
- press the Delete-button on the keyboard

Now you have an empty first row.



To define the Condition you must select ‘CalmSea’ in the ‘Wave model’ column and press ‘Apply’.



Creating the ‘CalmSea’ Condition

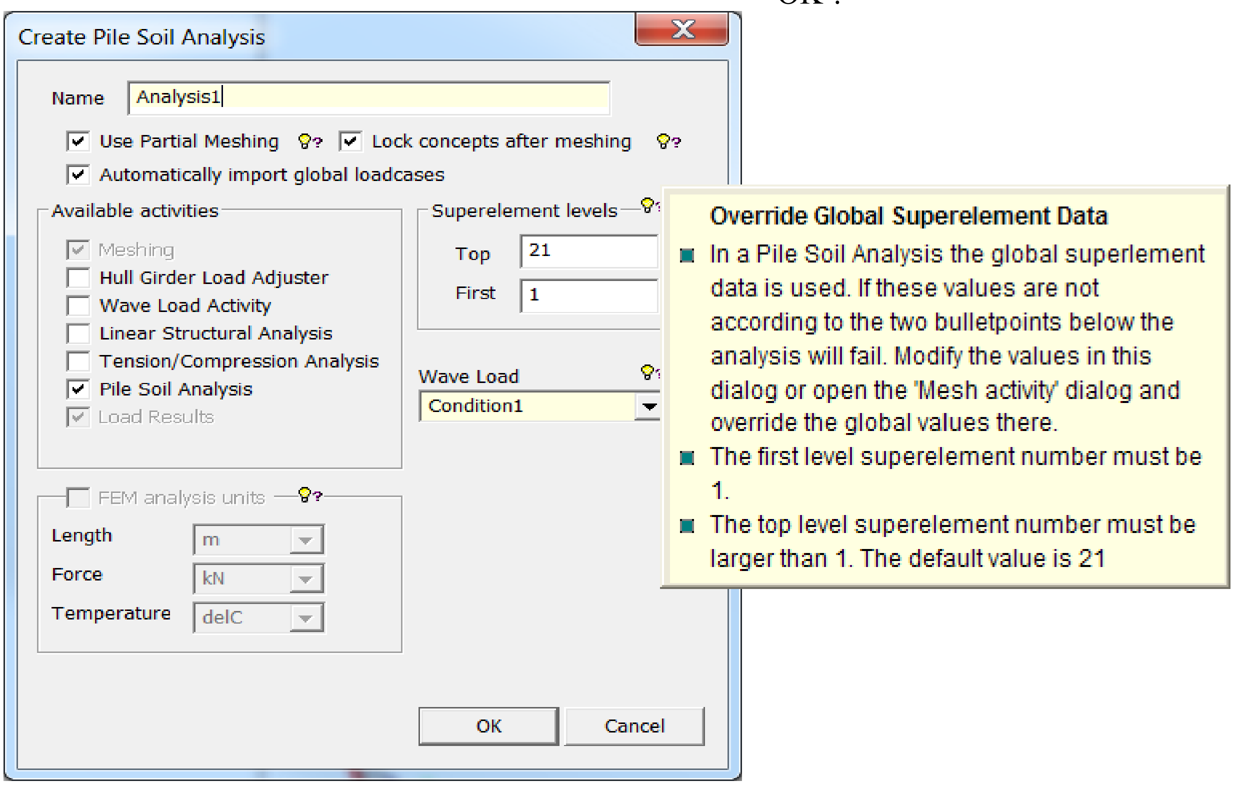
The above settings lead to the following js-commands:

```
Condition1 = DeterministicTime(Location1);
Condition1.addCalmSea();
```

Definition of the “Pile-Soil Analysis”

Select the “New Analysis…” entry on the RMB menu, over the browser node “Activities”.

The dialog for creating an Analysis appears and looks as in the next figure when ‘Pile Soil Analysis’ is checked. Select ‘Wave Load Condition’, check the ‘Superelement levels’ and press ‘OK’.



The dialog for creating the ‘Pile Soil Analysis’

Note the following:
- If the superelement numbers are not correct the analysis will not run.
- A wave load condition <u>must</u> be selected.

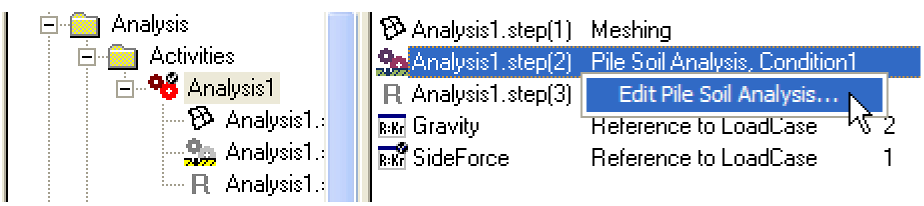
The above settings lead to the following js-command:

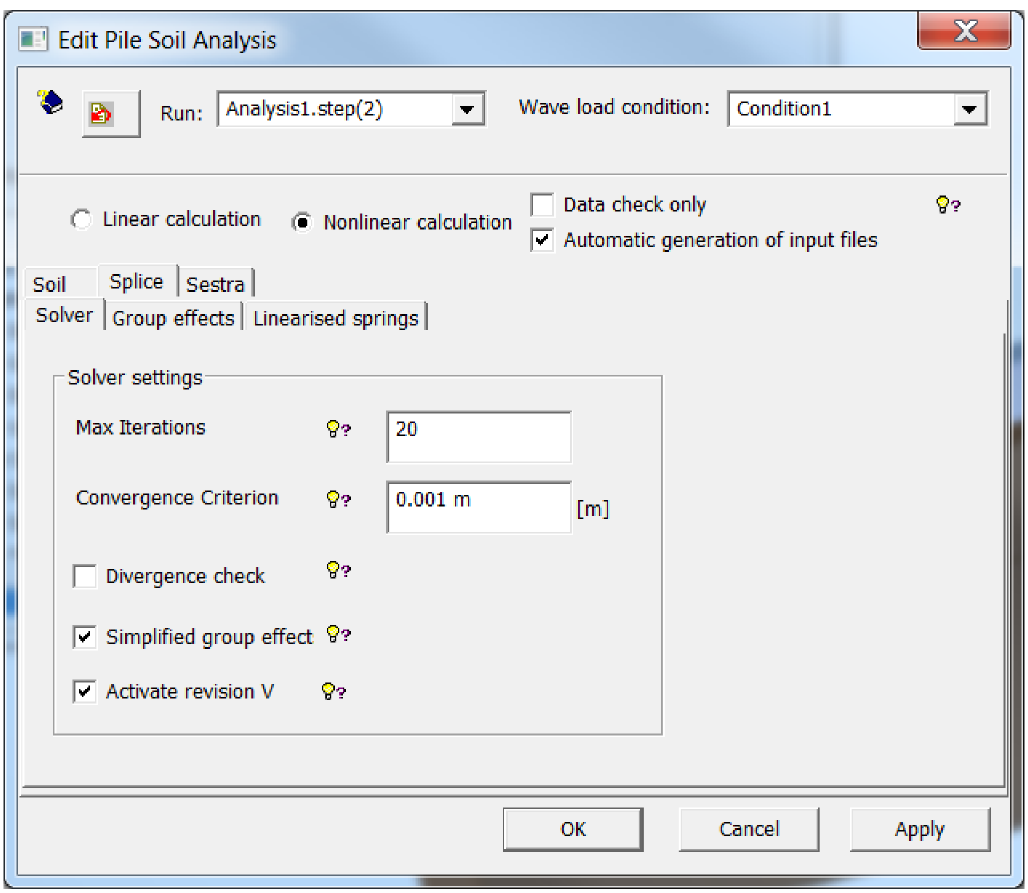
```
Analysis1 = Analysis(true);
```

```
Analysis1.add(MeshActivity());
Analysis1.step(1).superElementTypeTop = 21;
Analysis1.step(1).superElementType = 1;
Analysis1.add(PileSoilAnalysis(Condition1));
Analysis1.add(LoadResultsActivity());
```

Edit the Pile Soil Analysis

It may be necessary to modify some of the default settings of the Pile Soil Analysis. This is done in the ‘Edit Pile Soil Analysis’ dialog. Select ‘Edit Pile Soil Analysis…’ to activate the dialog.





The ‘Edit Pile Soil Analysis’ dialog

Only the solver tab will be described here, please consult user manual volume 2 for the other options. The options *Divergence check* and the *Simplified group effect* may stabilize and speed up the calculations

Divergence check
Option to activate/deactivate divergence check. The checkbox is unchecked by default.

Checkbox unchecked:
- No divergence check is performed.

Checkbox checked:
- Splice automatically checks if convergence is achieved. If after 3 iterations the solution does not improve, the iterations are stopped and splice will terminate for this loadcase.
- This means that Splice returns a solution even if the result does not converge.

Simplified group effects
Option to activate/deactivate simplified calculations of earth sliding due to group effects. Splice is instructed as to how pile/soil/pile interaction calculations shall be performed. The checkbox is checked by default.

Checkbox unchecked:
- This is the "normal" procedure. After each iteration the forces transmitted from each pile element to the soil are computed, and used at the start of next iteration to compute new incremental displacements of the soil volume surrounding all pile nodes.

Checkbox checked:
- For this case the system is first solved neglecting pile/soil/pile interaction by a number of iterations. When the convergence criterion has been satisfied, the forces transmitted from each pile element to the soil are computed. At the start of the next iteration the corresponding incremental soil displacements are computed. The iterations are then continued until the convergence criterion is again satisfied, or the maximum no of iterations has been reached, keeping the computed incremental soil displacement unchanged. This approach can be used to solve problems that tend to diverge, or simply to save computer time.

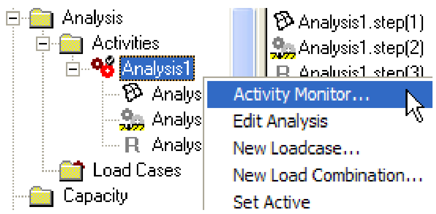
Revision V mode
Enabling revision V mode activates the latest features of Splice (requires Splice 7.2 or newer). When activated, Splice will create input files for revision V mode of Splice and Gensod. In revision V mode the following parameters are not needed:

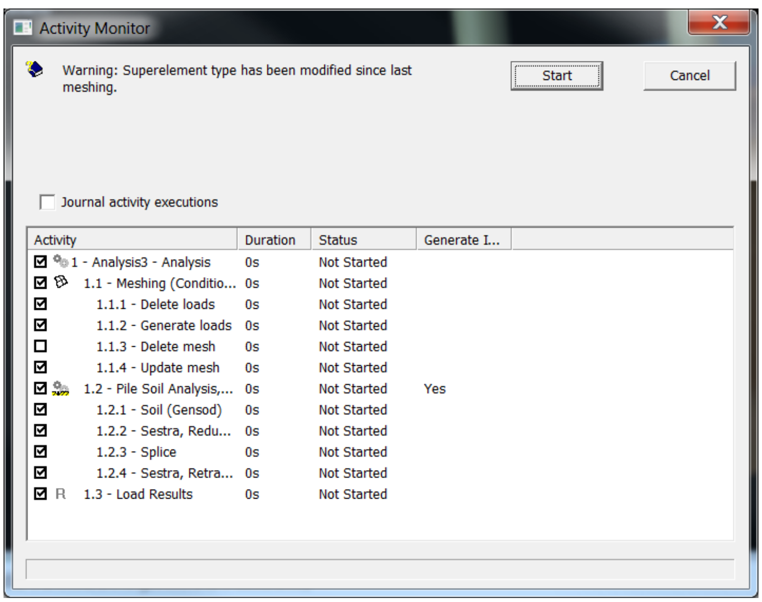
  - zone of influence ratio
  - soil poisson's ratio
  - curve shape factor
  - initial value of soil shear modulus,
  - over consolidation ratio
  - ratio between displacements to reach peak tip stress and pile diameter
  - t-z curve z displacement

These parameters can thus be set to 0 in the soil property dialogs described above, as they are calculated or set to reasonable values in Splice. Consult the release notes and user manuals for Splice 7.2 to get a full overview of the changes in revision V mode. Some of the new features of Splice revision V is currently not supported by GeniE, but requires manual modification of the Splice input files.

Executing the "Pile-Soil Analysis"

To execute the analysis select the "Activity Monitor…" entry on the RMB menu, over the relevant 'Analysis' browser node. The 'Activity Monitor' appears as shown below.



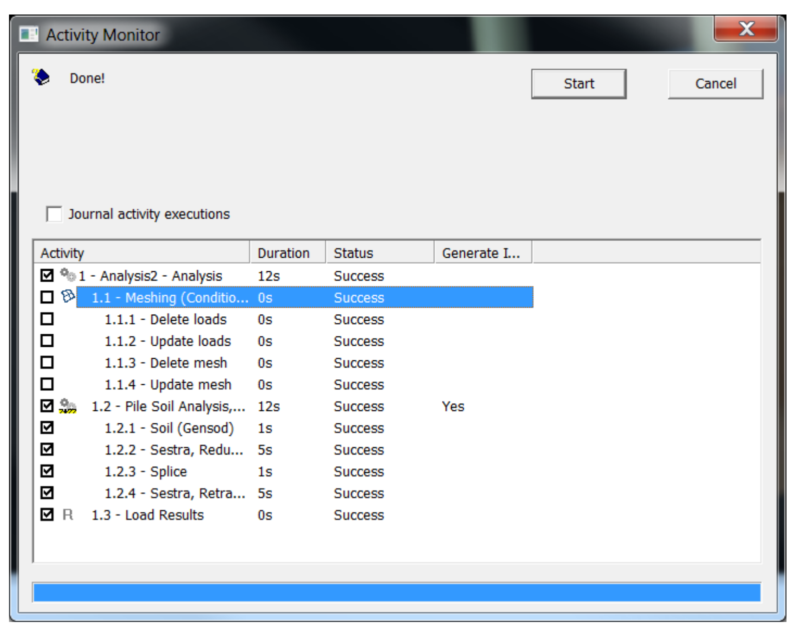


The Activity Monitor -before execution

For executing the analysis press 'Start'.

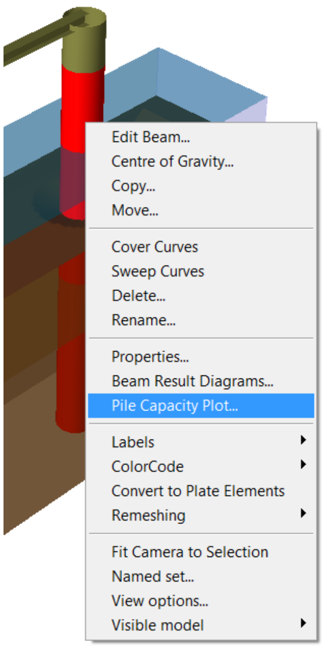
After execution has finished input to and/or output from many of the activities may be inspected by RMB on the activity. The figure shows the RMB menu of the Soil (Gensod) activity.

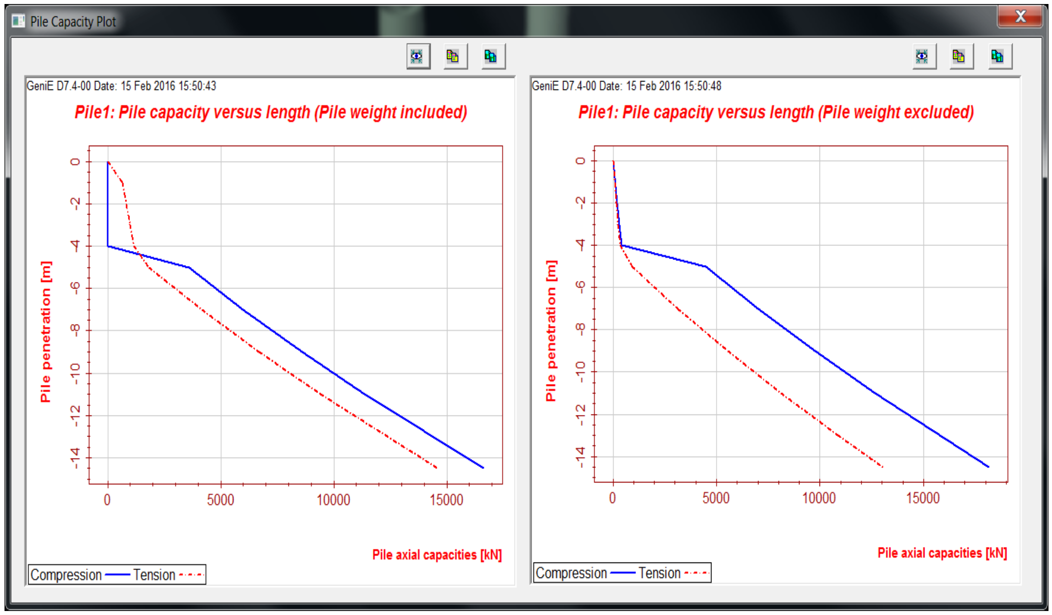
After execution - RMB on the Soil activity



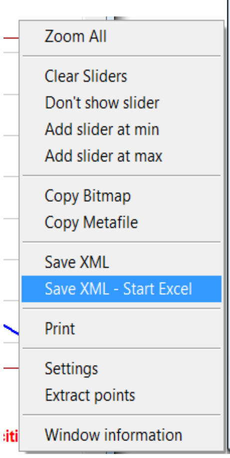
Pile Capacity Plot

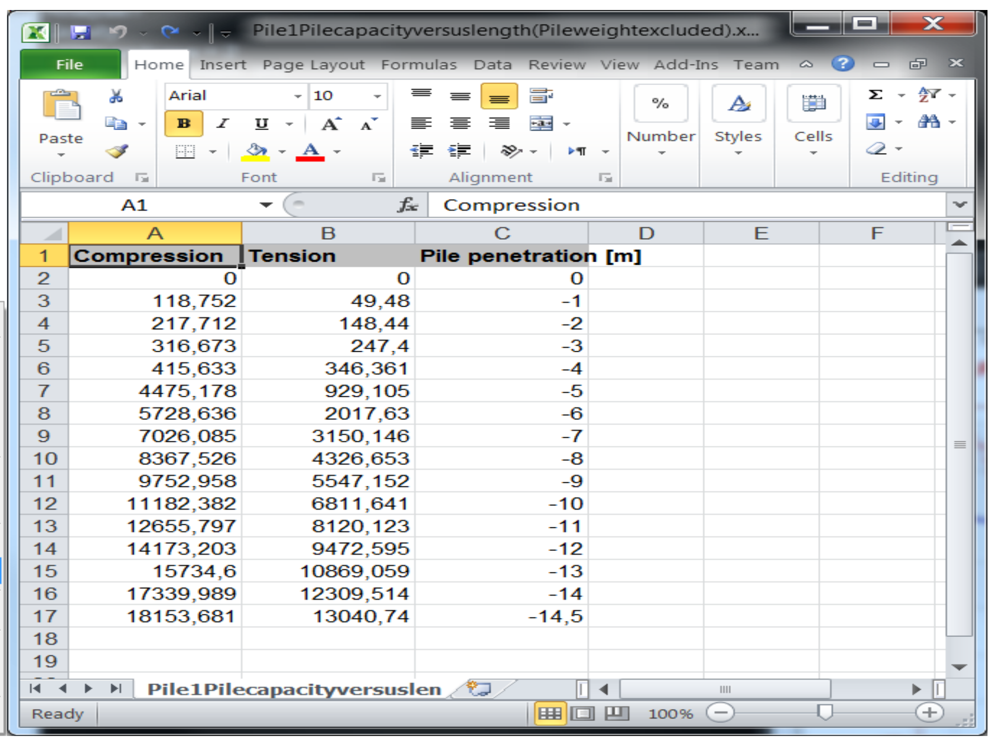
In order to verify soil data, a pile capacity curve may be used for comparison with the geotechnical report. In GeniE it is now possible to create such plots. This can be achieved by, right clicking the pile of interest and select Pile Capacity Plot:





The data may be opened in excel, by right clicking the graph:





	A	B	C
1	Compression	Tension	Pile penetration [m]
2	0	0	0
3	118,752	49,48	-1
4	217,712	148,44	-2
5	316,673	247,4	-3
6	415,633	346,361	-4
7	4475,178	929,105	-5
8	5728,636	2017,63	-6
9	7026,085	3150,146	-7
10	8367,526	4326,653	-8
11	9752,958	5547,152	-9
12	11182,382	6811,641	-10
13	12655,797	8120,123	-11
14	14173,203	9472,595	-12
15	15734,6	10869,059	-13
16	17339,989	12309,514	-14
17	18153,681	13040,74	-14,5

Appendix: The complete js command input file

```
//Units
GenieRules.Units.setDatabaseUnits("m", "kN", "delC");
GenieRules.Units.setInputUnit(Angle, "deg");
GenieRules.Units.setInputUnit(Force, "kN");
GenieRules.Units.setInputUnit(Length, "m");
GenieRules.Units.setInputUnit(TempDiff, "delC");

//***** PROPERTIES *****//
//Sections
I600 = ISection(0.6 m, 0.6 m, 0.15 m, 0.15 m);
Pipe21 = PipeSection(2.1 m, 0.08 m);

//Materials
Steel = MaterialLinear(255000000 Pa, 7.850 tonne/m^3, 2.1e+011 Pa, 0.3, 1.2e-005 delC^-1, 0.03
kN*s/m);

//Pile Characteristics
PileType1 = PileCharacteristics(1.000 tonne/m^3, tcFree);

//Seabed Deltas
Scour1 = Scour(0.5 m, 1 m, 20 deg);

//Soil Types
Clay1 = Clay(false, 1, 1.94 tonne/m^3, 0.01, 200 KPa, -10 m, 150 KPa, -25 m);
Clay1.apiJFactor = 0.5;

Sand1 = Sand(false, 1, 1.99 tonne/m^3, 20 deg);

//Soil Data and Soil Curves
SoilCurves1 = SoilCurves(pyManual, tzManual, qzManual);
SoilCurves1.addManualPY(2.1 m, Array(0 m, 0.02101 m, 0.04202 m, 0.06303 m, 0.08404 m, 0.105 m,
0.1261 m, 0.1471 m, 0.1681 m, 0.1891 m, 0.3 m), Array(0 KPa, 35.64 KPa, 61.51 KPa, 76.26 KPa,
83.52 KPa, 86.85 KPa, 88.32 KPa, 88.96 KPa, 89.23 KPa, 89.35 KPa, 89.44 KPa));
SoilCurves1.addManualTZ(2.1 m, Array(0 m, 0.005 m, 0.15 m), Array(0 KPa, 15 KPa, 15 KPa));
SoilCurves1.addManualQZ(2.1 m, Array(0 m, 0.0042 m, 0.0273 m, 0.0882 m, 0.1533 m, 0.21 m, 0.3 m),
Array(0 KPa, 5 KPa, 10 KPa, 15 KPa, 18 KPa, 20 KPa, 20 KPa));
SoilCurves2 = SoilCurves(pyManual, tzAPI1993, qzAPI1993);
SoilCurves2.addManualPY(2.1 m, Array(0 m, 0.0021 m, 0.0042 m, 0.0063 m, 0.01418 m, 0.02205 m,
0.02993 m, 0.0378 m, 0.0441 m, 0.1134 m, 0.3 m), Array(0 KPa, 409.9 KPa, 579.8 KPa, 710 KPa,
931.8 KPa, 1011 KPa, 1021 KPa, 985.3 KPa, 917 KPa, 160.8 KPa, 160.8 KPa));
SoilCurves2.addManualTZ(2.1 m, Array(0 m, 0.00336 m, 0.00651 m, 0.01197 m, 0.0168 m, 0.021 m,
0.15 m), Array(0 KPa, 65 KPa, 108.3 KPa, 162.5 KPa, 195 KPa, 216.7 KPa, 216.7 KPa));
SoilCurves2.addManualQZ(2.1 m, Array(0 m, 0.0042 m, 0.0273 m, 0.0882 m, 0.1533 m, 0.21 m, 0.3 m),
Array(0 KPa, 250 KPa, 500 KPa, 750 KPa, 900 KPa, 1000 KPa, 1000 KPa));
SoilData1 = SoilData(-1 KPa, 0.5, 15 KPa, 11 KPa, 0.01, 20 KPa, 0.05);
SoilData2 = SoilData(-1 KPa, 0.5, 150 KPa, 250 KPa, 125 KPa, 225 KPa, 0 m, -15 m, 0.01, 1000 KPa,
0.05);

//***** RULES *****//
//Compatibility Rules
GenieRules.Compatibility.version = "D7.3-0";
GenieRules.Compatibility.enable(SetDefaultNames, true);
GenieRules.Compatibility.enable(CaseInsensitiveFunctions, true);
GenieRules.Compatibility.enable(JournalledDefaultPrefix, true);
GenieRules.Compatibility.enable(SimplifyTopologyEnhancedVertexRemoval, true);
GenieRules.Compatibility.enable(PlateSnapping, true);
GenieRules.Compatibility.enable(PlateSortingCOGFirst, true);
GenieRules.Compatibility.enable(CurveSnapping, true);
GenieRules.Compatibility.enable(DefaultLongFemNames, true);
GenieRules.Compatibility.enable(DefaultEccentricHinghes, true);
GenieRules.Compatibility.enable(AutomaticallySaveModelAfterAnalysis, false);
GenieRules.Compatibility.enable(ValidateTransforms, true);
GenieRules.Compatibility.enable(CheckPlatesForErrorsDuringCreation, true);
GenieRules.Compatibility.enable(UseTopologySimplificationVersion7, true);

//Connected Move Rules
```

```
GenieRules.ConnectedMove.useStructuralPoints = false;
GenieRules.ConnectedMove.defaultConnected = false;
GenieRules.ConnectedMove.rearrangeXJoints = false;

//Geometry Rules
GenieRules.Geometry.beamTopologySnapping = true;
GenieRules.Geometry.guideCurveTopologySnapping = true;
GenieRules.Geometry.creationGrouping = cgGroupingOff;

//Joint Creation Rules
GenieRules.JointCreation.autoGenerate = false;
GenieRules.JointCreation.selectionAware = false;
GenieRules.JointCreation.exclude(geFreeThroughBeams, true);
GenieRules.JointCreation.exclude(geThroughBeamPure, true);
GenieRules.JointCreation.exclude(geThroughBeams, false);
GenieRules.JointCreation.exclude(geFreeBeamEnds, true);
GenieRules.JointCreation.exclude(ge2BeamAligned, true);
GenieRules.JointCreation.exclude(geBeamEnds, false);

//JointDesign Rules
GenieRules.JointDesign.setDefaultCanRule(0.25, 0.3 m);
GenieRules.JointDesign.setDefaultStubRule(1, 0.6 m);
GenieRules.JointDesign.coneAngle = 9.462322208 deg;
GenieRules.JointDesign.minimumGap = 0.0508 m;
GenieRules.JointDesign.gapTolerance = 0.001 m;
GenieRules.JointDesign.planeTolerance = 1 deg;
GenieRules.JointDesign.braceAngleMoveLimit = 10 deg;
GenieRules.JointDesign.chordAlignmentTolerance = 5 deg;
GenieRules.JointDesign.flushBraces = false;
GenieRules.JointDesign.iterations = 2;

//Local Joint Flexibility (LJF) Rules
GenieRules.LJF.method = ljfBuitrago1993;
GenieRules.LJF.setLimit(ljfAxial, 0.1, 5);
GenieRules.LJF.setLimit(ljfIPB, 0.1, 5);
GenieRules.LJF.setLimit(ljfOPB, 0.1, 5);

//Meshing rules
GenieRules.Meshing.elementType = mp1stOrder;
GenieRules.Meshing.superElementType = 1;
GenieRules.Meshing.autoSimplifyTopology = true;
GenieRules.Meshing.autoSplitPeriodicGeometry = false;
GenieRules.Meshing.repairSplitTopology = false;
GenieRules.Meshing.preference(mpPreferRectangularMesh, false);
GenieRules.Meshing.preference(mpAllowTriangularElements, true);
GenieRules.Meshing.preference(mpPreferPointMassAsNodeMass, true);
GenieRules.Meshing.preference(mpUseDrillingElements, false);
GenieRules.Meshing.preference(mpUseEccentricHinges, true);
GenieRules.Meshing.eliminateInternalEdges = true;
GenieRules.Meshing.eliminateInternalVertices = true;
GenieRules.Meshing.preference(mpIncludeUnusedProperties, false);
GenieRules.Meshing.preference(mpUseLongLoadcaseNames, true);
GenieRules.Meshing.preference(mpUseLongSetNames, true);
GenieRules.Meshing.preference(mpUseLongPropertyNames, true);
GenieRules.Meshing.preference(mpMeshDensityRounded, false);
GenieRules.Meshing.scantlings = msGross;
GenieRules.Meshing.ignoreEccentricities = false;
GenieRules.Meshing.useCocentricBeams = false;
GenieRules.Meshing.faceMeshStrategy = SesamQuadMesher;
GenieRules.Meshing.edgeMeshStrategy = UniformDistributionEdge;
GenieRules.Meshing.activate(mpMaxAngle, mpFail, true);
GenieRules.Meshing.setLimit(mpMaxAngle, mpFail, 179 deg);
GenieRules.Meshing.activate(mpMaxAngle, mpSplit, false);
GenieRules.Meshing.setLimit(mpMaxAngle, mpSplit, 165 deg);
GenieRules.Meshing.activate(mpMinAngle, mpFail, false);
GenieRules.Meshing.setLimit(mpMinAngle, mpFail, 1 deg);
GenieRules.Meshing.activate(mpMinAngle, mpSplit, false);
GenieRules.Meshing.setLimit(mpMinAngle, mpSplit, 15 deg);
GenieRules.Meshing.activate(mpMaxRelativeJacobi, mpFail, false);
GenieRules.Meshing.setLimit(mpMaxRelativeJacobi, mpFail, 10);
```

```
GenieRules.Meshing.activate(mpMaxRelativeJacobi, mpSplit, false);
GenieRules.Meshing.setLimit(mpMaxRelativeJacobi, mpSplit, 5);
GenieRules.Meshing.activate(mpMinNormalizedJacobi, mpFail, false);
GenieRules.Meshing.setLimit(mpMinNormalizedJacobi, mpFail, 0);
GenieRules.Meshing.activate(mpMinNormalizedJacobi, mpSplit, false);
GenieRules.Meshing.setLimit(mpMinNormalizedJacobi, mpSplit, 0.2);
GenieRules.Meshing.activate(mpMinEdge, false);
GenieRules.Meshing.setLimit(mpMinEdge, 0.1);
GenieRules.Meshing.activate(mpMaxChord, false);
GenieRules.Meshing.setLimit(mpMaxChord, 0.2);
GenieRules.Meshing.activate(mpMaxTwistAngle, mpFail, false);
GenieRules.Meshing.setLimit(mpMaxTwistAngle, mpFail, 30 deg);
GenieRules.Meshing.activate(mpMaxTwistAngle, mpSplit, false);
GenieRules.Meshing.setLimit(mpMaxTwistAngle, mpSplit, 10 deg);
GenieRules.Meshing.activate(mpMinMaxDensityRatio, false);
GenieRules.Meshing.setLimit(mpMinMaxDensityRatio, 0.1);
GenieRules.Meshing.basicLCfactor = 1;
GenieRules.Meshing.analysisFolders = true;
GenieRules.Meshing.preference(mpAdjustNumberOfElements, true);
GenieRules.Meshing.useUniformizedFaceParameterization = false;
GenieRules.Meshing.longitudinalMassOnNonStructuralElements = true;

//Tolerances Rules
GenieRules.Tolerances.angleTolerance = 2 deg;
GenieRules.Tolerances.pointTolerance = 0.01 m;
GenieRules.Tolerances.useTolerantModelling = true;

//Set Rules
GenieRules.Sets.scriptCompact = true;

//Beam Creation Rules

//Beam Creation Rules
GenieRules.Transformation.CopyTransformerMethod = tmUseModelTransformer;
//***** STRUCTURE *****//
//Beams
Steel.setDefault();
I600.setDefault();
Bm1 = Beam(Point(0 m,0 m,0 m), Point(0 m,10 m,0 m));

Pipe21.setDefault();
Bm2 = Beam(Point(0 m,0 m,0 m), Point(0 m,0 m,-2.5 m));
Bm3 = Beam(Point(0 m,10 m,0 m), Point(0 m,10 m,-2.5 m));
Pile1 = Pile(Point(0 m,0 m,-2.5 m), Point(0 m,0 m,-25 m));
Pile1.pileCharacteristics = PileType1;
Pile2 = Pile(Point(0 m,10 m,-2.5 m), Point(0 m,10 m,-25 m));
Pile2.pileCharacteristics = PileType1;


//***** GUIDING GEOMETRY *****//
//***** ENVIRONMENT *****//
Location1 = Location(-7 m, -10 m);
Location1.gravity = 9.80665 m/s^2;
Location1.air().density = 0.001226 tonne/m^3;
Location1.air().kinematicViscosity = 1.462e-005 m^2/s;
Location1.water().density = 1.025 tonne/m^3;
Location1.water().kinematicViscosity = 1.19e-006 m^2/s;
Location1.seabed().normaldirection = Vector3d(0 m,0 m,1 m);
Location1.seabed().seabedDelta = Scour1;
Location1.insertSoilBorder(-15 m);
Location1.insertSoilBorder(-25 m);
Location1.soil(1).soilCurves = SoilCurves1;
Location1.soil(1).soilData = SoilData1;
Location1.soil(1).soilType = Sand1;
Location1.soil(1).numberOfSublayers = 5;
Location1.soil(2).soilCurves = SoilCurves2;
Location1.soil(2).soilData = SoilData2;
Location1.soil(2).soilType = Clay1;
Location1.soil(2).numberOfSublayers = 10;
```

```
//Conditions
Condition1 = DeterministicTime(Location1);
Condition1.water().setNoCurrent();
Condition1.populate();
Condition1.addCalmSea();
Condition1.component(1).water().setNoCurrent();//***** EQUIPMENTS *****//
//***** SETS ( Create ) *****//
//***** LOAD MODELLING AND ANALYSIS *****//
SideForce = LoadCase();
SideForce.setFemLoadcase(1);
SideForce.designCondition(lcOperating);
Gravity = LoadCase();
Gravity.setFemLoadcase(2);
Gravity.designCondition(lcOperating);
SideForce.meshLoadsAsMass(false);
//  Loads
PLoad1 = PointLoad(SideForce, Point(0 m,0 m,0 m), 0 kN, 100 kN, 0 kN, 0 kN*m, 0 kN*m, 0 kN*m);

SideForce.excludeSelfWeight();
SideForce.includeStructureMassWithRotationField();

Gravity.includeSelfWeight();
Gravity.includeStructureMassWithRotationField();
Gravity.meshLoadsAsMass(false);
//Analyses
Analysis1 = Analysis(true);
Analysis1.add(MeshActivity());
Analysis1.step(1).beamsAsMembers = true;
Analysis1.step(1).smartLoadCombinations = true;
Analysis1.step(1).includeLoadsOnMesh = true;
Analysis1.step(1).usePartialMesher = true;
Analysis1.step(1).lockMeshedConcepts = true;
Analysis1.step(1).pileBoundaryCondition = pmPileSoilInteraction;
Analysis1.step(1).superElementTypeTop = 21;
Analysis1.step(1).superElementType = 1;
Analysis1.step(1).nodeNumberFromJointName = false;
Analysis1.step(1).elementNumberFromBeamName = false;
Analysis1.step(1).regenerateMeshOption = anAlwaysRegenerateMesh;
Analysis1.add(PileSoilAnalysis(Condition1));
Analysis1.step(2).soil.materialCoeffs.tanPhiCoeff = 1;
Analysis1.step(2).soil.materialCoeffs.shearStrengthCoeff = 1;
Analysis1.step(2).soil.materialCoeffs.skinFrictionCoeff = 1;
Analysis1.step(2).soil.materialCoeffs.pileTipResistanceCoeff = 1;
Analysis1.step(2).soil.curveGeneration.lowestShearStiff = 100 KPa;
Analysis1.step(2).soil.curveGeneration.lowestLevelWithCyclicPY = 0 m;
Analysis1.step(2).soil.curveGeneration.zoneOfInfluenceTZ = 10;
Analysis1.step(2).soil.curveGeneration.curveShapeFactorTZ = 0.9;
Analysis1.step(2).soil.groupEffects.averagePoissonRatio = 0.5;
Analysis1.step(2).soil.groupEffects.modulusOfElasticity(10000 KPa, 0 m, 10000 KPa, -100 m);
Analysis1.step(2).soil.loadsAtSurface.verticalStressAtSurface = 0 KPa;
Analysis1.step(2).soil.loadsAtSurface.verticalStressUnderEmbankment = 0 KPa;
Analysis1.step(2).soil.loadsAtSurface.widthOfEmbankmentSlopingPart = 0 m;
Analysis1.step(2).soil.loadsAtSurface.distancePileToEmbankmentToe = 0 m;
Analysis1.step(2).soil.loadsAtSurface.verticalStressUnderCircularLoadedArea = 0 KPa;
Analysis1.step(2).soil.loadsAtSurface.radiusOfCircularLoadedArea = 0 m;
Analysis1.step(2).splice.solver.maxIterations = 20;
Analysis1.step(2).splice.solver.convergenceCriterion = 0.001 m;
Analysis1.step(2).splice.solver.divergenceCheck = false;
Analysis1.step(2).splice.solver.simplifiedGroupEffects = true;
Analysis1.step(2).splice.solver.revisionV = true;
Analysis1.step(2).splice.groupEffects.interactionCode = anOff;
Analysis1.step(2).splice.groupEffects.interactionDistance = 0 m;
Analysis1.step(2).splice.linearisedSprings.computeLinearisedSprings = false;
Analysis1.step(2).sestra.warpCorrection = true;
Analysis1.step(2).sestra.continueOnError = false;
Analysis1.add(LoadResultsActivity());
```