GMS 7.0 TUTORIALS

UTEXAS – Underwater Slope

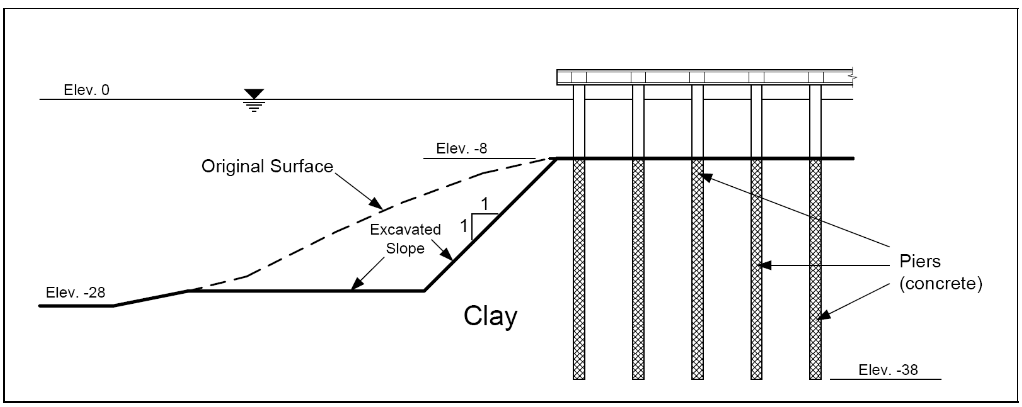

Figure 1. Underwater Slope Excavation Problem.

1 Introduction

This tutorial illustrates how to build a UTEXAS model in GMS that uses a slope geometry line. This tutorial is similar to tutorial number eight in the UTEXAS tutorial manual ("UTEXPREP4 Preprocessor For UTEXAS4 Slope Stability Software" by Stephen G. Wright, Shinoak Software, Austin Texas, 2003.).

The problem is illustrated in Figure 1. A dock supported by concrete piers is being built on an underwater slope. The slope will then be excavated below the original surface as shown in the figure. The slope will be modeled using two different approaches. First, we will use line loads on the top of the slope to represent the weight of the dock structure on the slope. Then we will add reinforcement lines representing the concrete piers to determine the impact they have on the stability of the slope.

The *UTEXAS – Embankment on Soft Clay* tutorial explains more about UTEXAS and provides a good introduction. You may wish to complete it before beginning this tutorial.

You should also be familiar with feature objects and have completed the *Feature Objects* tutorial.

1.1 Contents

1.2 Outline

In this tutorial, we'll be examining the underwater slope problem illustrated in Figure 1. This is what you will do:

1. Create the basic slope profile.
2. Define material properties.
3. Create the slope geometry line.
4. Create the distributed loads and line loads.
5. Set up the analysis options.
6. Save the model, run UTEXAS4 to get a solution, and view the solution in GMS.
7. Add reinforcement lines to the model.
8. Save the model, run UTEXAS4 to get a solution, and view the solution in GMS.

1.3 Required Modules/Interfaces

You will need the following components enabled to complete this tutorial:

- Map
- UTEXAS

You can see if these components are enabled by selecting the *File* | *Register*.

2 Getting Started

Let's get started.

1. If necessary, launch GMS. If GMS is already running, select the *File* | *New* command to ensure that the program settings are restored to their default state.

3 Create the Slope

We will first create a UTEXAS conceptual model and create the feature objects defining the slope geometry.

3.1 Create the Conceptual Model

To create a new conceptual model:

1. Right-click in the *Project Explorer* and select the *New* | *Conceptual Model* menu command.

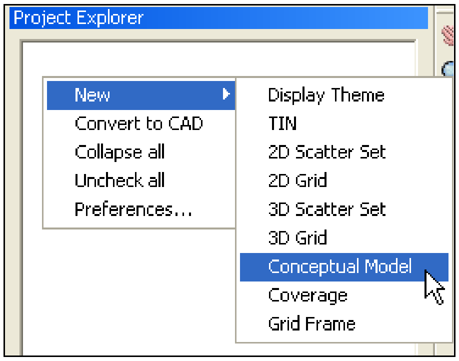

Figure 2. Creating a New Conceptual Model.

2. In the *Conceptual Model Properties* dialog, change the *Name* to **Underwater Slope**.
3. Change the *Type* to **SEEP2D / UTEXAS**.
4. Turn **off** *SEEP2D*
5. Make sure *UTEXAS* is turned **on**.
6. Click *OK* to exit the dialog.

3.2 Create the Main Coverage

Now we'll create a coverage that will include the main soil profile.

1. In the *Project Explorer,* right-click on the *Underwater Slope* conceptual model you just created and select the *New Coverage* command from the pop-up menu.
2. In the *Coverage Setup* dialog, change the *Coverage Name* to **profile.**
3. Click *OK* to exit the dialog.

3.3 Create the Points

Next we will enter points defining the profile geometry:

1. In the *Project Explorer*, right-click on the **profile** coverage and select the *Attribute Table* command from the pop-up menu. This brings up the *Properties* dialog.
2. Make sure the *Feature type* is **Points**.

3. Make sure the *Show point coordinates* option is turned **on**.

4. Enter the X and Y coordinates shown in the table below. If you are viewing this tutorial electronically, you can copy and paste these values into the GMS spreadsheet.

X	Y
0	-28
10	-28
20	-26
28	-24
40	-18
49	-14
60	-10
69	-8
110	-8
0	-40
110	-40

5. Click *OK* to exit the dialog.

6. Click the *Frame* button to frame the image.

You should now see the eleven points defining the outline of the slope.

3.4 Connect the Points to Create Arcs

1. Select the *Create Arcs* tool.

2. Hold down the *Shift* key. This makes it so that you can create multiple arcs continuously without having to stop and restart at each point. Double-click whenever you want to stop creating arcs.

3. Using Figure 3 (below) as a guide, click on the points to connect them with arcs to create the slope. It doesn't matter what point you start at or which direction you go.

4. Select the *Feature Objects | Build Polygons* menu command.

At this point you should see something like Figure 3 below.

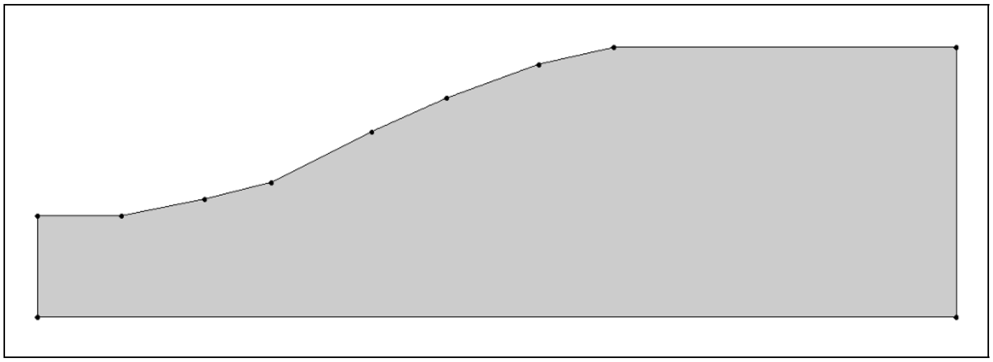

Figure 3. The Underwater Slope Before Excavation.

4 Save the GMS Project File

Before continuing, we will save what we have done so far to a GMS project file:

1. Select the *Save* button. This brings up the *Save As* dialog.
2. Locate and open the directory entitled **tutfiles\UTEXAS\underwater**
3. Enter a name for the project file (ex. "**embank-utexas.gpr**") and select the *Save* button.

You may wish to select the *Save* button occasionally to save your work as you continue with the tutorial.

5 Material Properties

The next step is to define the properties associated with the soil material. We will model the shear strength of the clay using the linear strength method, which is similar to a c/p approach. We will enter an initial undrained strength of 100 lb/ft^2 for the ground surface and a rate of change defining the increase in shear strength vs. depth (10 lb/ft^2/ft).

1. Select the *Edit* | *Materials* menu command.
2. Click on the material named "material_1" and rename it **Clay**.
3. Click on the *Color / Pattern* button and change the color to **orange** or some other attractive color.
4. Change the material properties to those shown in the following table:

Unit Weight Stage 1	Shear Strength Method Stage 1	Linear Increase Strength Stage 1	Linear Increase Rate Stage 1
100	Linear	100	10

5. Make sure the *Pore Water Pressure Method Stage 1* is set to **No Pore Pressure**. You may have to scroll the spreadsheet to the right to see this column.

6. Click *OK* to exit the dialog.

6 Create the Piezometric Line

The next step is to create a piezometric line. Since this is a total stress analysis, UTEXAS does not use the piezometric line to compute pore pressures. However, it does use the line to compute the total stresses. We will put the piezometric line in its own coverage. This is usually a good idea since the piezometric line often crosses the arcs that form the rest of the model. In this case the piezometric line is entirely above the model and does not cross any other arcs so we could include it in the *profile* coverage, but we'll put it in its own coverage anyway.

6.1 Create a New Coverage

To create the new coverage:

1. In the *Project Explorer,* right-click on the *Underwater Slope* conceptual model and select the *New Coverage* command from the pop-up menu.

2. In the *Coverage Setup* dialog, change the *Coverage Name* to **piezometric line**

3. Turn **on** the *Piezometric Line* option.

4. Click *OK* to exit the dialog.

6.2 Create the Arc

1. Select the *Create Arcs* tool.

2. Create a new arc above the model, as shown in Figure 4 below. Don't worry about the exact location of the arc as we'll reposition it in the next steps.

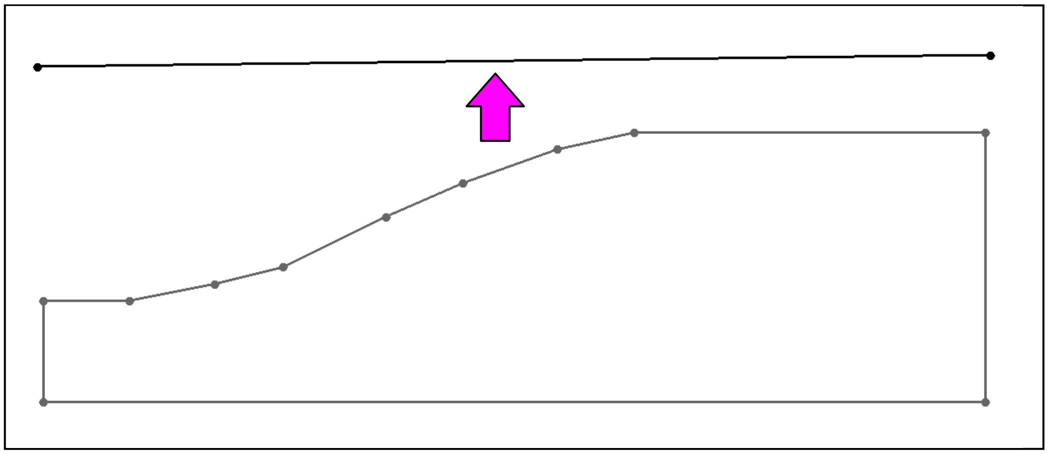

Figure 4. The Initial Piezometric Line.

3. Switch to the *Select* tool .
4. Select the node on the left of the new arc you just created.
5. In the *GMS Edit Window*, change the XYZ coordinates to (**0, 0, 0**).
6. Similarly, select the node on the right side of the new arc and change it's coordinates to (**110, 0, 0**).

6.3 Set the Arc Type

1. With the *Select* tool still active, double-click on the arc.
2. Change the *Type* to **piezometric line**.
3. Click *OK* to exit the dialog.

7 Create the Slope Geometry

This model uses a slope geometry arc in addition to the other arcs to define the model geometry. A slope geometry arc is typically used when modeling a "cut" or excavation into an existing slope. The soil layers are modeled with one set of lines and the cut line is overlaid on top defining the new slope geometry. This approach makes it possible to define a slope using the original, unexcavated geometry and then test the impact of various excavations without having to change all of the profiles associated with the slope. Only the slope geometry line needs to be altered. Because the slope geometry line lies on top of the other model arcs, we will put it in a separate coverage.

7.1 Create a New Coverage

To create the coverage:

1. In the *Project Explorer,* right-click on the *Underwater Slope* conceptual model and select the *New Coverage* command from the pop-up menu.

2. In the *Coverage Setup* dialog, change the *Coverage Name* to **slope geometry.**

3. Turn **on** the *Slope Geometry* option.

4. Click *OK* to exit the dialog.

7.2 Create the Points

To enter the points defining the excavation:

1. Right-click on the new *slope geometry* coverage and select the *Attribute Table* command from the pop-up menu.

2. In the dialog, make sure the *Feature type* is set to **Points**.

3. Make sure the *Show point coordinates* option is turned **on**.

4. Enter the X and Y coordinates shown in the table below. If you are viewing this tutorial electronically, you can copy and paste these values into the GMS spreadsheet.

X	Y
0	-28
10	-28
20	-26
52	-26
70	-8
110	-8

5. Click *OK* to exit the dialog.

You should see the new points. Some might be obscured by the inactive coverages. We'll fix that.

6. In the *Project Explorer*, turn off the *Profile* and *piezometric line* coverages.

7.3 Create the Arc

Next, we will connect the points to create the arc.

1. Select the *Create Arcs* tool.

2. Hold down the *Shift* key. This makes it so that you can create multiple arcs continuously without having to stop and restart at each point. Double-click whenever you want to stop creating arcs.

3. Using Figure 5 (below) as a guide, click on the points to connect them with arcs to create the slope.

At this point you should see something like Figure 5 below.

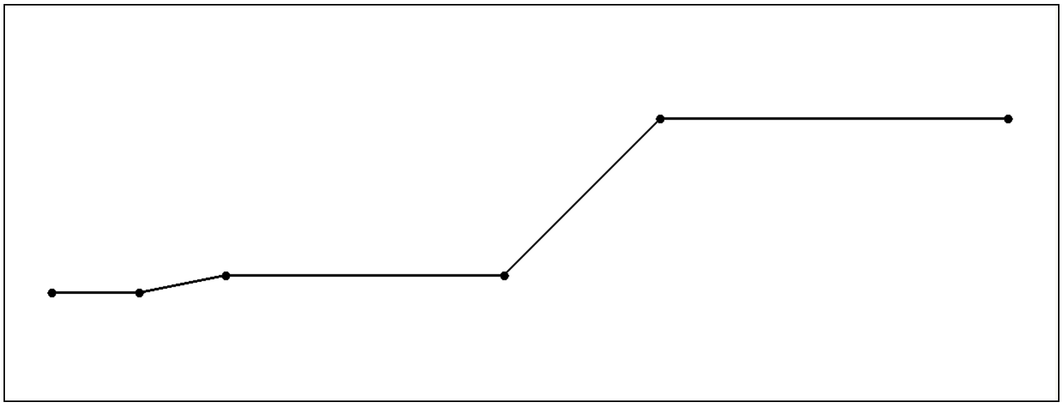

Figure 5. The Slope Geometry Arcs.

7.4 Convert Nodes to Vertices

Now we have five slope geometry arcs. However, we only can have one since each arc will be exported as a slope geometry line in the UTEXAS input file and UTEXAS can only handle one slope geometry line. We will change it so that we only have one slope geometry arc.

1. Select the *Select Points/Nodes* tool.
2. Drag a box around the four middle nodes, as shown in Figure 6 below.

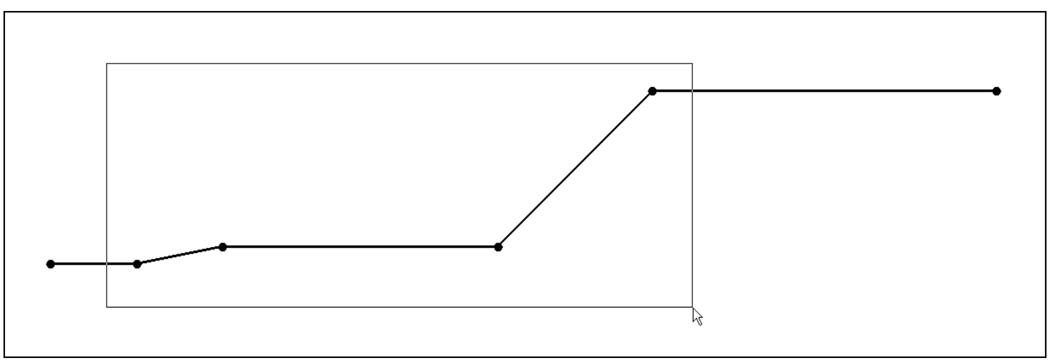

Figure 6. Selecting the Interior Nodes by Dragging a Box.

3. Select the *Feature Objects* | *Nodes -> Vertices* menu command.

7.5 Set the Arc Type

Now we'll change the arc type to *slope geometry*.

1. Switch to the *Select* tool .
2. Double-click on the arc.
3. Change the *Type* to **slope geom. line**.
4. Click *OK* to exit the dialog.
5. Click anywhere not on the model to unselect the arc.

We'll turn the other coverages back on now.

6. In the *Project Explorer*, turn on the *slope* and *piezometric line* coverages.

8 Assign the Distributed Load

Now we'll set up the distributed load. In this problem, the piezometric line doubles as the distributed load. If we mark a piezometric line as a distributed load, UTEXAS automatically calculates the appropriate load on the top of the slope. Another approach is to input the distributed load directly on the slope. The piezometric line method is typically the simplest approach.

8.1 Assign the Distributed Load Arc

1. In the *Project Explorer*, double-click on the *piezometric line* coverage.
2. In the *Coverage Setup* dialog, turn **on** *Distributed Load*.
3. Click *OK* to exit the dialog.
4. Make sure the *Select* tool is still active, or switch to it if necessary.
5. Double click on the piezometric line arc.
6. Turn **on** the *Dist. Load Stage 1* option. You may need to scroll to the right to see this column.
7. Click *OK* to exit the dialog.

9 Create Line Loads

The weight of the dock structure on the top of the slope will be represented using line loads. Each line load represents a row of piers in a direction perpendicular to the plane of the slope and will be applied at points along the top of the slope. We will apply an average line load of 2000 lbs per foot.

9.1 Create a New Coverage

1. In the *Project Explorer,* right-click on the *Underwater Slope* conceptual model and select the *New Coverage* command from the pop-up menu.

2. In the *Coverage Setup* dialog, change the *Coverage Name* to **line loads**

3. Turn **on** the *Line Load* option.

4. Click *OK* to exit the dialog.

9.2 Enter the Points

1. In the *Project Explorer*, right-click on the **line loads** coverage and select the *Attribute Table* command from the pop-up menu.

2. In the dialog, make sure the *Feature type* is set to **Points**.

3. Make sure the *Show point coordinates* option is turned **on**.

4. Enter the X and Y coordinates shown in the table below. If you are viewing this tutorial electronically, you can copy and paste these values into the GMS spreadsheet.

X	Y
73	-8
81	-8
89	-8
97	-8
105	-8

5. In the *All* row, change the *Type* to **line load**. This should change the type in all the rows.

6. In the *All* row, change the *Line Load Method Stage 1* to **Horz. And Vert. Forces**. This should change it for all the rows.

7. In the *All* row, enter a value of **-2000** for the *V Force or Incl Stage 1* and hit *Enter*. This should enter the value in all the rows.

8. Click *OK* to exit the dialog.

10 Analysis Options

The only thing left to do before we save and run the model is to set the UTEXAS analysis options.

1. In the *Project Explorer*, right-click on the **UTEXAS** model and select the *Analysis Options* command from the pop-up menu.

2. In the *Headings* section, enter the following headings:

   Underwater Slope
   GMS UTEXAS Tutorial

3. Change the *Type of Surface Analysis* to **Automatic Search Circular Floating Grid**.
4. Change the *Circle Center X* to **50**.
5. Change the *Circle Center Y* to **25**.
6. Change the *Radius Definition Method* to **Specify Point on Circle**.
7. Change the *Radius Point X* to **52**.
8. Change the *Radius Point Y* to **-26**.
9. Change the *Min Search Grid Spacing* to **0.1**.
10. Change the *Limiting Depth for Circles* to **-100**.
11. Click *OK* to exit the dialog.

At this point you should see the starting circle displayed.

11 Save the GMS file

Before continuing, we will save the gms project file.

1. Select the *File* | *Save* command.

12 Run UTEXAS

We're ready to export and run the model in UTEXAS.

12.1 Export the Model

To export the model.

1. In the *Project Explorer*, right-click on the **UTEXAS** model and select the *Export* command from the pop-up menu.
2. If necessary, locate and open the directory entitled **tutfiles\UTEXAS\underwater**.
3. Change the *File name* to **underwater slope - 1** and click *Save*.

12.2 Run UTEXAS

Now that we've saved the UTEXAS input file, we're ready to run UTEXAS.

1. In the *Project Explorer*, right-click on the **UTEXAS** model and select the *Launch UTEXAS4* command from the pop-up menu. This should bring up the UTEXAS4 program.

2. In UTEXAS4, select the *Open File* button.

3. Change the *Files of type* to **All Files (*.*)**.

4. Locate the **underwater slope - 1.utx** file you just saved (in the **tutfiles\UTEXAS\underwater**) folder and open it.

5. When UTEXAS4 finishes, look at the things mentioned in the *Errors, Warnings* window, then close the window.

12.3 Read the Solution

Now we need to read the UTEXAS solution.

1. In the *Project Explorer*, right-click on the **UTEXAS** model and select the *Read Solution* command from the pop-up menu.

2. Locate and open the file named **underwater slope - 1.out**.

You should now see a line representing the critical failure surface, and the factor of safety.

13 Alternate Model

The first part of this tutorial is complete. You should see a factor of safety of 1.09. Now we'll modify our model to include the affect of the internal reinforcement in the slope from the concrete piers. The compressive force in the piers will decrease from the top to the bottom due to load transfer from the piers to the soil. Including the reinforcement should increase the factor of safety.

14 Reinforcement Lines

We will create the reinforcement lines in a separate coverage.

14.1 Create a New Coverage

1. In the *Project Explorer,* right-click on the *Underwater Slope* conceptual model and select the *New Coverage* command from the pop-up menu.

2. In the *Coverage Setup* dialog, change the *Coverage Name* to **reinforcement lines.**

3. Turn **on** the *Reinforcement Line* option.

4. Click *OK* to exit the dialog.

14.2 Enter the Points

1. In the *Project Explorer*, right-click on the **reinforcement lines** coverage and select the *Attribute Table* command from the pop-up menu.

2. In the dialog, make sure the *Feature type* is set to **Points**.

3. Make sure the *Show point coordinates* option is turned **on**.

4. Enter the X and Y coordinates shown in the table below. If you are viewing this tutorial electronically, you can copy and paste these values into the GMS spreadsheet.

X	Y
73	-8
73	-13
73	-18
73	-23
73	-28
73	-33
73	-38
81	-8
81	-13
81	-18
81	-23
81	-28
81	-33
81	-38
89	-8
89	-13
89	-18
89	-23
89	-28
89	-33
89	-38
97	-8
97	-13
97	-18
97	-23
97	-28
97	-33

97	-38
105	-8
105	-13
105	-18
105	-23
105	-28
105	-33
105	-38

5. Click *OK* to exit the dialog.

14.3 Connect the Points to Create Arcs

1. Select the *Create Arcs* tool.

2. Hold down the *Shift* key. This makes it so that you can create multiple arcs continuously without having to stop and restart at each point. Double-click whenever you want to stop creating arcs.

3. Using Figure 7 (below) as a guide, click on the points to connect them with arcs to create the slope.

At this point you should see something like Figure 7 below.

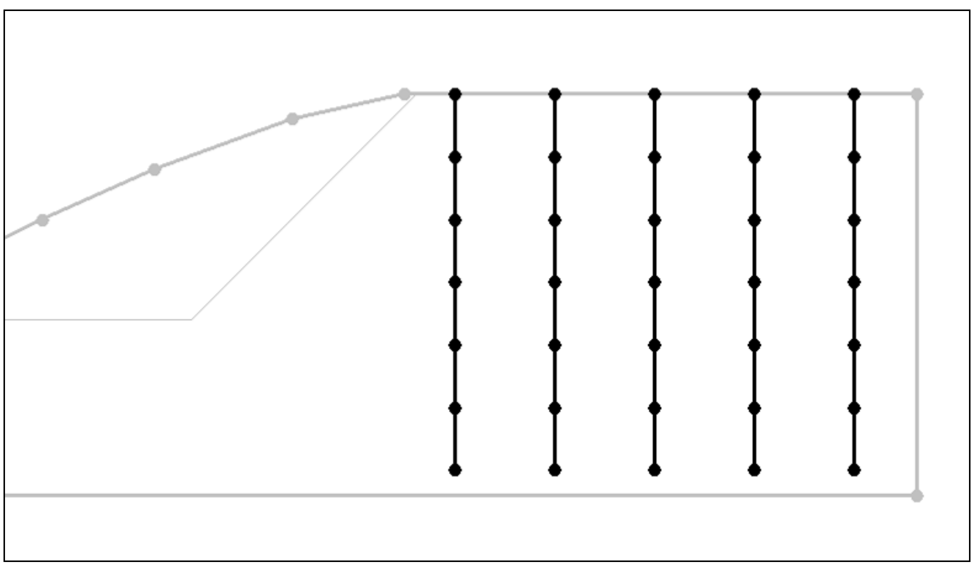

Figure 7. The Piers Represented as Reinforcement Lines.

14.4 Assign the Arc Attribute

1. Switch to the *Select Arcs* tool.

2. Drag a box around all the reinforcement line arcs to select them.

3. Select the *Properties* button. This brings up the *Properties* dialog.

4. In the *All row*, change the *Type* to **reinforcement line**. This should change the type in all the rows.

5. Click *OK* to exit the dialog.

You should notice the line color has changed indicating the new arc type.

14.5 Assign the Node Attributes

The forces on the reinforcement lines are specified at the nodes. We'll assign them now.

1. Switch to the *Select Points/Nodes* tool.

2. Select all the top nodes by dragging a box around them as shown in Figure 8 below.

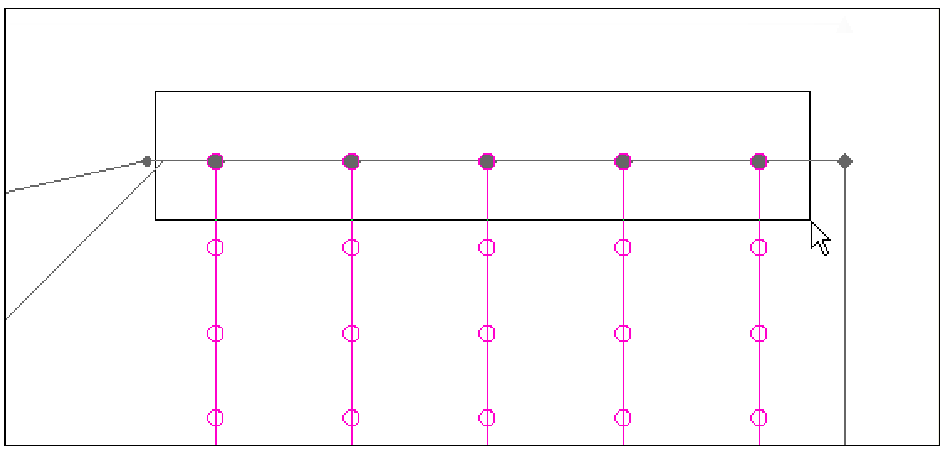

Figure 8. Selecting the Top Reinforcement Nodes by Dragging a Box.

3. Select the *Properties* button. This brings up the *Properties* dialog.

4. In the *All* row, change the *Long. Force* to be **-2000** and hit *Enter*. This should change the value in all the rows.

5. Click *OK* to exit the dialog.

Now we'll repeat the above procedure several times to assign all the node values.

6. Repeat the above steps to assign the *Long. Force* values shown in Figure 9 below.

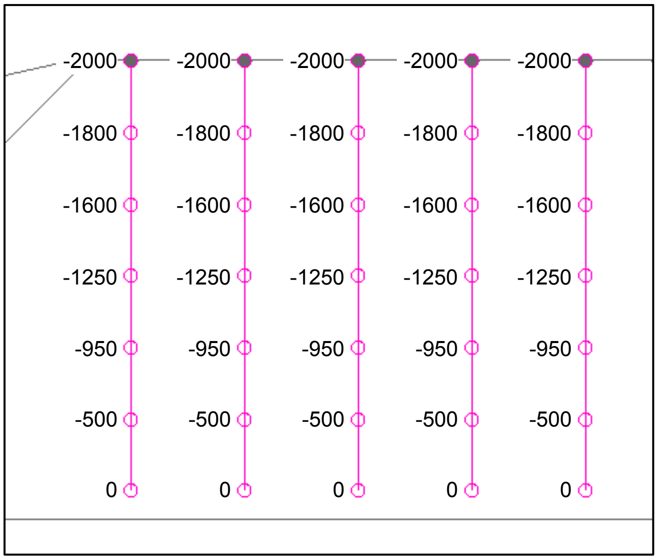

Figure 9. Longitudinal Forces Assigned to the Reinforcement Lines.

15 Save the GMS file

Before continuing, we will save the gms project file.

1. Select the *File* | *Save* command.

16 Run UTEXAS

We are ready to save our changes and run UTEXAS again.

16.1 Export the Model

We're ready to save the model.

1. In the *Project Explorer*, right-click on the **UTEXAS** model and select the *Export* command from the pop-up menu.
2. If necessary, locate and open the directory entitled **tutfiles\UTEXAS\underwater**.
3. Change the *File name* to **underwater slope - 2** and click *Save*.

16.2 Run UTEXAS

Now that we've saved the UTEXAS input file, we're ready to run UTEXAS.

1. In the *Project Explorer*, right-click on the **UTEXAS** model and select the *Launch UTEXAS4* command from the pop-up menu. This should bring up the UTEXAS4 program.
2. In UTEXAS4, select the *Open File* button.
3. Change the *Files of type* to **All Files (*.*)**.
4. Locate the **underwater slope - 2.utx** file you just saved (in the **tutfiles\UTEXAS\underwater**) folder and open it.
5. When UTEXAS4 finishes, look at the things mentioned in the *Errors, Warnings* window, then close the window.

16.3 Read the Solution

Now we need to read the UTEXAS solution.

1. In the *Project Explorer*, right-click on the **UTEXAS** model and select the *Read Solution* command from the pop-up menu.
2. Locate and open the file named **underwater slope - 2.out**.

17 Compare the Solutions

Now we have two solutions in memory and you should see two failure surface lines. Both factors of safety are being displayed, and since they are in the same place, they are obscuring each other. Let's look at the solutions one at a time.

1. In the *Project Explorer*, turn **off** the *underwater slope – 1 (UTEXAS)* solution .

Now you are seeing just one of the solutions being displayed.

2. In the *Project Explorer*, turn **on** the *underwater slope – 1 (UTEXAS)* solution and turn **off** the *underwater slope – 2 (UTEXAS)* solution .

The factor of safety for the second case should be about 1.71 (compared to 1.09 for the first model). Both line loads and the reinforcement act in the vertical direction only. The reinforcement lines tend to balance out the effect of the line loads at the surface. In other words, the net load applied at the failure surface is the difference between the line load and the reinforcement line force. The reinforcement loads starts at 2000 at the ground surface and decreases with depth. Thus, the reinforcement load at the top of the slope (in the area where the failure surface intersects the piers) is close to the line load value resulting in a small net load and a larger factor of safety.

18 Conclusion

This concludes the tutorial. Here are some of the key concepts in this tutorial:

- You can use GMS to build slopes with slope geometry lines for analysis by UTEXAS. Slope geometry lines are helpful in cut or fill scenarios.
- You should only have one slope geometry arc in your model. If you have multiple arcs forming a line, you should convert them into one arc.
- Arcs and points which cross other feature objects should be placed in a separate coverage.