UTEXAS – Reinforced Slope

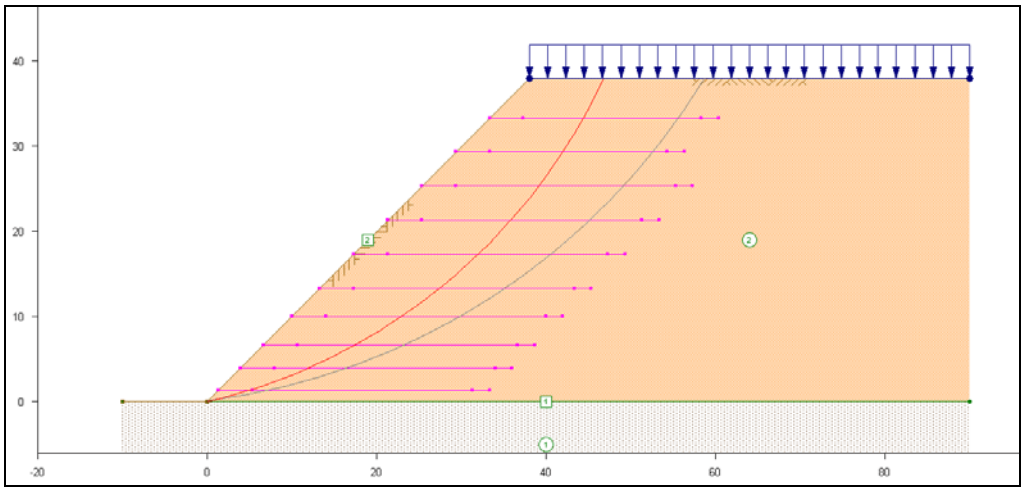

Figure 1. A reinforced slope. From the UTEXAS4 tutorials.

1 Introduction

This tutorial illustrates how to build a UTEXAS model in GMS that uses soil reinforcement to stabilize a slope. This tutorial is similar to tutorial number five 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 fairly steep embankment is subjected to loading. The slope has several reinforcement elements to help strengthen it against failure. Reinforcement elements include geotextiles, nails, piers etc.

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

1.1 Contents

1.2 Outline

In this tutorial, we'll be examining a reinforced embankment problem that looks like the one shown in Figure 1 above. This is what you will do:

1. Create the slope.
2. Create material properties and assign materials to polygons.
3. Assign the distributed load.
4. Create the reinforcement lines.
5. Set the analysis options.
6. Export the UTEXAS input file, run UTEXAS, 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'll start by creating a new UTEXAS conceptual model and building the arcs and polygons defining the slope geometry.

3.1 Create the Conceptual Model

To create the conceptual model:

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

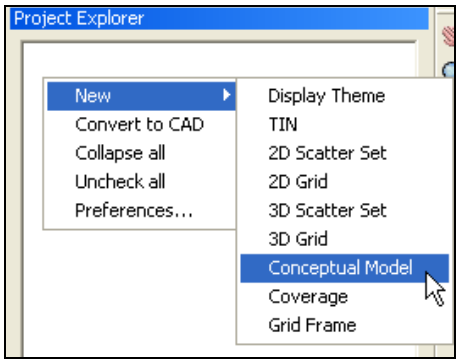

Figure 2. Creating a New Conceptual Model.

2. In the *Conceptual Model Properties* dialog, change the *Name* to **Reinforced 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 profile lines, the distributed load, and the reinforcement lines.

7. In the *Project Explorer*, right-click on the *Reinforced Slope* conceptual model you just created and select the *New Coverage* command from the pop-up menu.

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

9. Turn **on** the *Distributed Load* option.

10. Click *OK* to exit the dialog.

3.3 Create the Profile Lines

Next, we will create the profile lines defining the slope.

Create the Points

The locations of the points defining the slope were determined beforehand. We will simply enter the points and then connect them with arcs.

1. In the *Project Explorer*, right-click on the **slope** coverage and select the *Attribute Table* command from the pop-up menu. This brings up the coverage *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
-10	0
90	0
0	0
38	38
90	38
-10	-10
90	-10

5. Click *OK* to exit the dialog.

6. Click the Frame button to frame the image.

You should now see the seven points defining the corners of the slope.

Connect the Points to Create Arcs

Next, we will connect the points to form 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. Release the shift key, or double-click whenever you want to stop creating arcs.
3. Using Figure 1 as a guide (or Figure 3 below), click on the points to connect them with arcs to create the slope.
4. Select the *Feature Objects* | *Build Polygons* menu command.

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

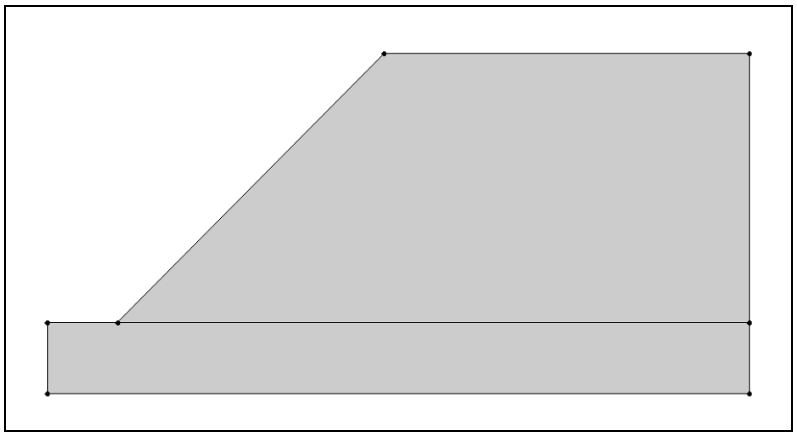

Figure 3. The basic slope.

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\reinforcement**
3. Enter a name for the project file (ex. "**reinforced slope.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 materials.

5.1 Create the Materials

1. Select the *Edit* | *Materials* menu command.
2. On the left side of the dialog, double-click on the material named "material_1" and rename it **Bedrock**.
3. Click on the *Material color / pattern* button and change the color to **Dark yellow** or some other attractive color.
4. Click the *New* button to create a new material.
5. Rename the new material **Sand**.
6. Change the material color to **Light orange**.
7. On the right side of the dialog, make sure the *UTEXAS* tab is displayed.
8. Change the material properties to those shown in the following table:

Unit Weight Stage 1	Shear Strength Method Stage 1	Cohesion Stage 1	Angle of Internal Friction Phi Stage 1
160	Very strong material		
120	Conventional	0	32

9. Make sure the *Pore Water Pressure Method Stage 1* is set to **No Pore Pressure** for the second material (Sand). You may have to scroll the spreadsheet to the right to see this column.
10. Leave the other settings at the defaults.
11. Click *OK* to exit the dialog.

5.2 Assign Materials to Polygons

Next, we will associate the materials with the polygons defining the soil zones in the profile:

1. Switch to the *Select* tool .
2. Double-click on the upper polygon (the big one).
3. Change the *Material* to **Sand** and click *OK* to exit the dialog.
4. Double-click on the lower polygon.

5. Change the *Material* to **Bedrock** (it may already be set) and click *OK* to exit the dialog.

6 Assign the Distributed Load

Now we'll set up the distributed load.

1. With the *Select* tool still active, double click on the arc that forms the top of the slope as shown in Figure 4 below.

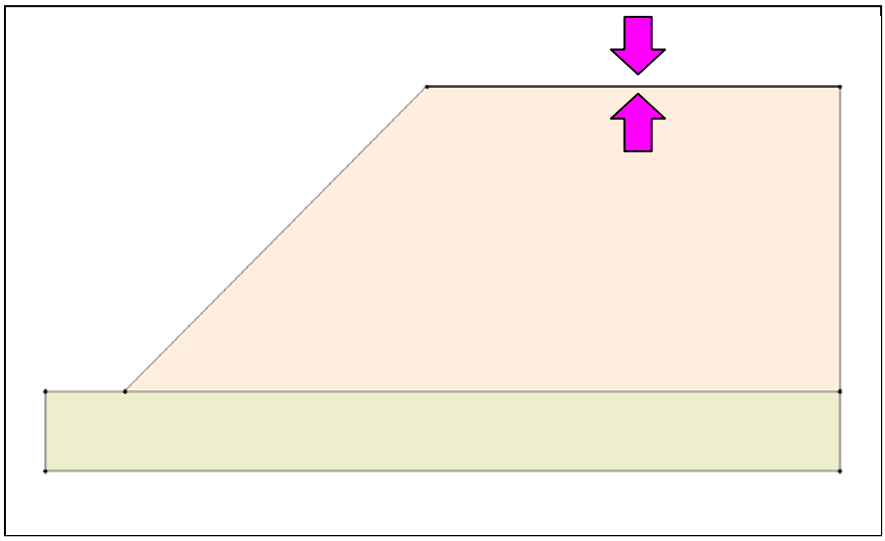

Figure 4. Selecting the distributed load arc.

2. Change the *Type* to **distrib. load**.
3. Change *Beg. Load Stage 1* to **240.0**.
4. Change *End Load Stage 1* to **240.0**.
5. Leave the other values alone and click *OK* to exit the dialog.

You should now see the arrow heads indicating there is a distributed load.

7 Create Reinforcement Lines

Now we need to create the arcs for the reinforcement. The following diagram from the UTEXAS tutorials shows the location of the reinforcement:

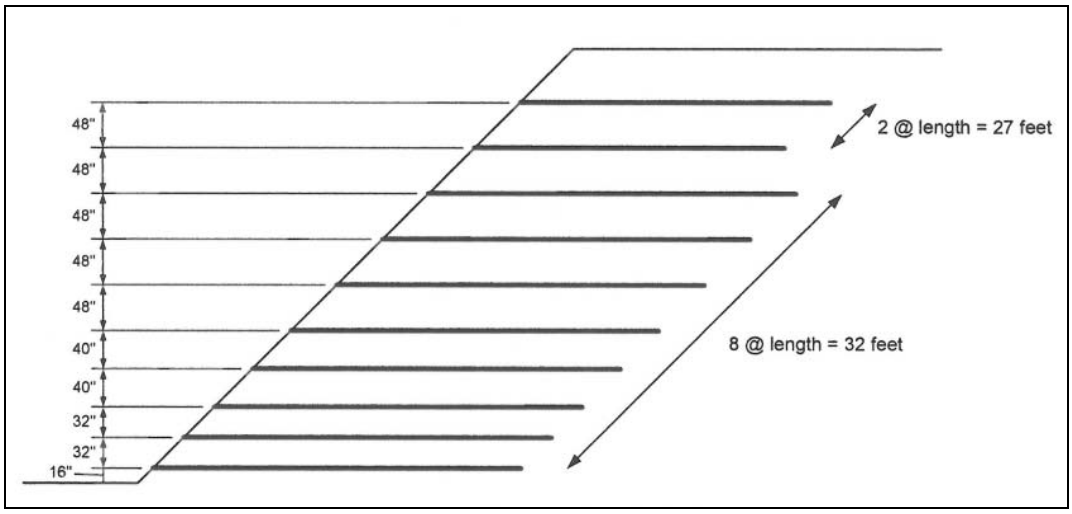

Figure 5. Reinforcement layout diagram, from "UTEXPREP4 Preprocessor For UTEXAS4 Slope Stability Software" by Stephen G. Wright, Shinoak Software, Austin Texas, 2003.

7.1 Create a New Coverage

We can either add the reinforcement lines to the main coverage ("slope"), or we can put them in a separate coverage. Either way works. In this case, we will create a seperate coverage for the reinforcement lines.

1. In the *Project Explorer*, right-click on the *Reinforced 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**
3. Turn **on** the *Reinforcement Line* option.
4. Click *OK* to exit the dialog.

7.2 Enter the Points

The XY coordinates of the reinforcement lines have been computed for you and are provided below. You simply need to enter them in to GMS.

1. In the *Project Explorer*, right-click on the **reinforcement** coverage you just created and select the *Attribute Table* command from the pop-up menu.
2. In the dialog, change the *Feature type* 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
1.33	1.33
5.33	1.33
31.33	1.33
33.33	1.33
6.67	6.67
10.67	6.67
36.67	6.67
38.67	6.67
13.33	13.33
17.33	13.33
43.33	13.33
45.33	13.33
17.33	17.33
21.33	17.33
47.33	17.33
49.33	17.33
21.33	21.33
25.33	21.33
51.33	21.33
53.33	21.33
25.33	25.33
29.33	25.33
55.33	25.33
57.33	25.33
29.33	29.33
33.33	29.33
54.33	29.33
56.33	29.33
33.33	33.33
37.33	33.33
58.33	33.33
60.33	33.33
4	4
8	4
34	4
36	4
10	10
14	10
40	10
42	10

5. Click *OK* to exit the dialog.

7.3 Connect the Points to Create Arcs

Now we'll 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. Release the shift key, or double-click whenever you want to stop creating arcs.

3. Using Figure 6 (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 6 below.

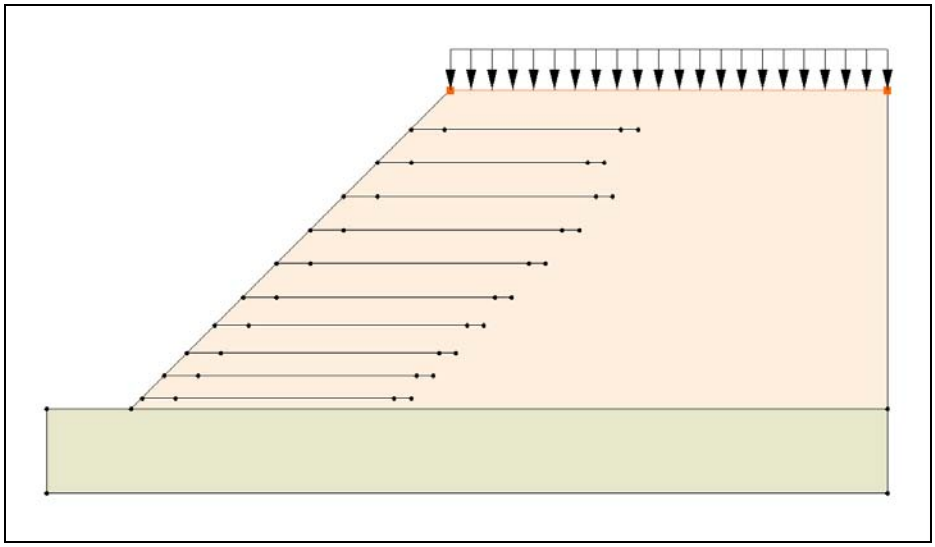

Figure 6. After adding reinforcement lines.

7.4 Change the Arc Type to Reinforcement Lines

The reinforcement lines are in place. Now we need to assign the appropriate attributes to them.

1. Switch to the *Select Arcs* tool.

2. Select all the reinforcement arcs by dragging a box around all of them, as shown in Figure 7.

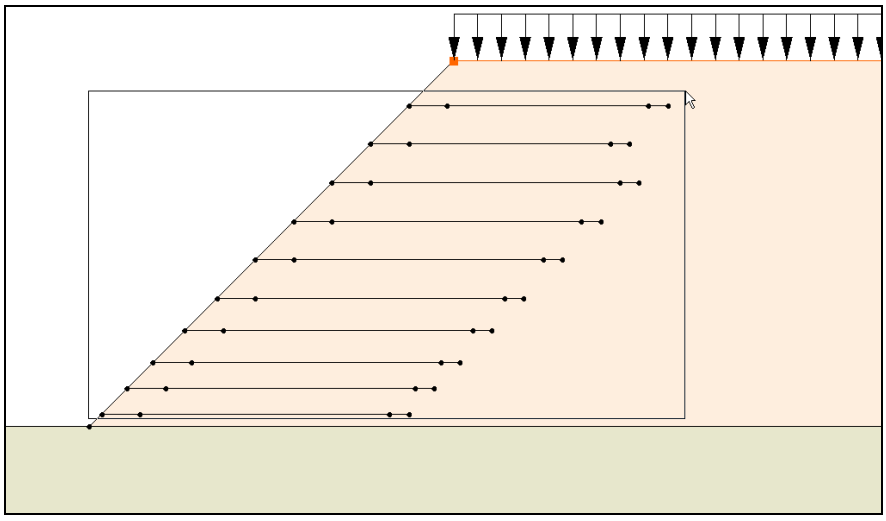

Figure 7. Selecting the reinforcement lines by dragging a box.

3. Select the *Properties* button to open the coverage properties dialog.
4. In the *All* row at the top, change the *Type* to reinforcement line. This should change the type in all the rows.
5. Click *OK* to exit the dialog.
6. Click anywhere not on the model to unselect the arcs.

You should notice that the reinforcement arcs and nodes are now colored differently to indicate they are reinforcement arcs.

7.5 Assign the Forces at the Nodes

At each point along the reinforcement line, UTEXAS requires that we specify a longitudinal force and a transverse force. We will assign those now.

Nodes Along the Slope

1. Switch to the *Select Points/Nodes* tool.
2. Hold down the shift key and select all the reinforcement nodes on the left ends of the reinforcement arcs – the nodes that intersect the slope – as shown in Figure 8 below.

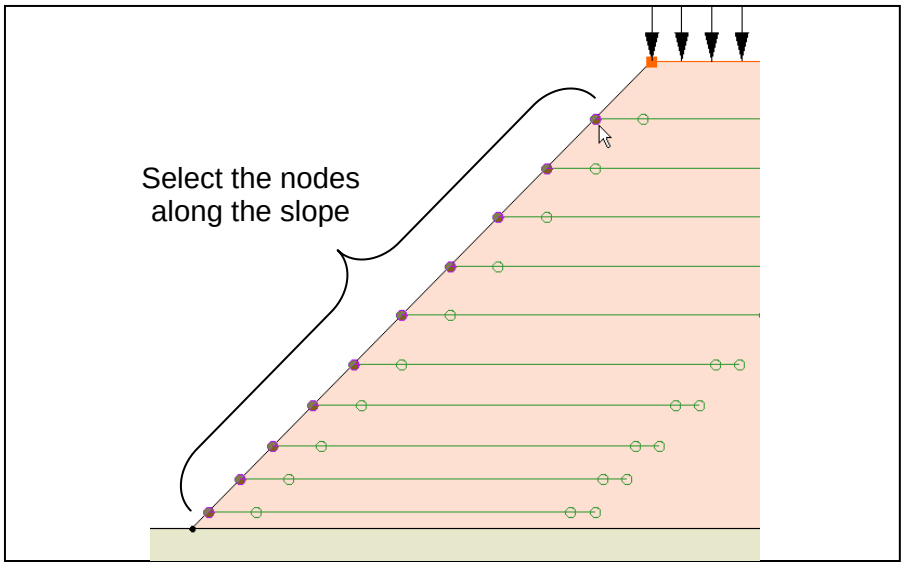

Figure 8. Selecting the reinforcement nodes along the slope.

3. Select the *Properties* button to open the coverage properties dialog.

4. In the *All* row at the top of the spreadsheet, change the *Long. Force* to **500** and hit the tab key. This should change the *Long. Force* to 500 in all the rows.

5. Leave the *Trans. Force* at **0.0**.

6. Click *OK* to exit the dialog.

7. Click anywhere not on the model to unselect the nodes.

Nodes Just to the Right of the Slope

1. Repeat the above procedure to assign a *Long. Force* of **1000** to all the nodes just inside the slope – all the nodes just to the right of the ones you just selected.

2. Again repeat the above procedure to assign a *Long. Force* of **1000** to the nodes to the right of the ones you just assigned – not the nodes on the right ends of the arcs but the nodes just to the left of those.

The nodes on the right ends of the reinforcement arcs are supposed to have both forces at 0.0. That is the default so we don't need to change those nodes.

8 Analysis Options

The only thing left to do before we save and run the model is to set the UTEXAS analysis options. We will select an automated search for the critical factor of safety using circular surfaces using Shepard's Method.

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

2. Change the settings to match those shown in the following figure.

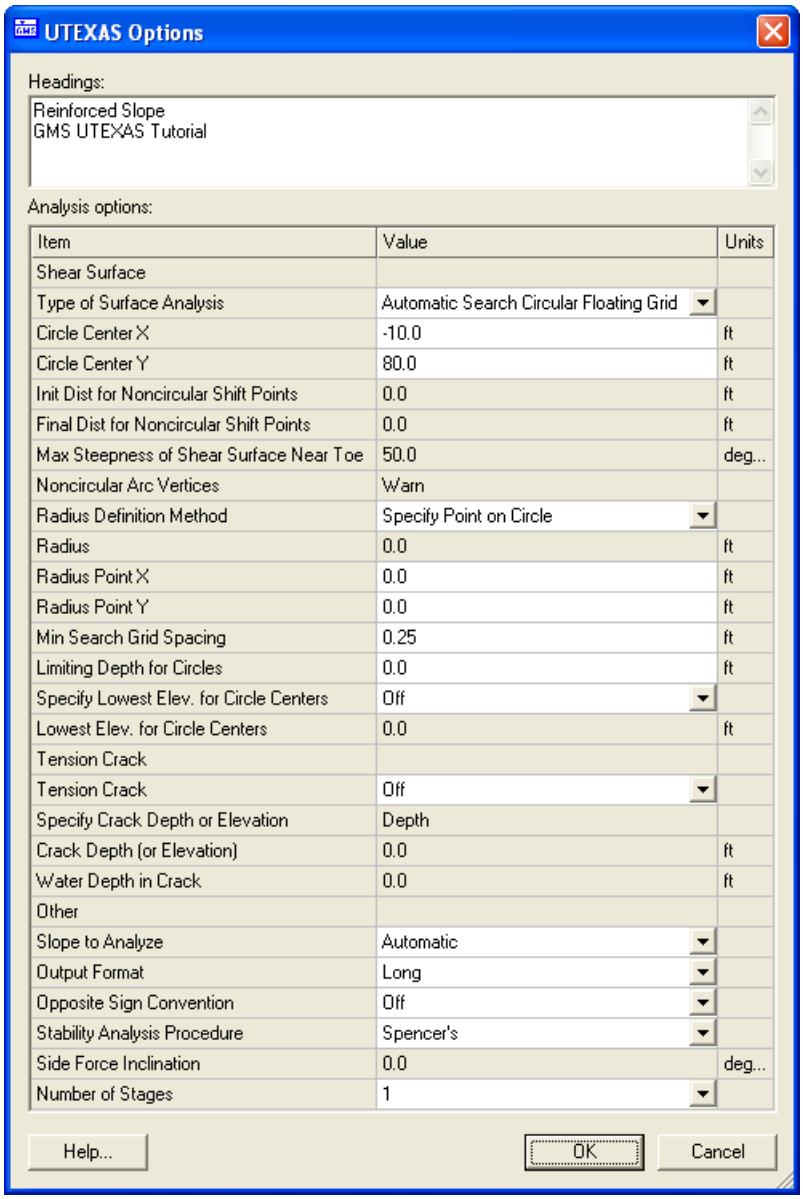

Figure 9. Selecting the reinforcement nodes along the slope.

3. When you're done, click *OK*.

At this point you should see the starting circle displayed.

9 Save the GMS file

Before continuing, we will save the GMS project file.

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

10 Run UTEXAS

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

10.1 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\reinforcement**.
3. Change the *File name* to **reinforced slope** and click *Save*.

10.2 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 **reinforced slope.utx** file you just saved (in the **tutfiles\UTEXAS\reinforcement**) folder and open it.
5. When UTEXAS4 finishes, look at the things mentioned in the *Errors, Warnings* window, then close the window.

10.3 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 **reinforced slope.out**.

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

11 Conclusion

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

- You can use GMS to build reinforced slopes for analysis by UTEXAS.
- Reinforcement lines can be placed alone in a separate coverage or included in an existing coverage.
- In GMS, the forces applied along the length of the reinforcement lines are specified at the nodes.

