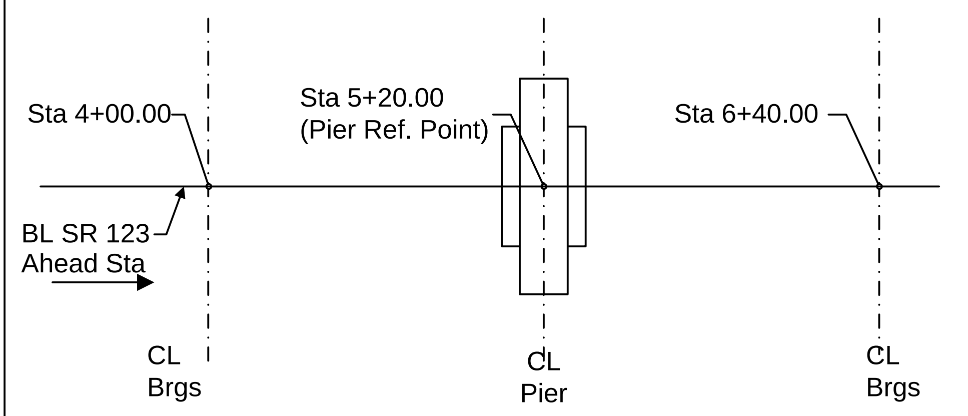
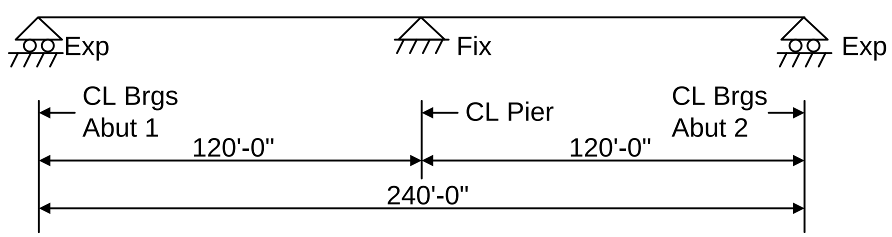
*AASHTOWare BrD 6.8*

# *Substructure Tutorial*

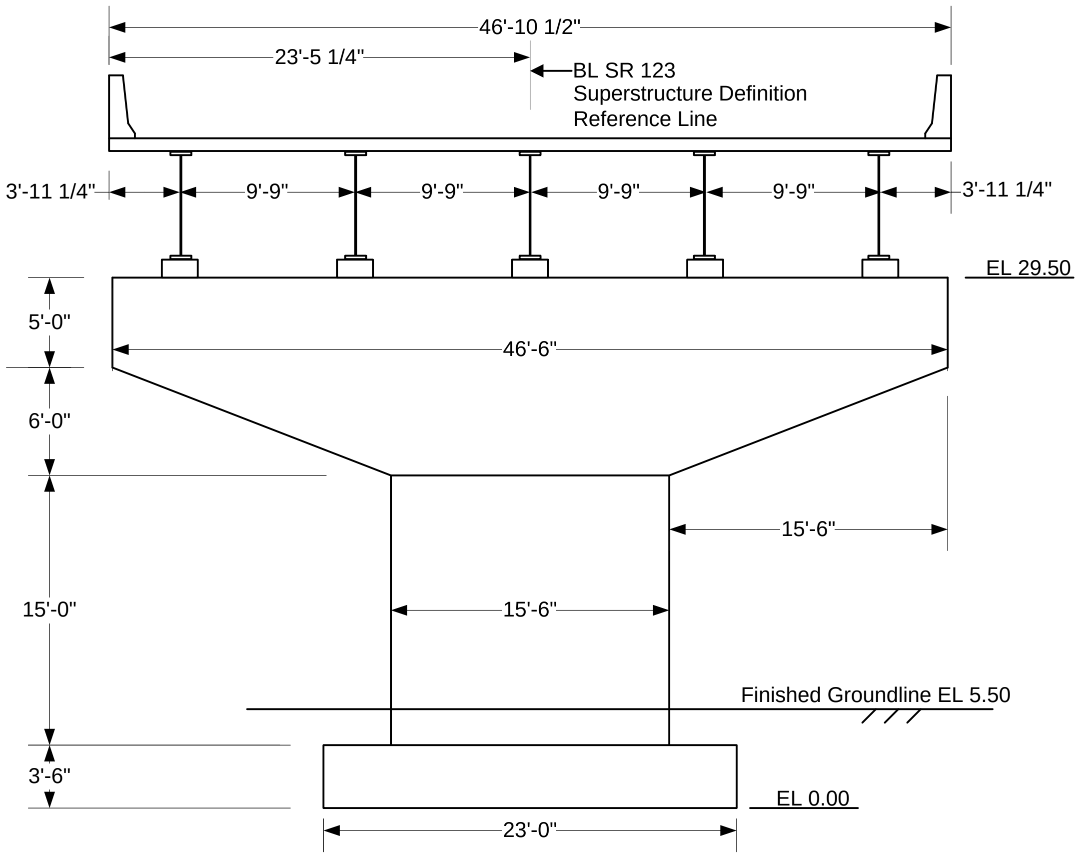
*Solid Shaft Pier Example*



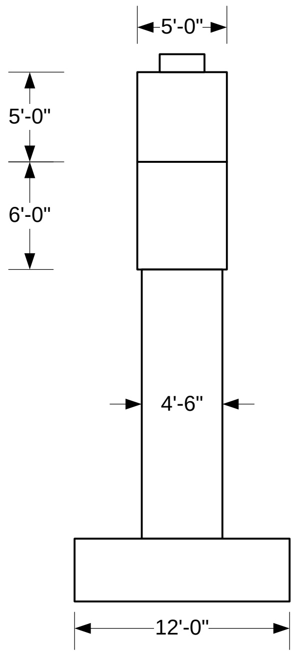

Bridge Layout



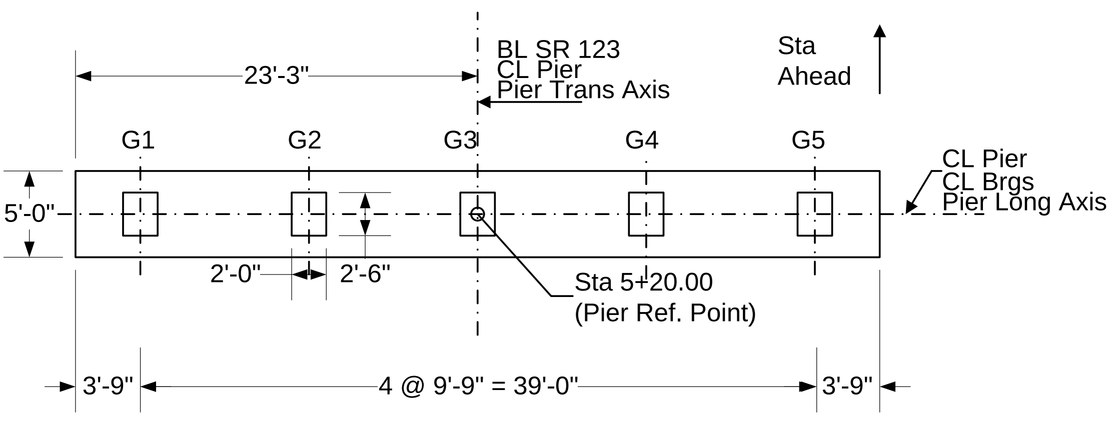

Span Arrangement



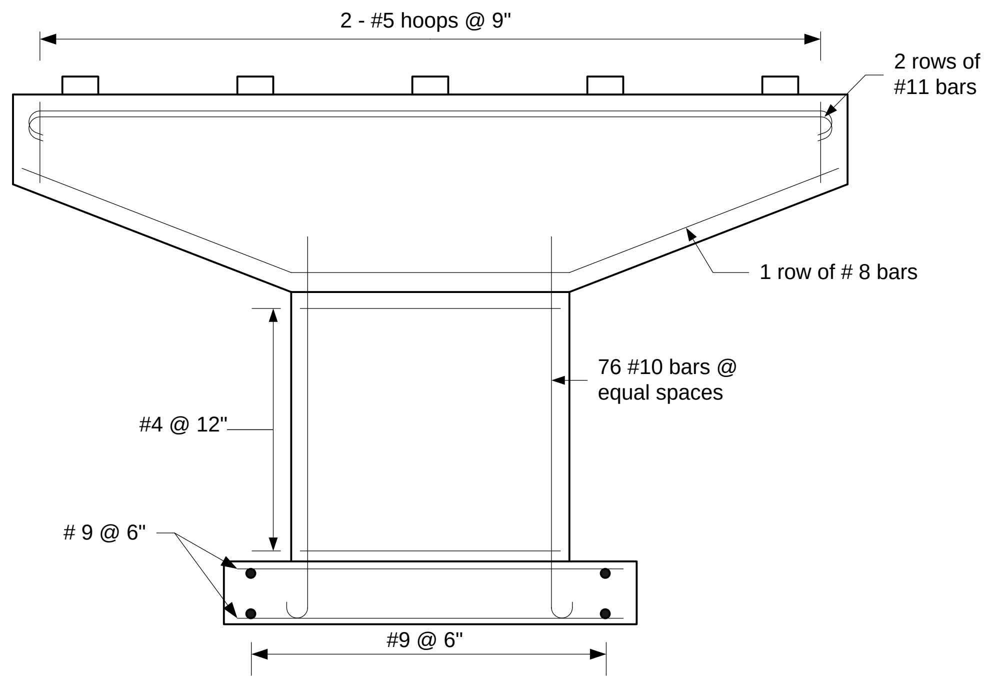

Pier Elevation
Looking Sta Ahead



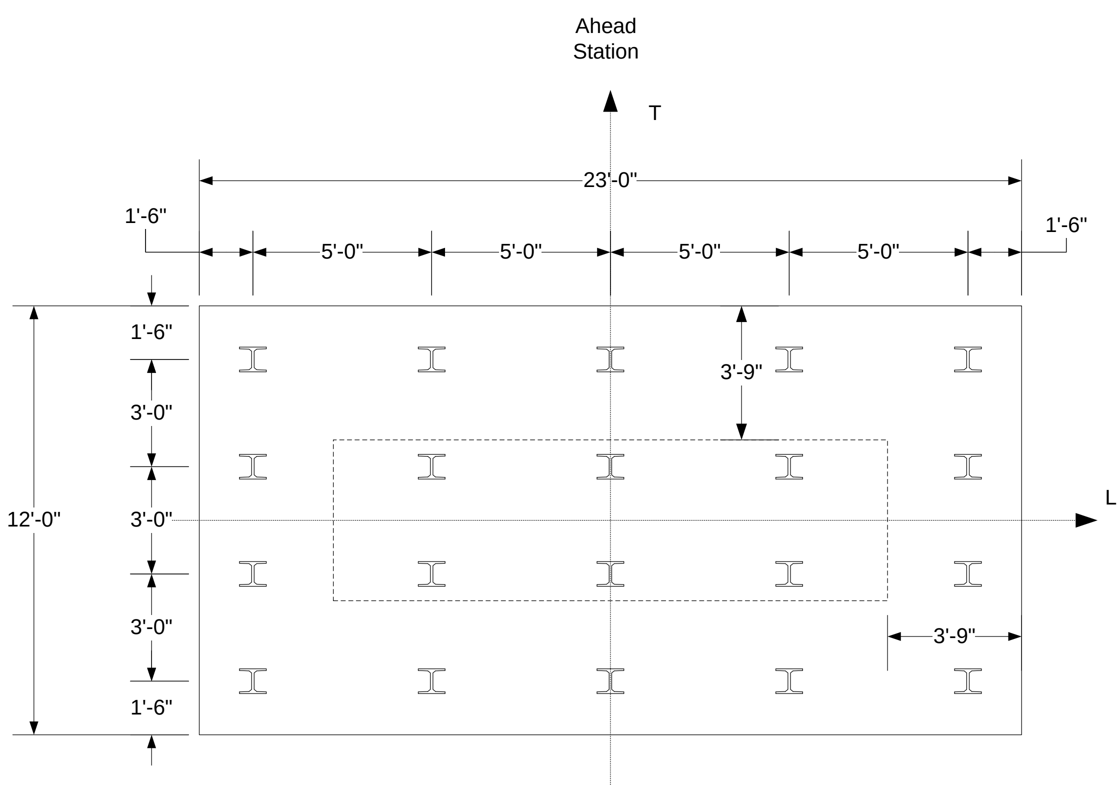

Pier Side View




Cap Plan View




**Pier Reinforcement**




**Footing Plan View**

# BrD Substructure Training

# Pier 1 – Solid Shaft Pier Example

This example describes the entry and analysis of a reinforced concrete solid shaft pier in BrD Substructure. In this example, a two span continuous steel superstructure is supported by a solid shaft pier.

Example features:

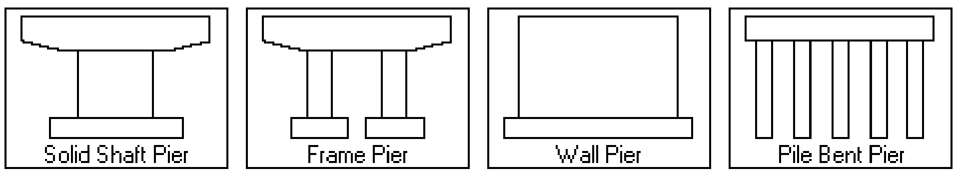
- Two span continuous steel superstructure
- Reinforced concrete, solid shaft pier on a pile footing
- Pier skew – 0 degrees
- Specification checking of reinforcement

This example uses many default settings and loadings in BrD Substructure instead of overriding these values with user defined input. For example, the Environmental Conditions window contains default wind and temperature settings from the AASHTO specifications. Users have the ability to override these values but this example uses the default values and thus that window is not shown in this example. Another feature users have in the program is to override the computed loads on the pier with user defined loads. This example uses the computed loads and does not override any of them.

Note: It is assumed that users are familiar with the BrD Superstructure module and as such this example does not go into detail describing BrD Superstructure windows or bridge workspace navigation.

## BrD Substructure Capabilities

The BrD Substructure module currently has the capability to describe the pier gross geometry, compute loads acting on the pier, perform a finite element analysis of the pier, compute the load combination results and perform specification checks for the reinforcement. Four types of reinforced concrete pier alternatives can be described: solid shaft (hammerhead) piers, frame piers, wall piers and pile bent piers.

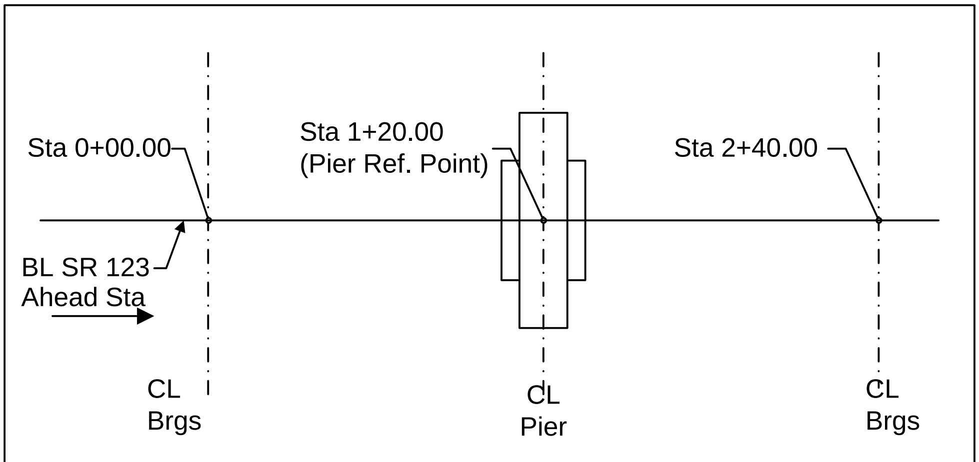



A three-dimensional schematic is available where you can view a to-scale drawing of your pier alternative. BrD can compute the loads acting on the pier for you or you can enter your own override forces. Superstructure dead load and live load reactions are computed for you based on the superstructure definition assigned to the superstructure supported by the pier. BrD generates a three-dimensional finite element model of the pier based on modeling parameters you input. A finite element analysis of the pier is performed and load combination results are generated based on the limit states you choose to include. The analysis results can be viewed in a text output and also be viewed on the three-dimensional schematic of the pier. Detailed specification check results can be viewed and summary reports of the specification results can be generated.

## Locating Substructure Units

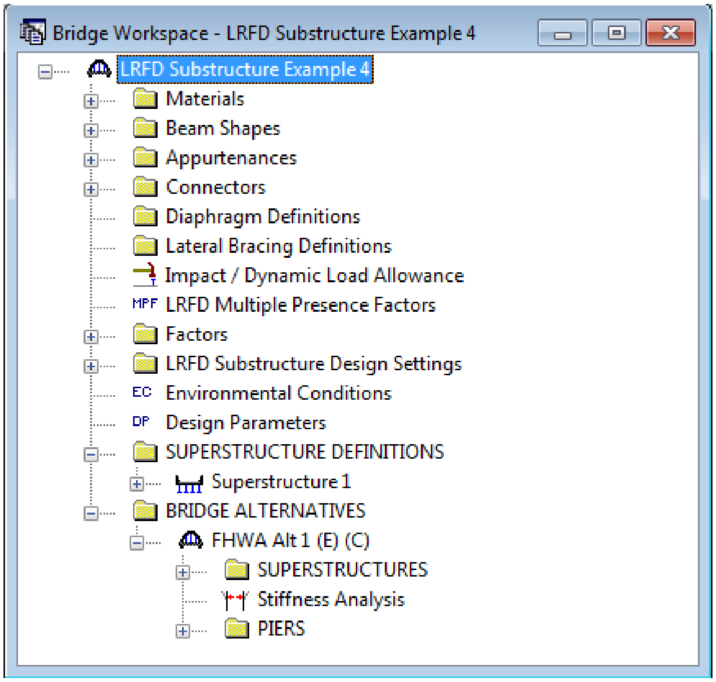
In BrD, substructures are defined relative to bridge alternatives and the superstructures in a bridge alternative. Through this arrangement, loads from the superstructure can be carried down to the substructures.

Our example has the following bridge layout:

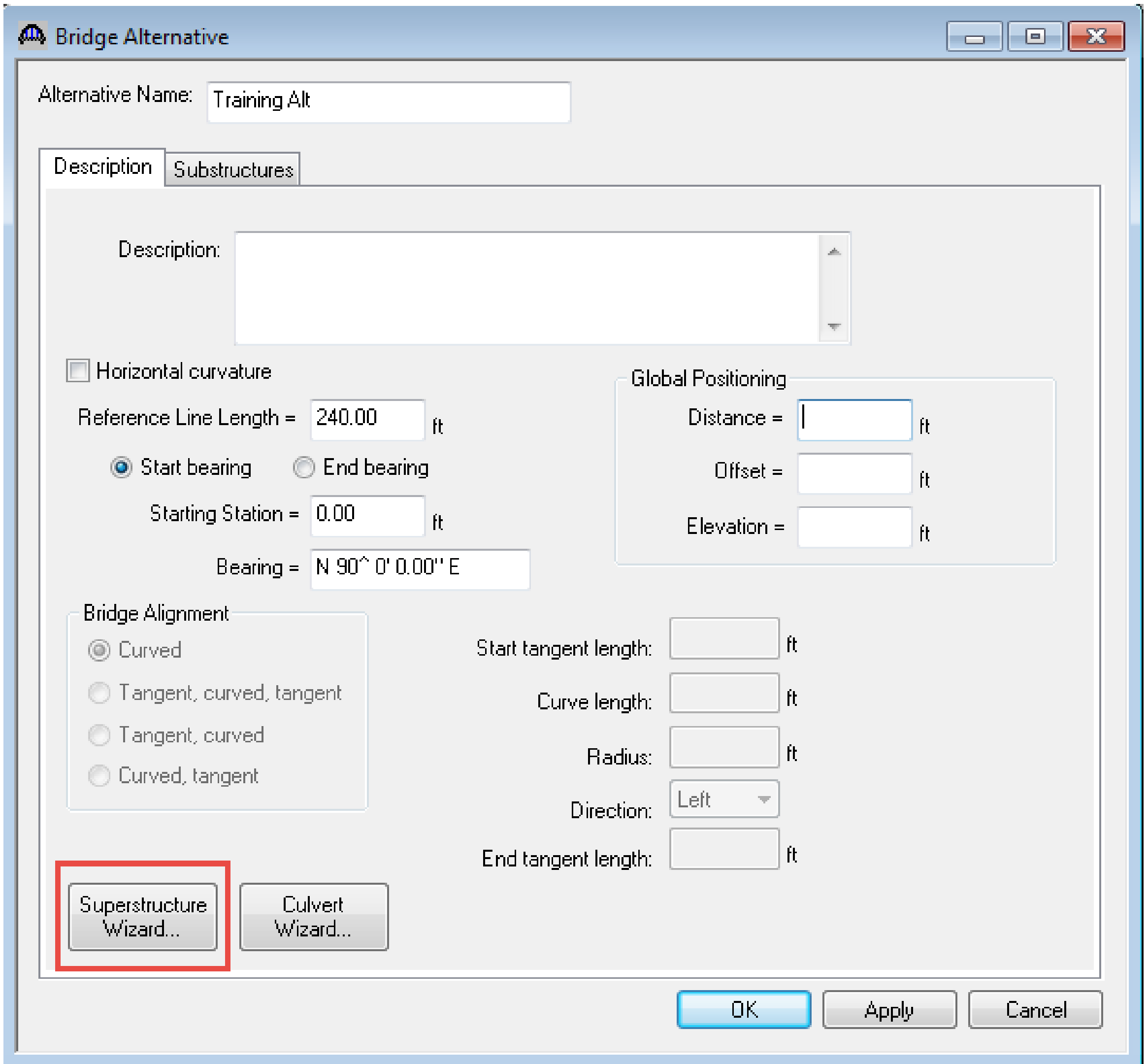



Bridge Layout

We are going to describe this bridge alternative and pier in BrD Substructure by adding a bridge alternative to the bridge with BID 23 in our sample database. Open the bridge workspace for BID 23. As shown below, this bridge already contains a superstructure definition and a bridge alternative. We are going to re-use this superstructure definition and create a new bridge alternative and a new pier in this example.



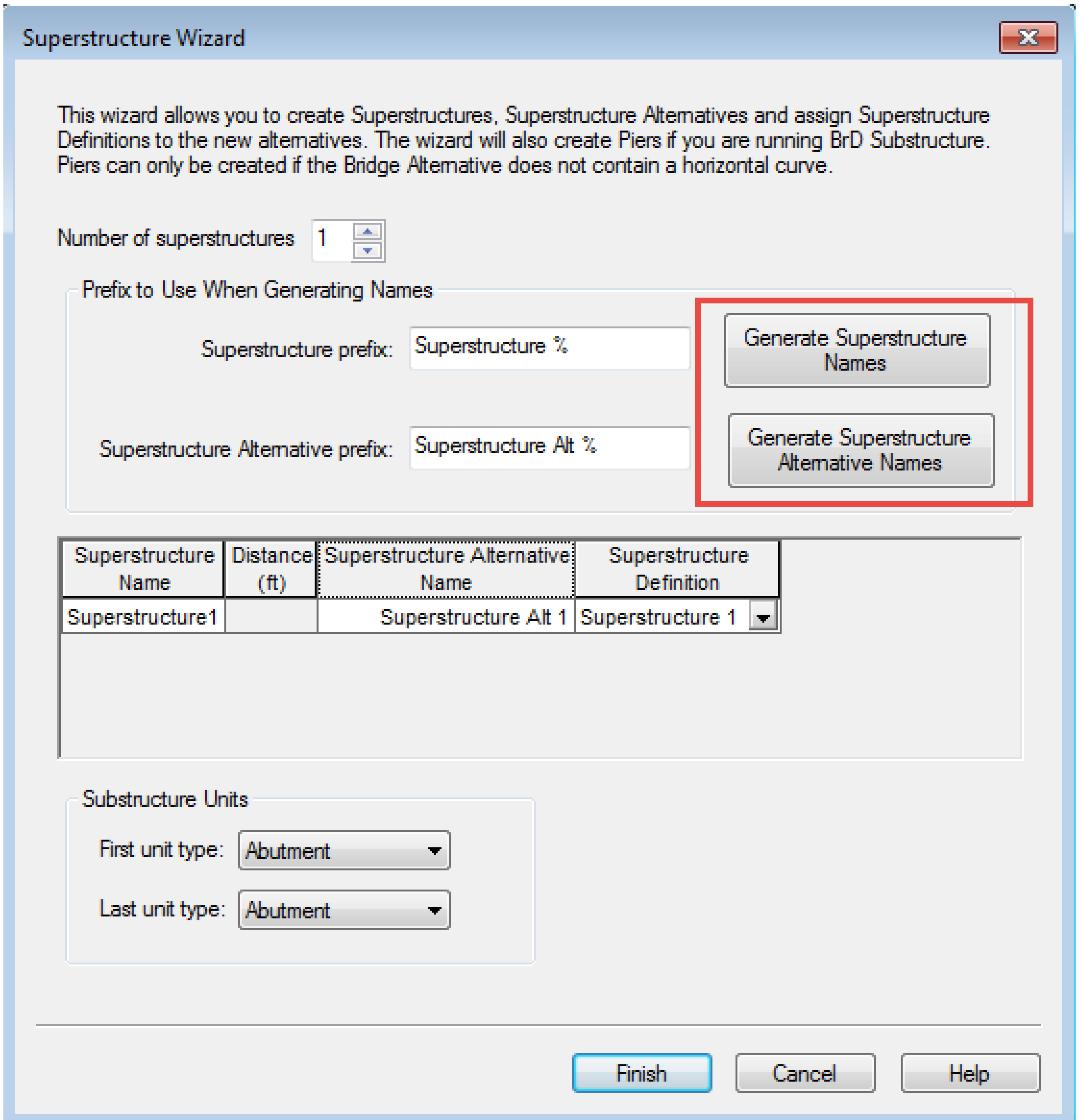

We are going to jump down to the Bridge Alternatives section and create a new bridge alternative. Double click the "BRIDGE ALTERNATIVES" label and enter the following information.



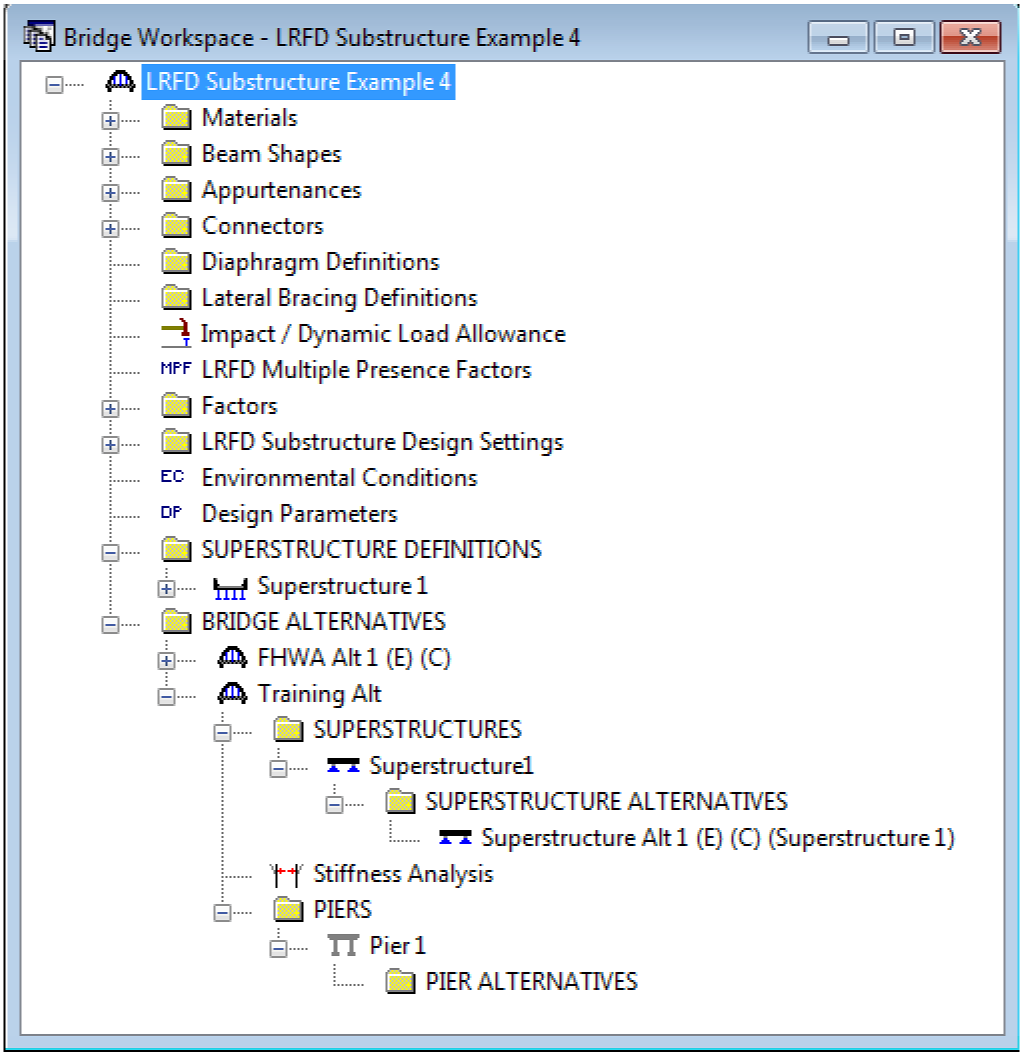

The data on this tab orients the bridge alternative reference line. Our substructure units will be located with respect to this bridge alternative reference line. Our bridge alternative is 240 feet long and the starting station is 0+00.

Click the ‘Superstructure Wizard’ button to have BrD create our Superstructure and Pier for us.

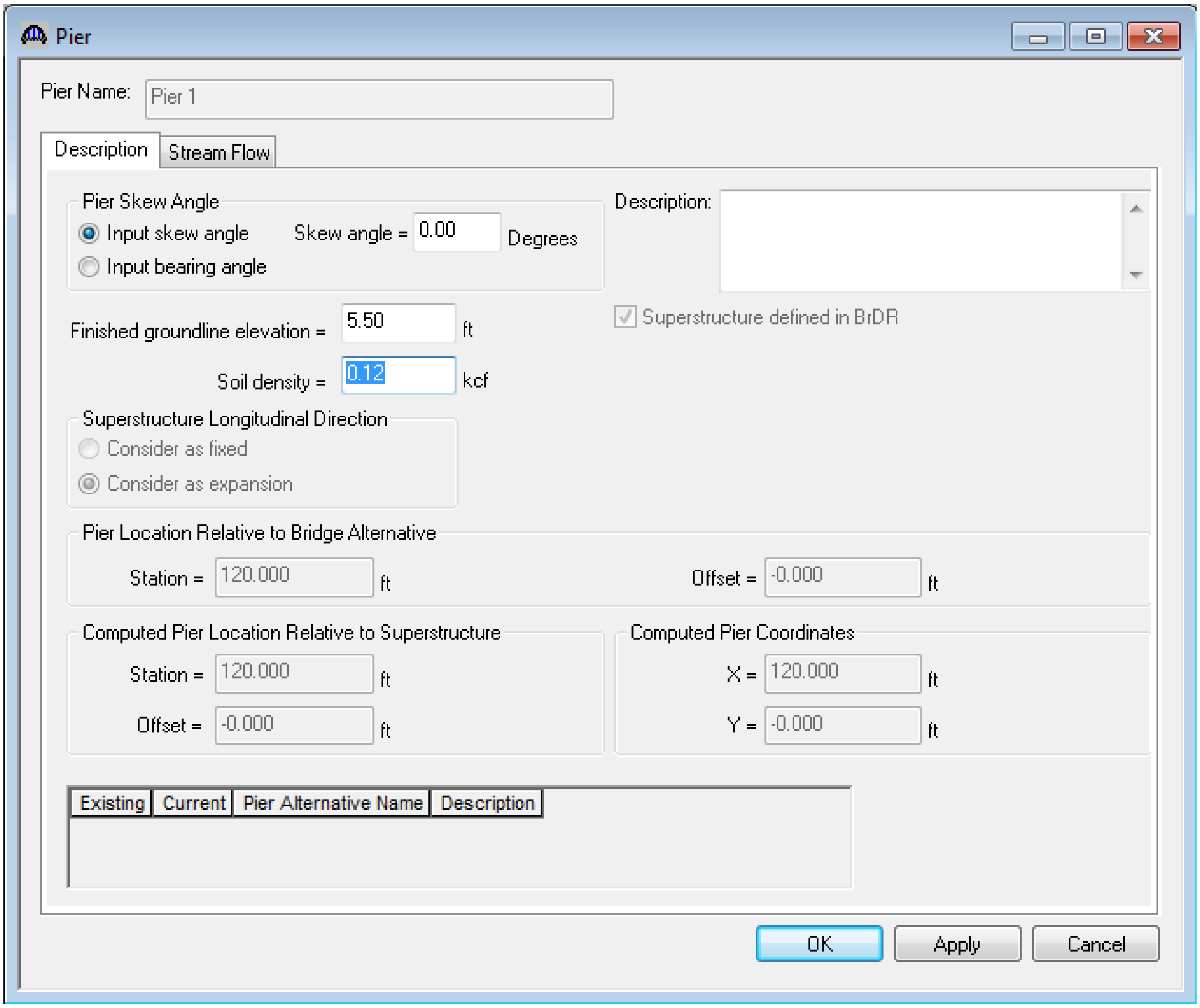
Click the ‘Generate ..’ buttons to have the wizard generate Superstructure names for us and then click the ‘Finish’ button.



Click ‘OK’ on the Bridge Alternative window and the Bridge Workspace tree appears as follows.



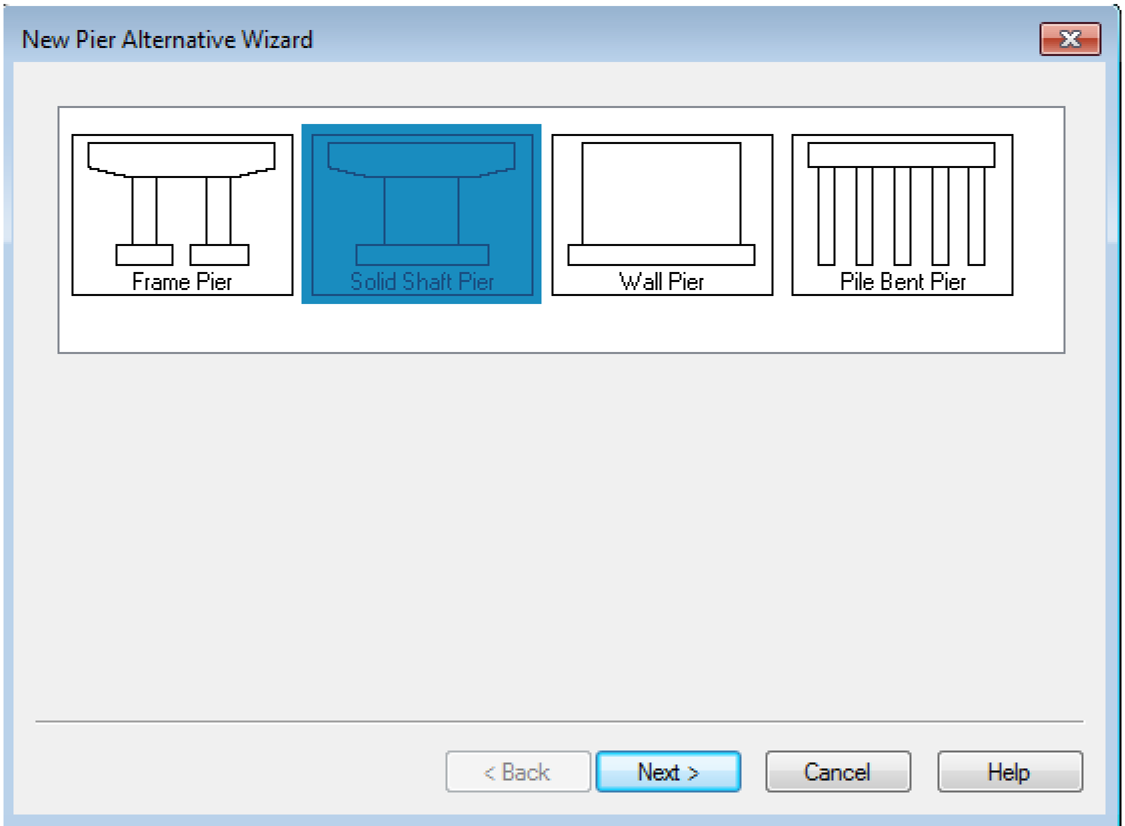
Open the Pier window and enter the following data.




This pier is not subject to stream flow so we do not have to enter anything on the Stream Flow tab. Click OK to close the window.

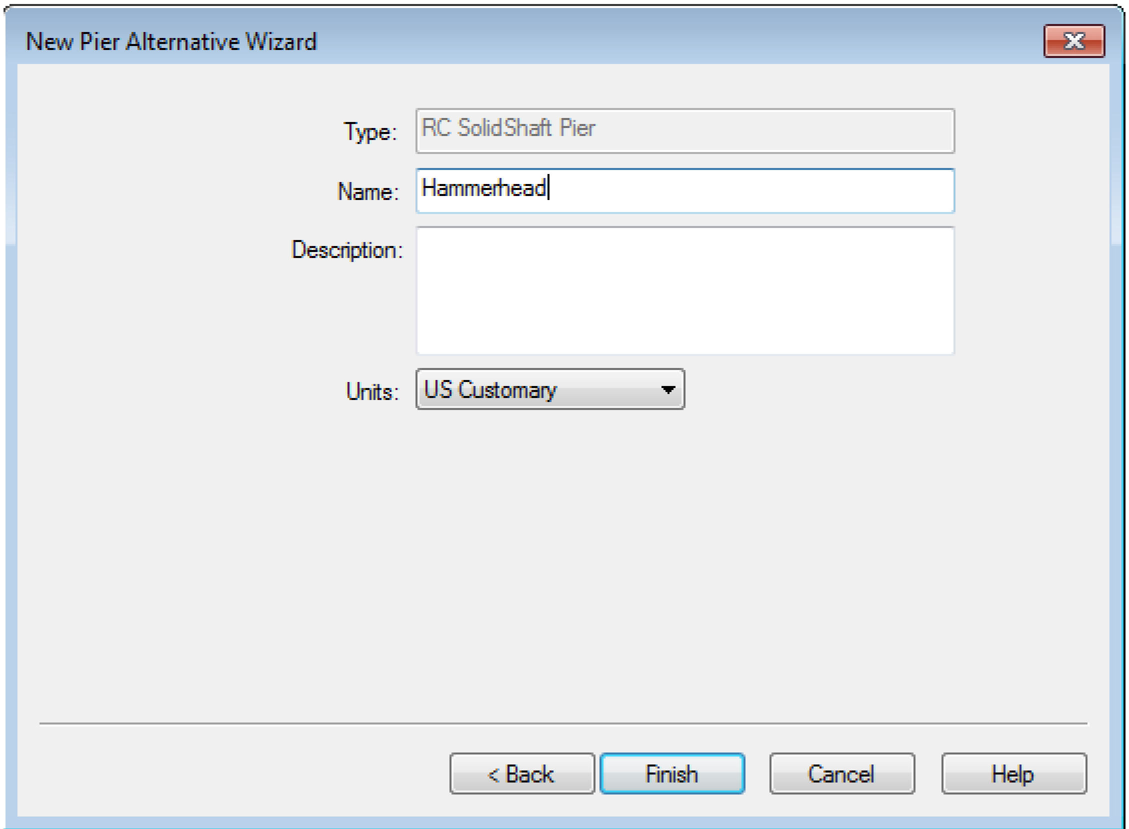
## Pier Alternatives

We are now ready to create our solid shaft pier alternative. Double click the PIER ALTERNATIVES label and the following New Pier Alternative Wizard will open.

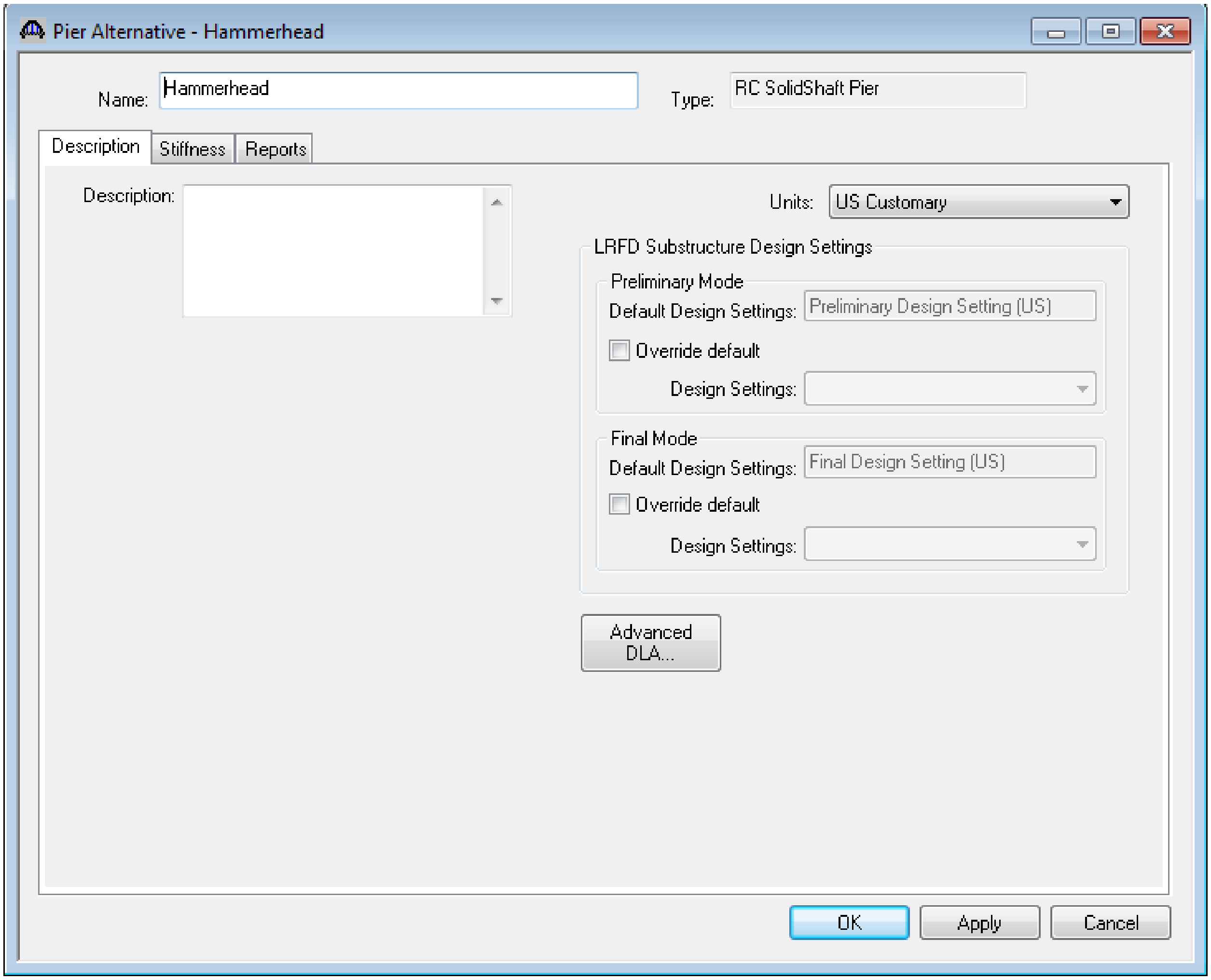



Select the solid shaft pier and click Next.

Enter a name for the pier alternative and click Finish to close the wizard and create the new pier alternative.

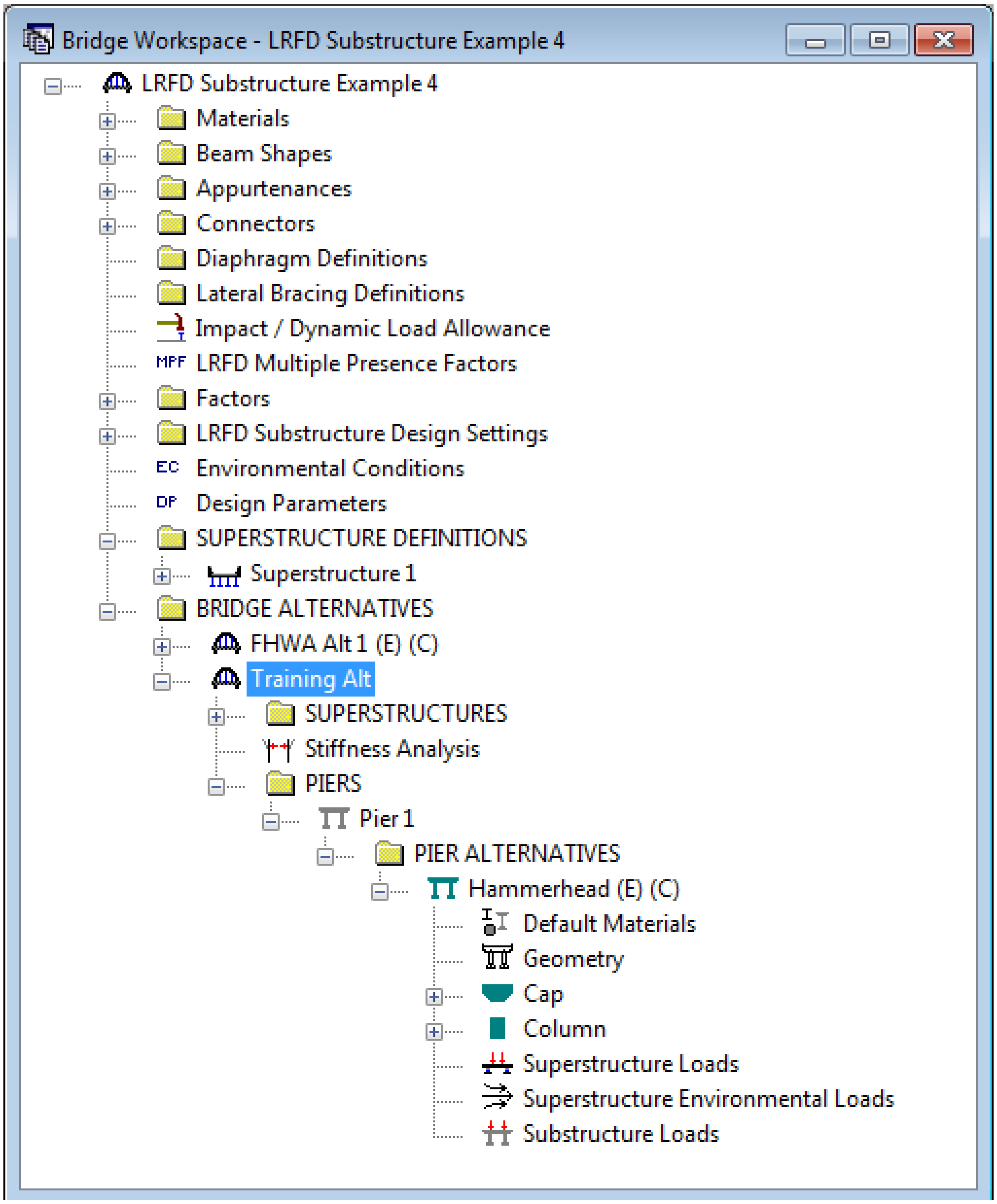


The Pier Alternative window will automatically open.



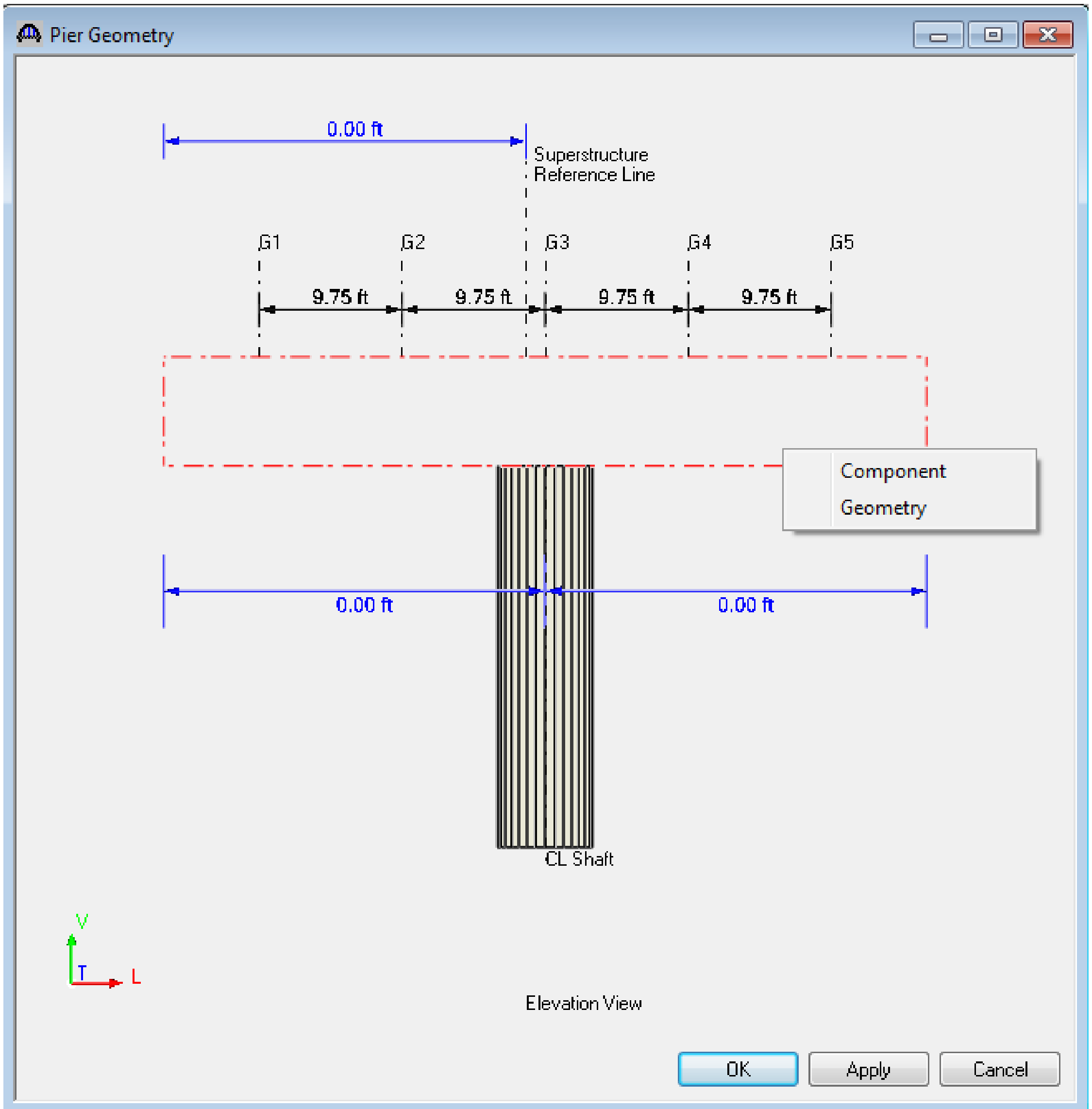

Click the Ok button to close this window. Do **not** click the Cancel button as that will cause the creation of the new pier alternative to be canceled.

The bridge workspace under Pier Alternative is shown below.



## Pier Geometry

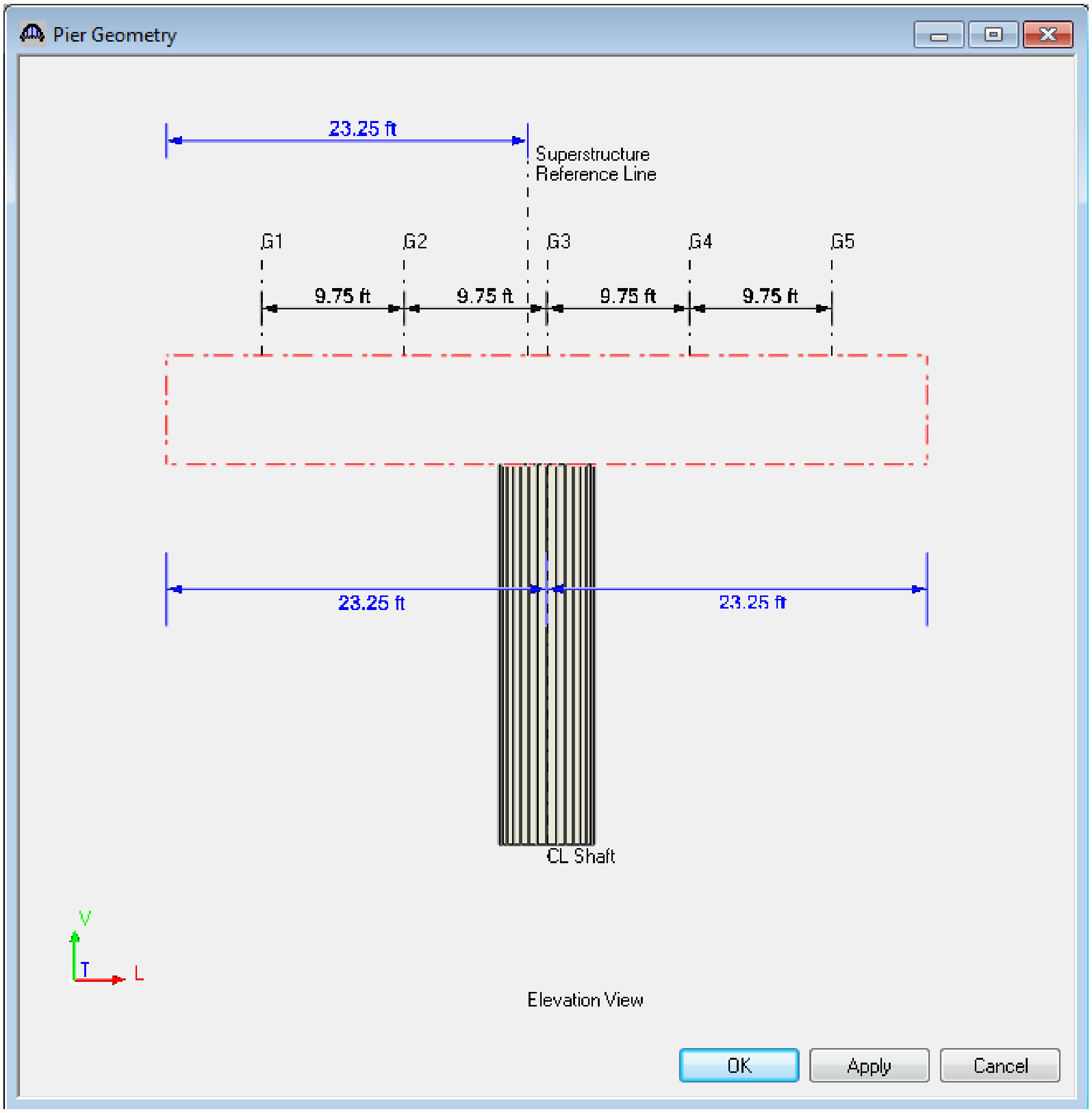
We can now start entering the geometry of our pier. Open the following Geometry window.



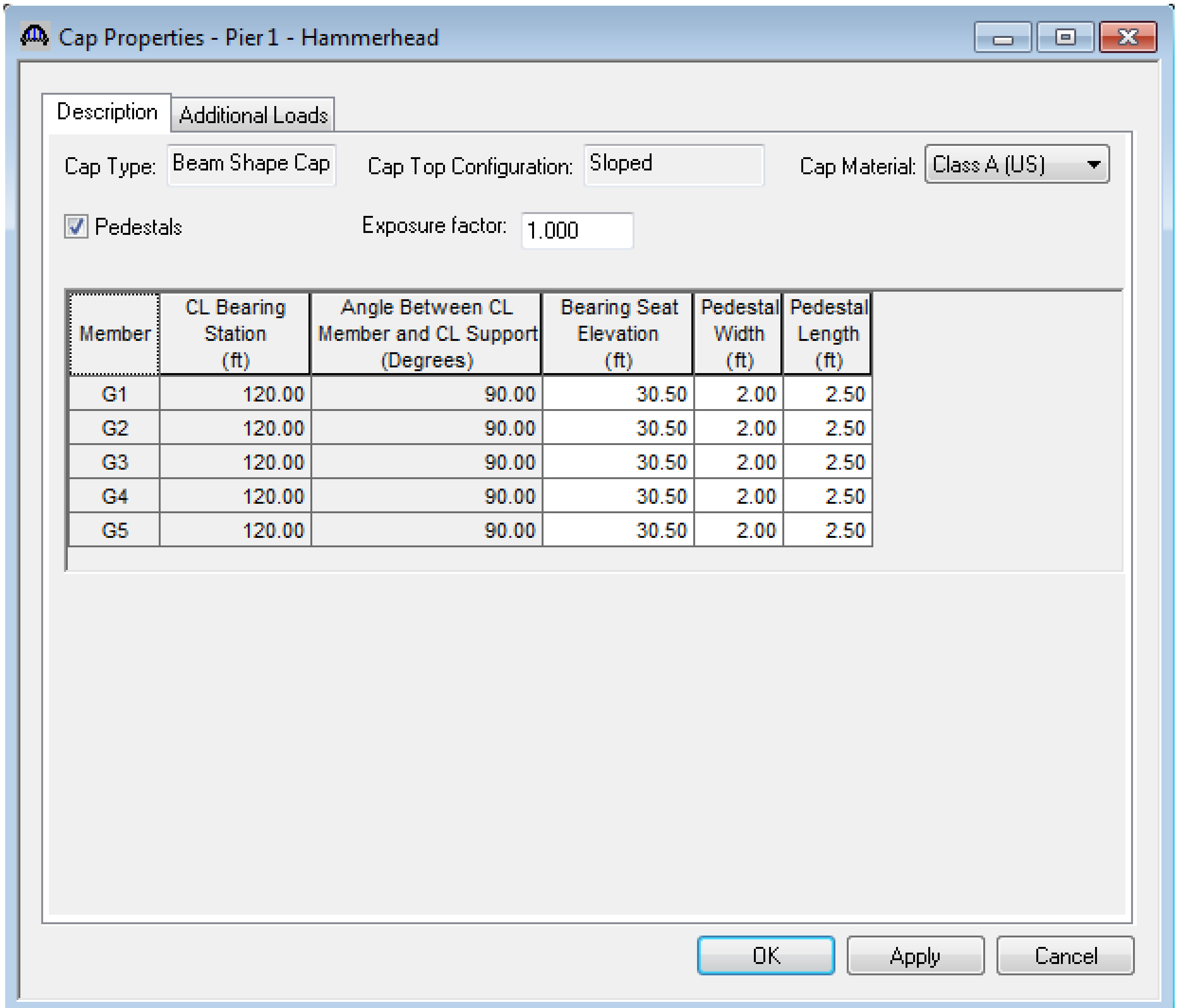

This window allows you to define some basic pier geometry. The following items should be noted about the geometry windows in BrD Substructure:

- The window is **not** drawn to scale.
- Only the values in blue font can be edited.
- If a pier component, such as the cap or column, does not have any geometry defined yet, that component is drawn with a dashed red line.
- A right click menu is available for each pier component, such as the cap or a column, which you can use to navigate to the component or geometry window for that component.

In this window, the location of the pier beneath the superstructure is set in this window by entering the distance from the superstructure reference line to the left end of the cap or wall. This is a very important dimension to input correctly since a bad value could result in your girders not being supported by the pier. Enter the following data and click the OK button.



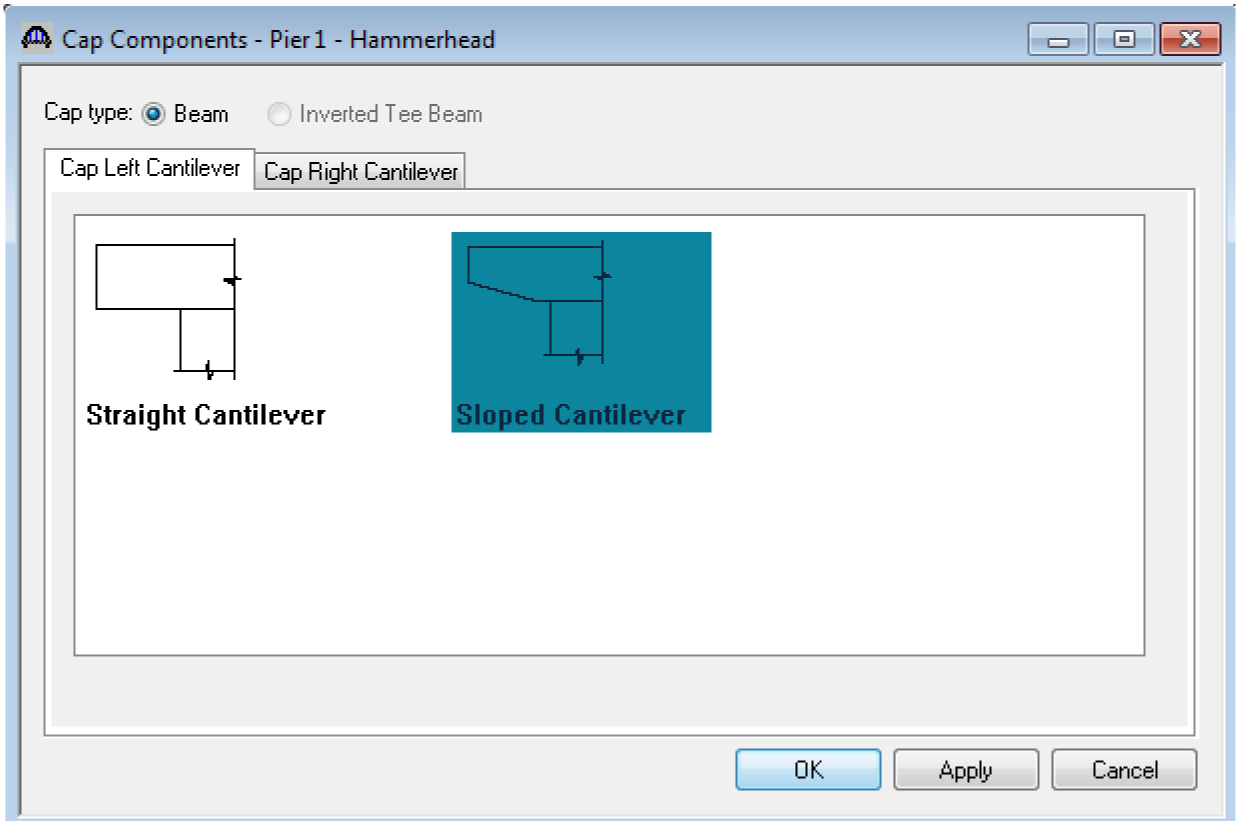
Open the Cap window and enter the following data.



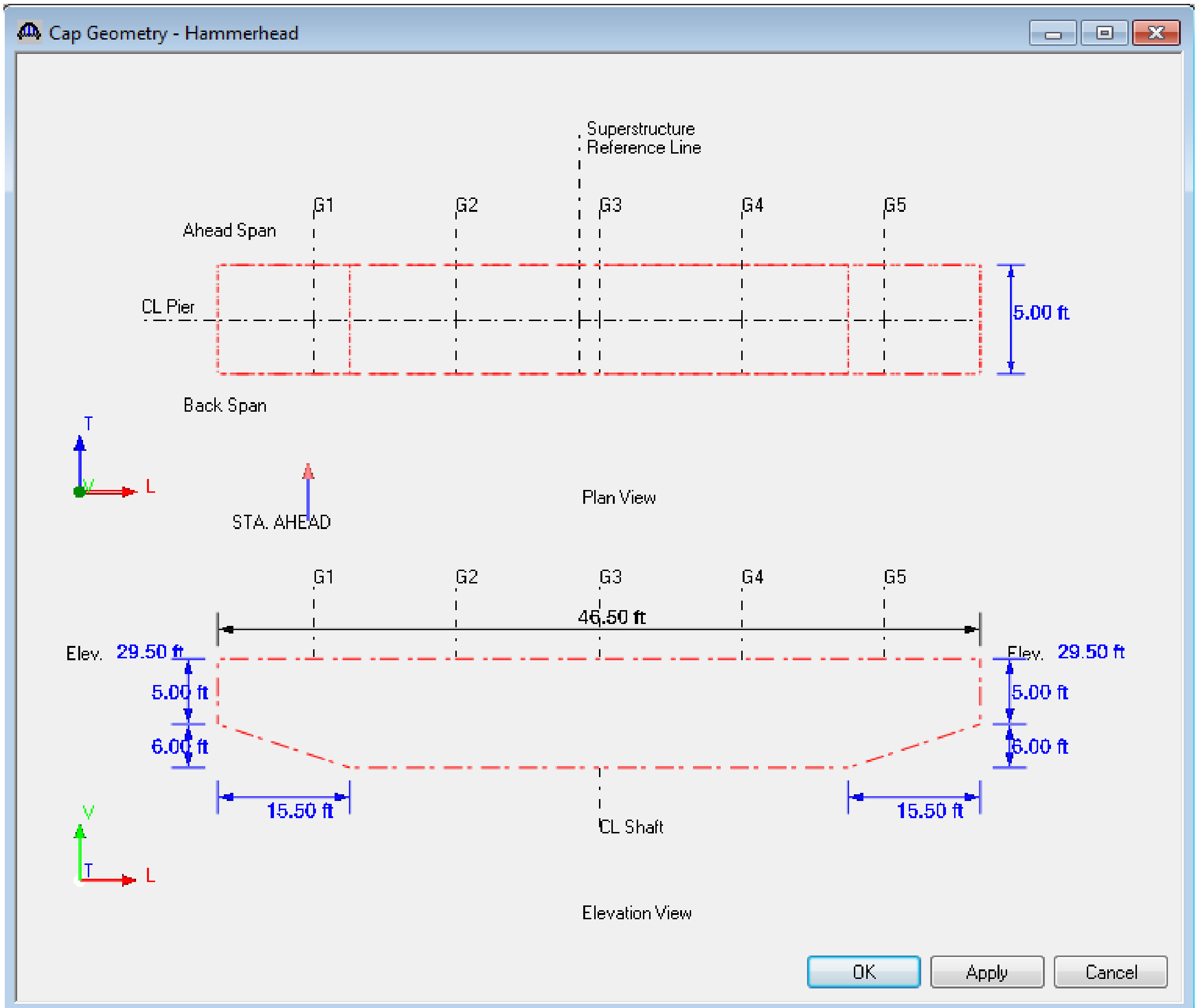

The loads from the superstructure will be applied at the bearing seat elevation specified on this tab.

The Additional Loads tab allows you to define additional, user defined loads on the cap. Our example does not contain any additional loads on the cap. Click the OK button to close the window and save the data to memory.

Expand the bridge workspace tree under the Cap label and open the Components window. Select the following type of cap cantilever component for both the left and right cantilevers.

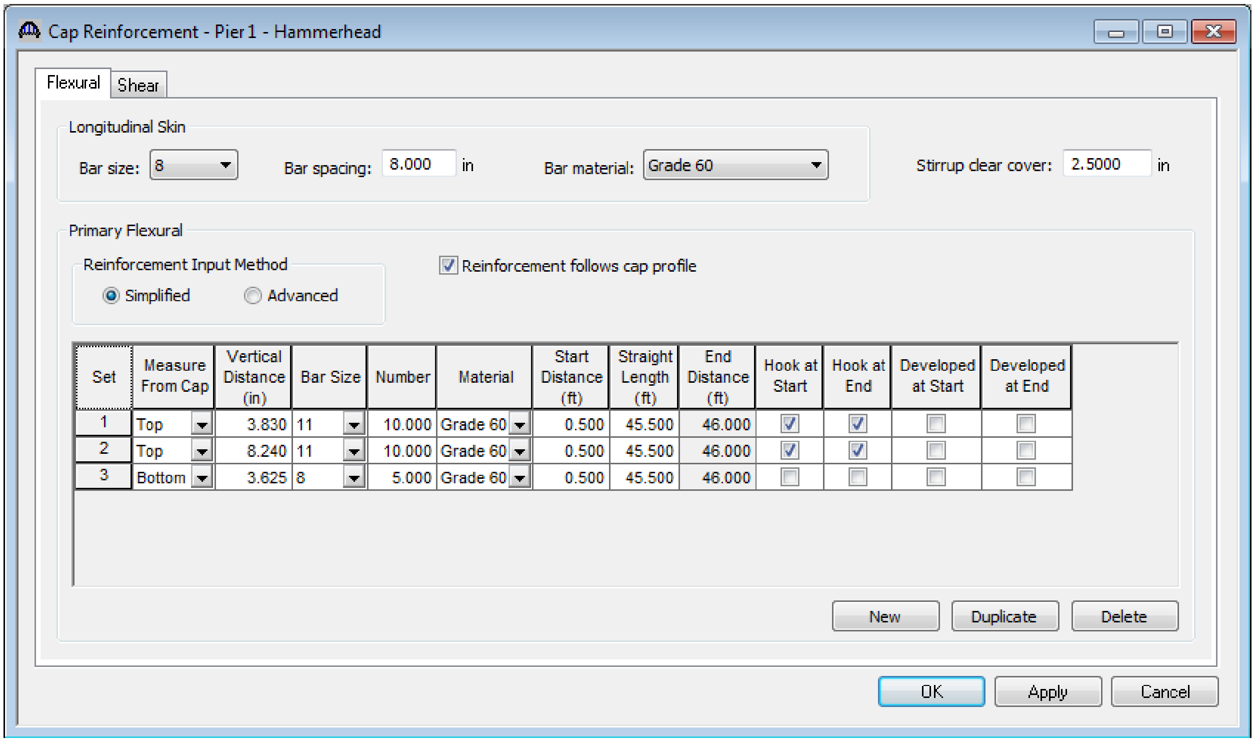


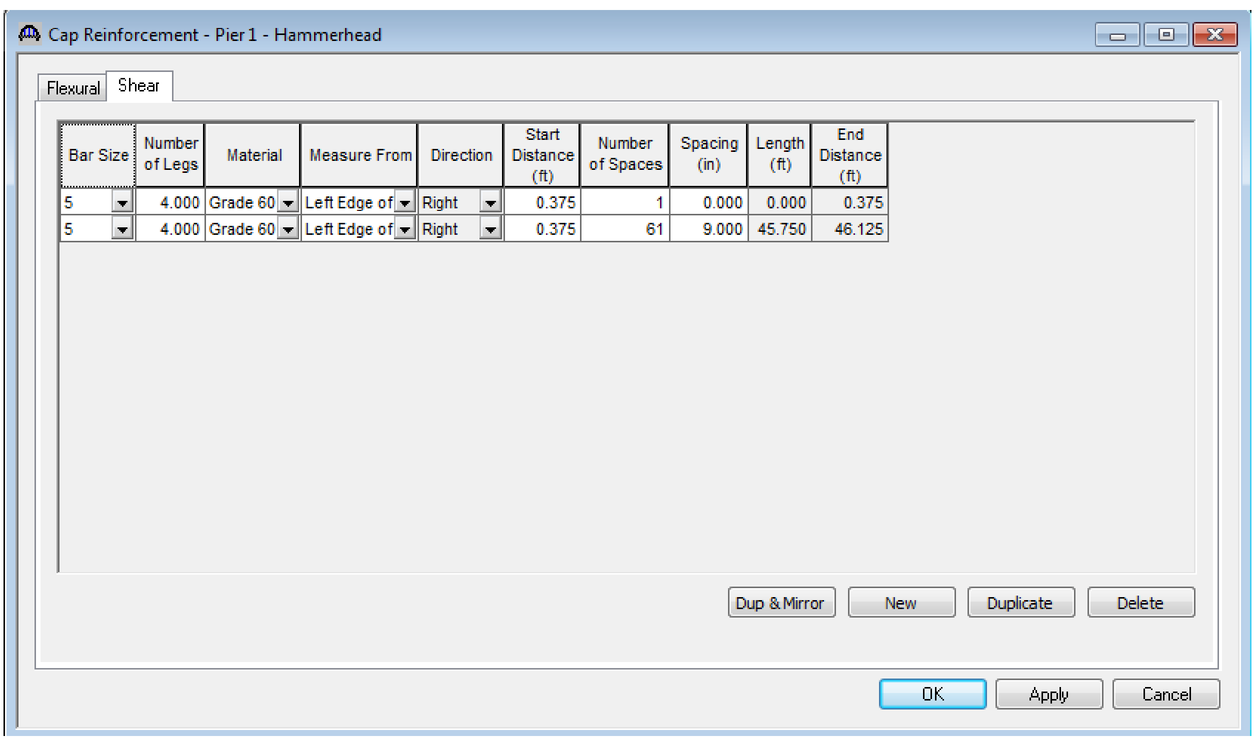
Now open the Cap Geometry window and enter the following cap geometry data.



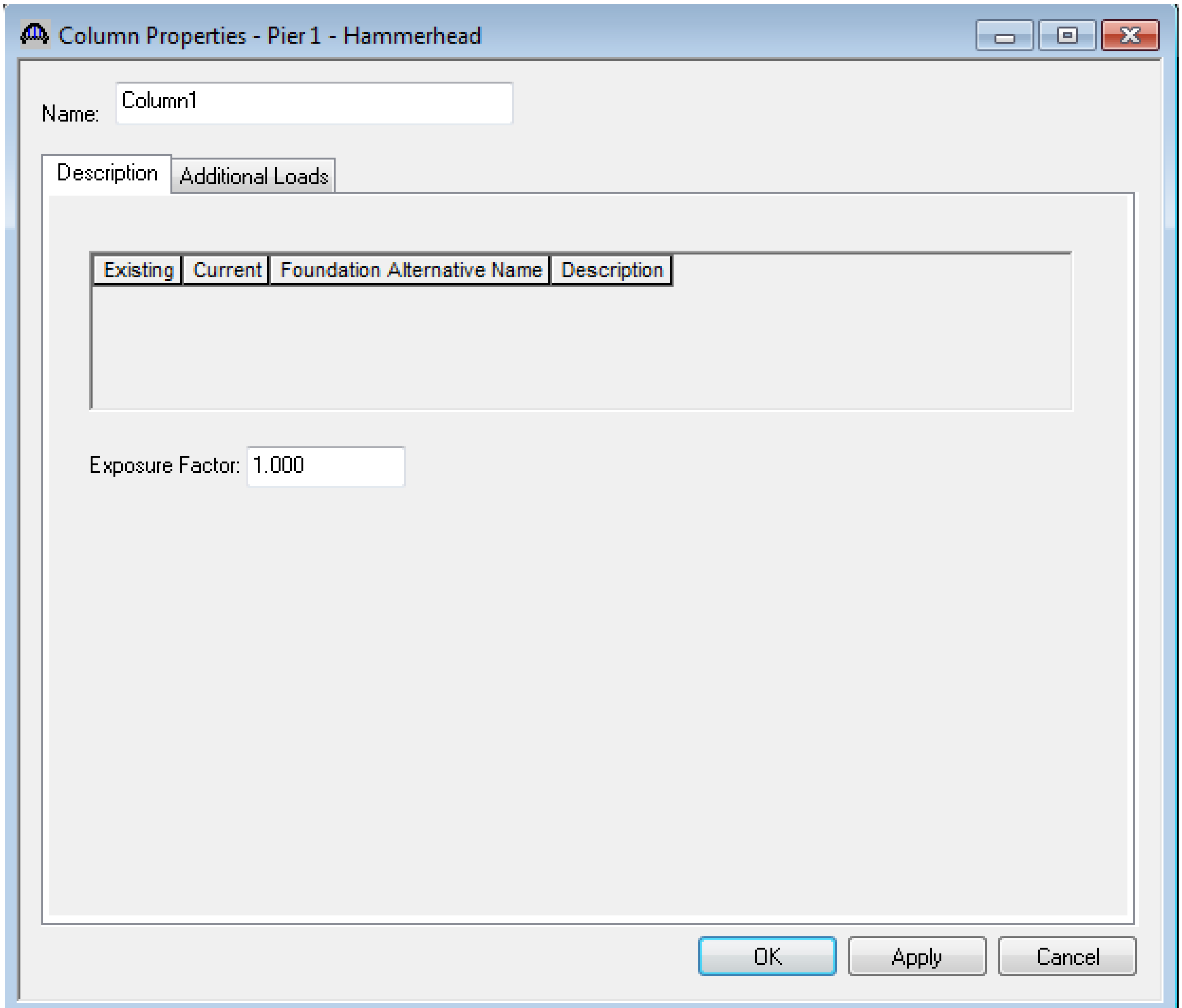

Click OK to close the window.

Open the Reinforcement window and enter the following data.

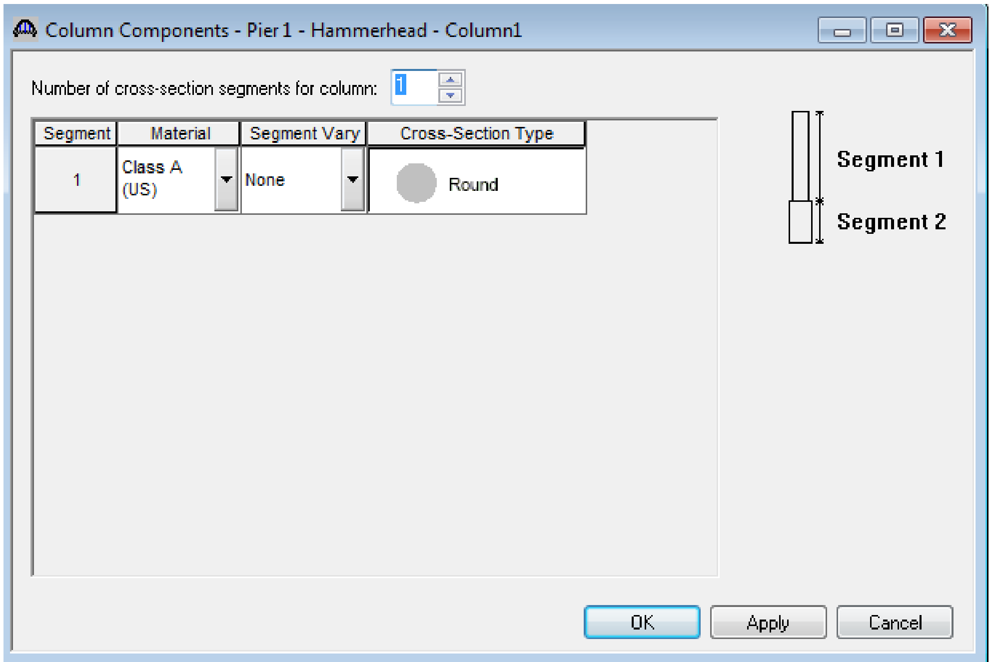


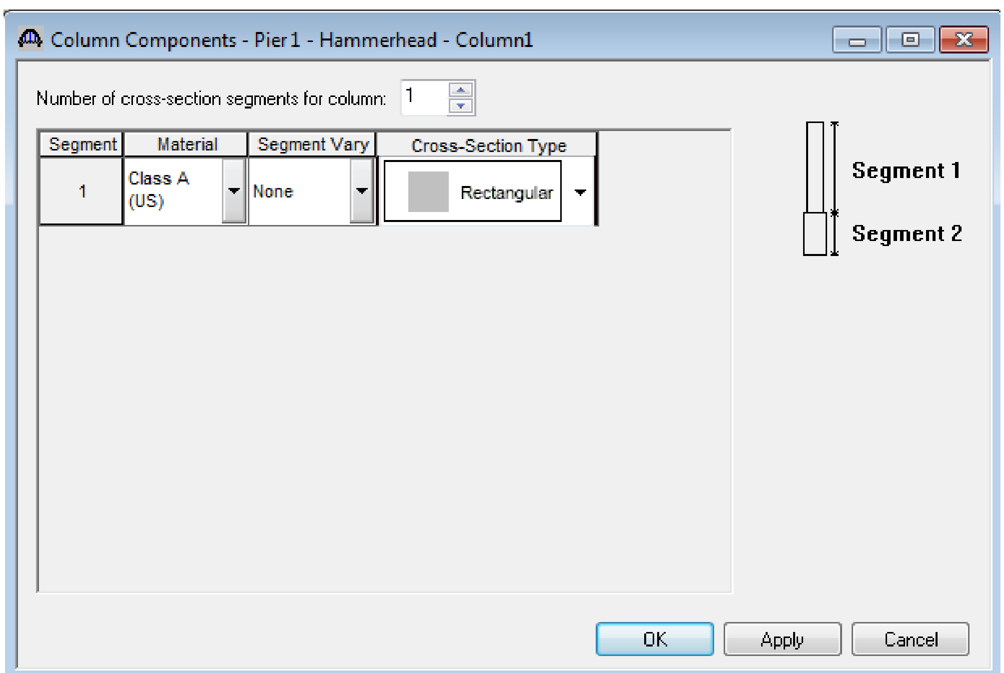
Open the Column window, enter the Exposure Factor and click OK to close the window.



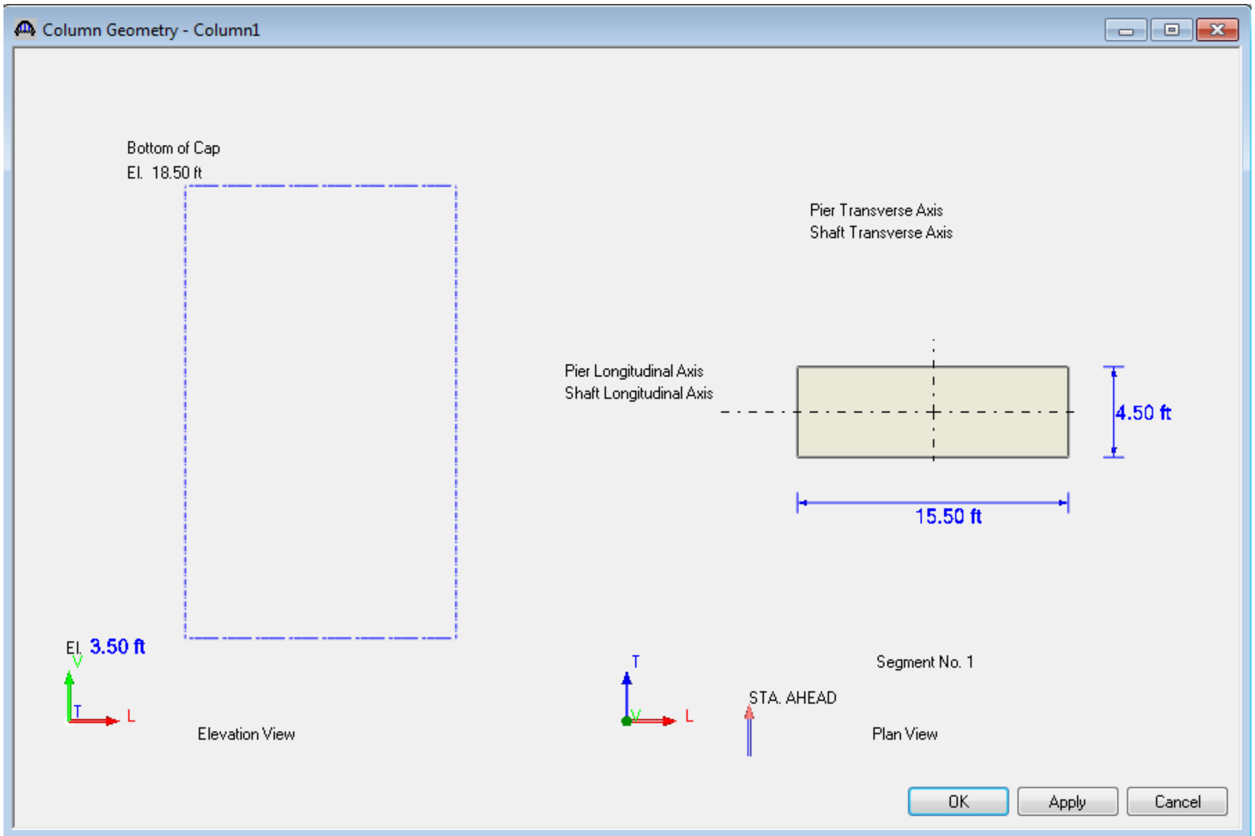
The Column Components window is shown below. This window allows you to specify the cross-section segments in the column. Segment cross-sections can vary linearly over their height. In our example, the cross-section is constant over its height.




BrD sets the default column cross section type as circular when a column is created. Our example has a rectangular column cross section so change the cross section type to rectangular as shown and click OK.

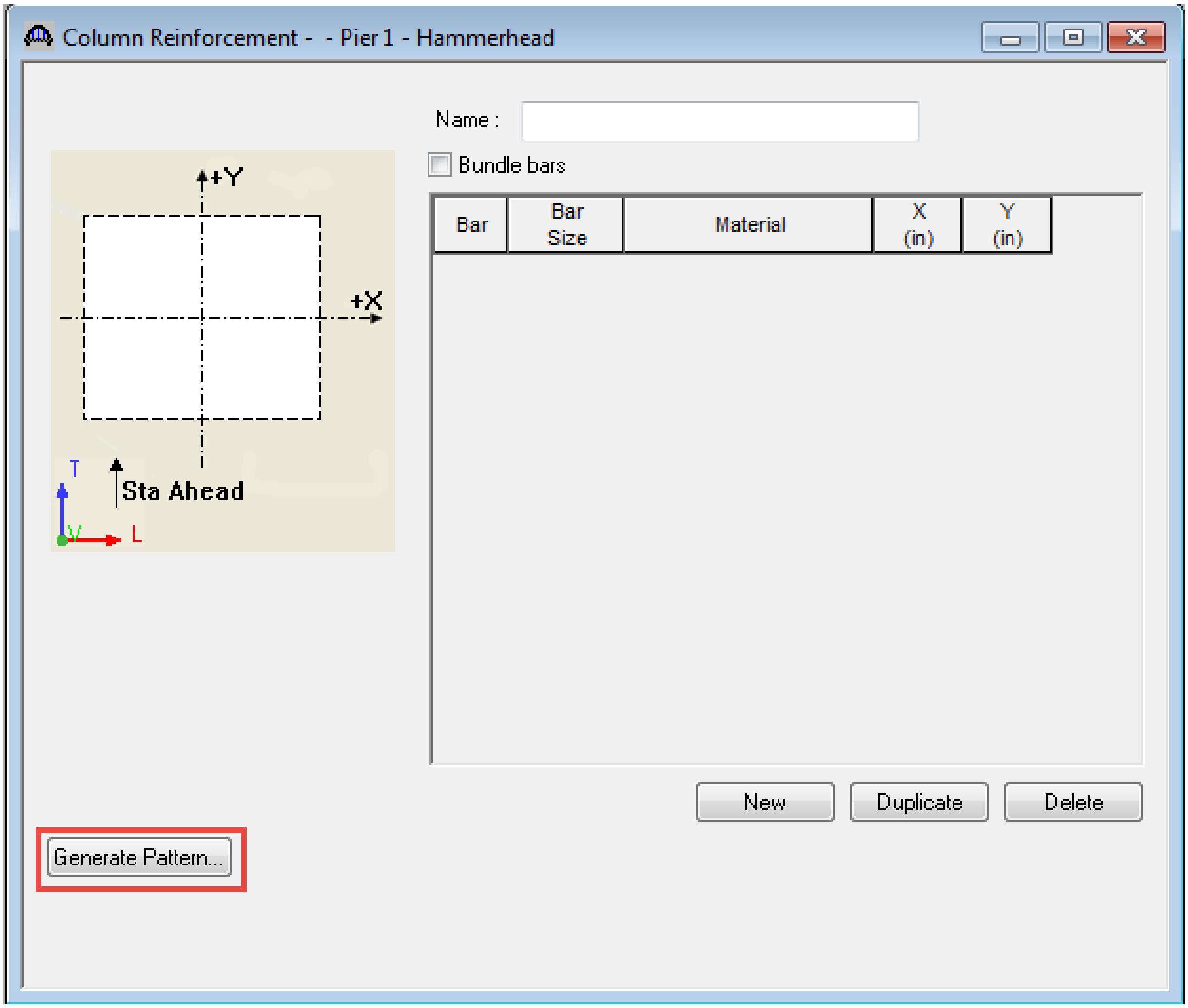


Open the Column Geometry window and enter the following column geometry data.



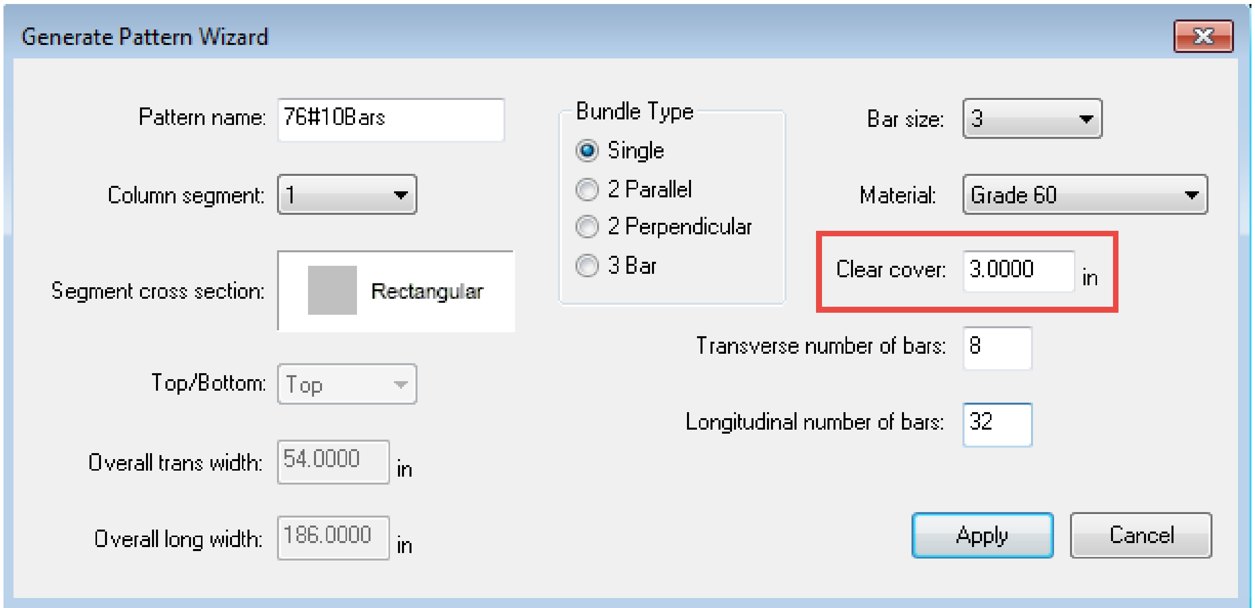

Click OK to close the window.

Double-click the Reinforcement Definitions label to create a new reinforcement definition for the column. The reinforcement definition will later be assigned to ranges over the height of the column.

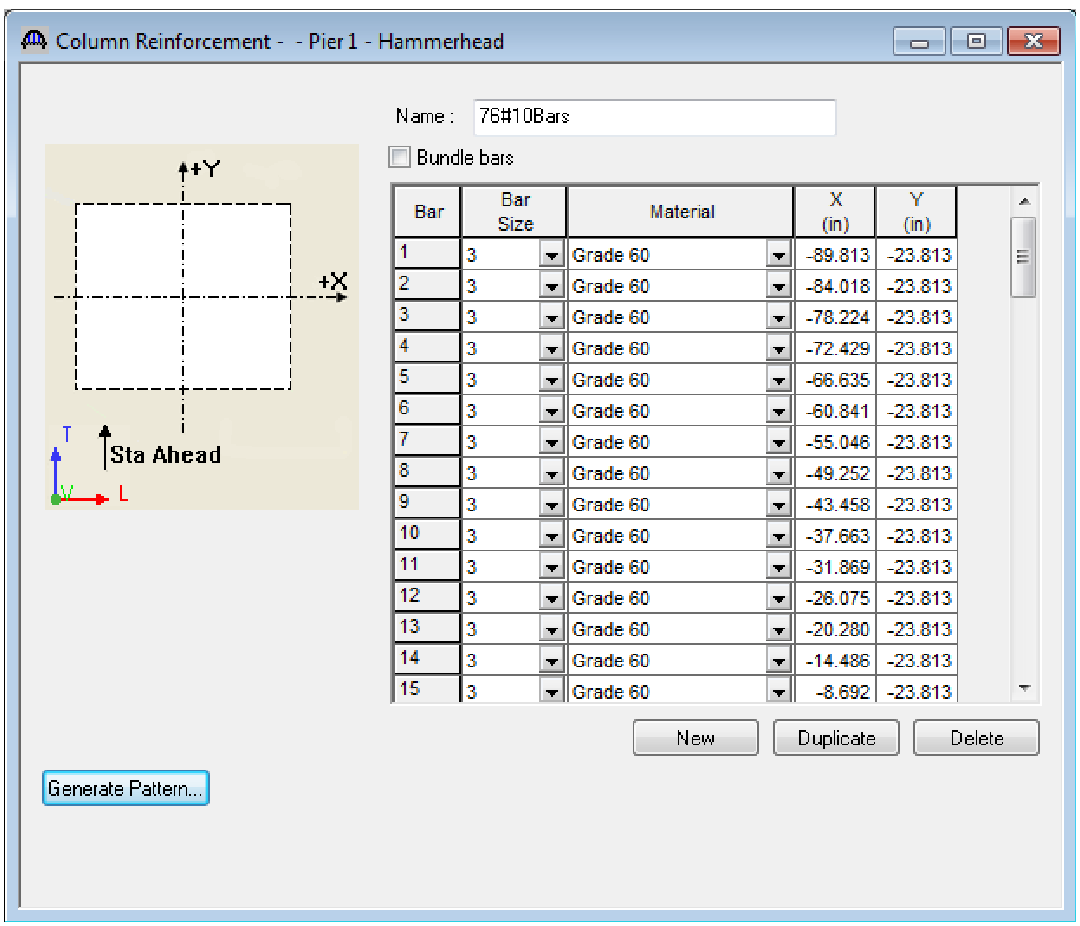



Click the Generate Pattern button to open the following wizard to create a pattern for the column flexural reinforcement.

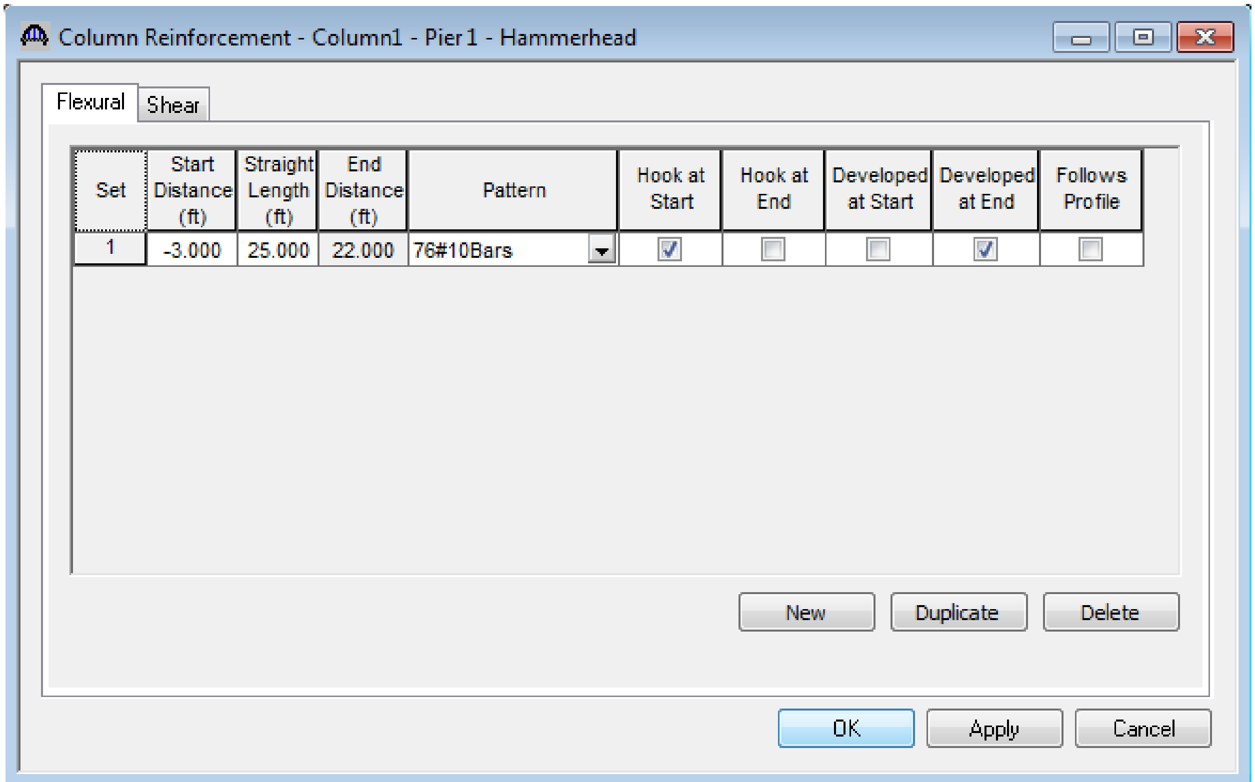
The clear cover is cover to the face of the flexural reinforcement. In this case the cover to the face of the ties is 2.5" and the tie is a #4 bar so the clear cover is 3.0".



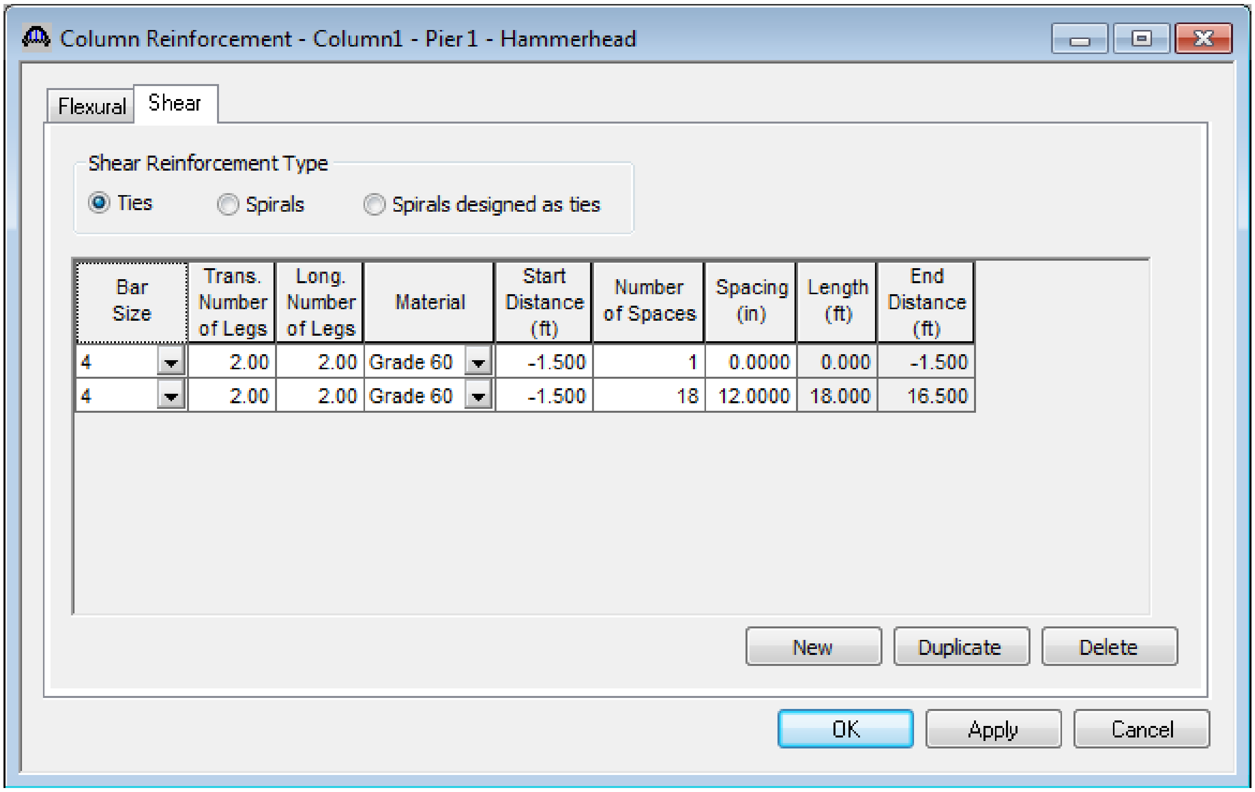

Clicking the Apply button will create the following pattern.



Now open the Column Reinforcement window and assign this pattern as follows. The negative start distance is used because the rebars extend into the footing.

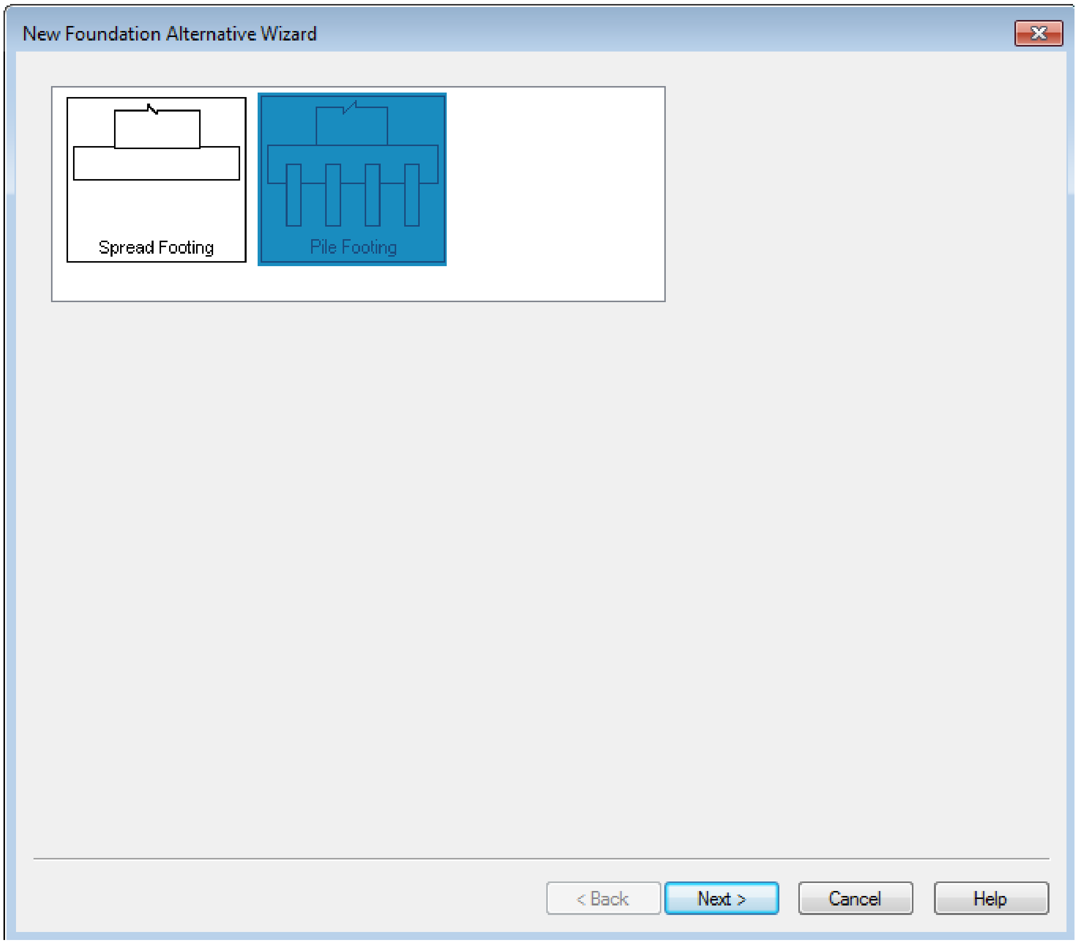


Enter the following shear reinforcement. The ties extend into the footing and cap as they would be detailed on the design drawings but BrD will not consider the shear reinforcement in the footing or cap when performing specification checks.

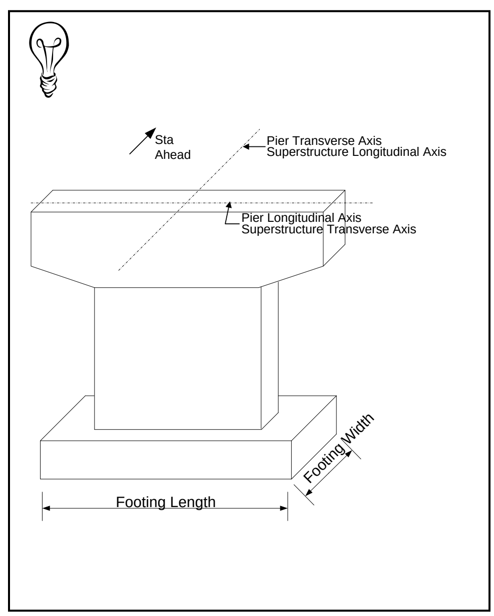


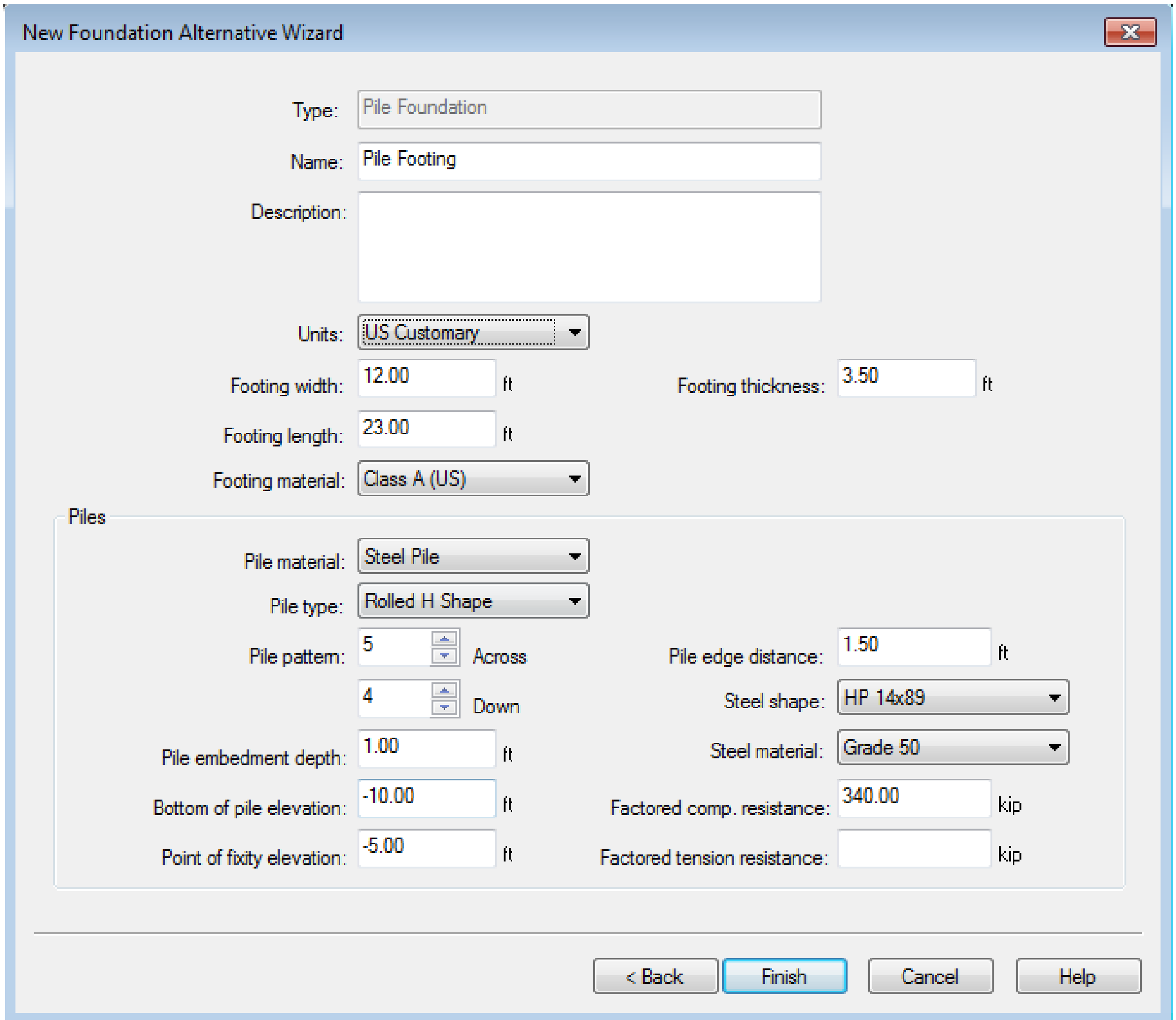

Click 'OK' to save this data. You will get a warning message that the flexural reinforcement is not located inside the footing and that the shear reinforcement extends below the column. This message is issued because the rebar is defined as extending into the footing but the footing dimensions have not been entered yet. Click 'Yes' to save the reinforcement data.

Double click the FOUNDATION ALTERNATIVES label and the New Foundation Alternatives wizard will open. Select the Pile Footing option. Click Next.

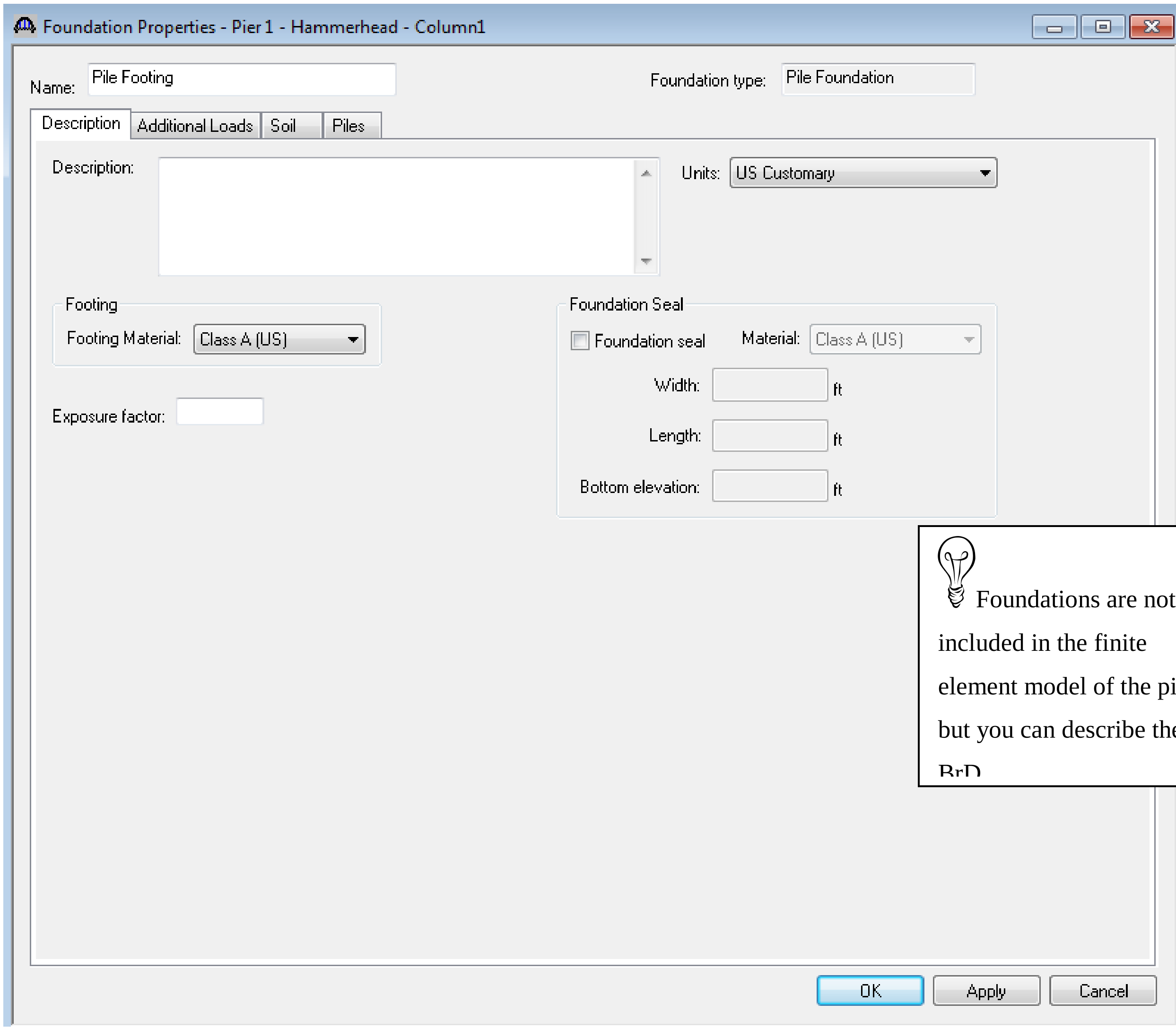



Enter the following description of the foundation.



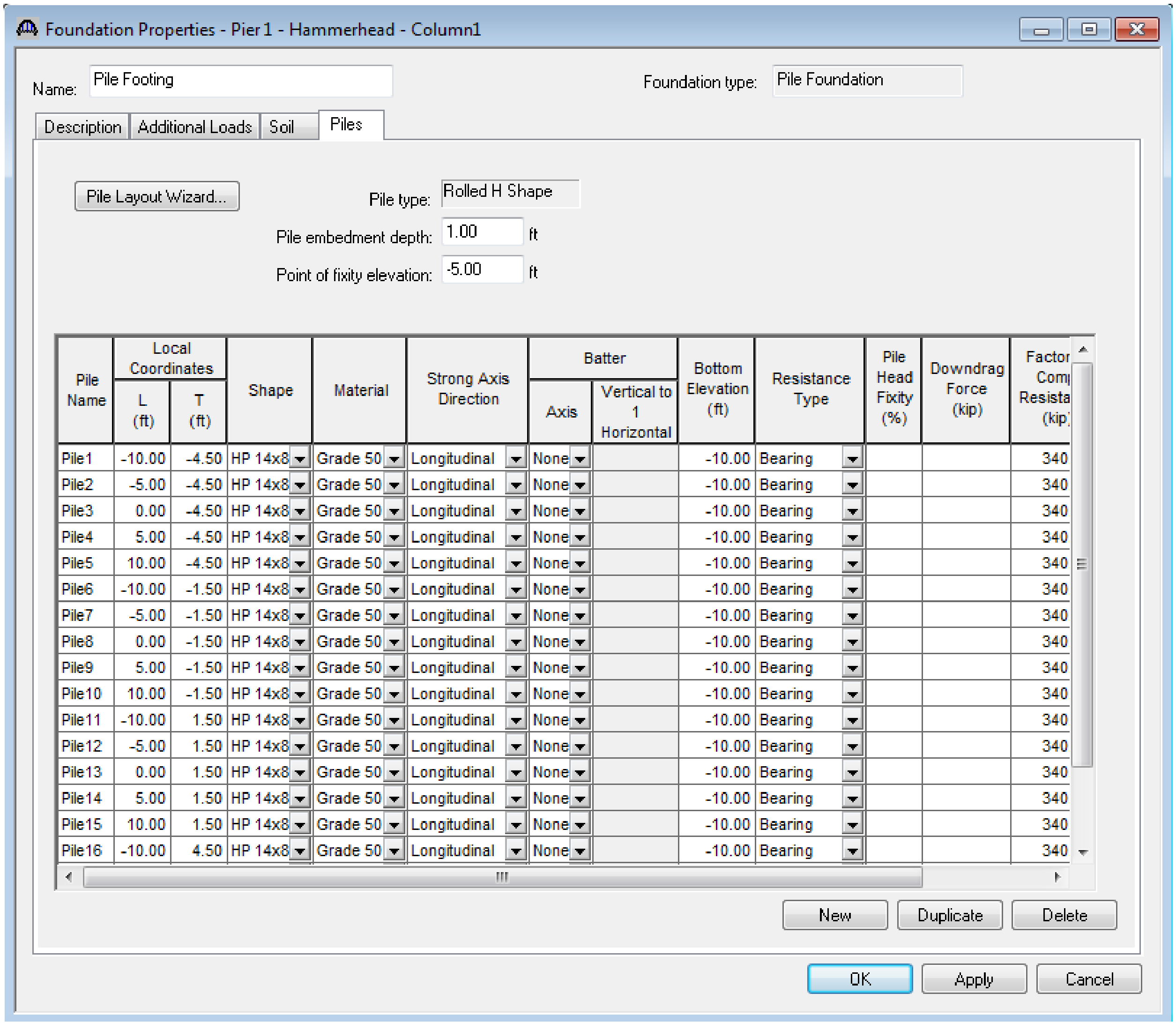



Click Finish and the Foundation Properties window will open.



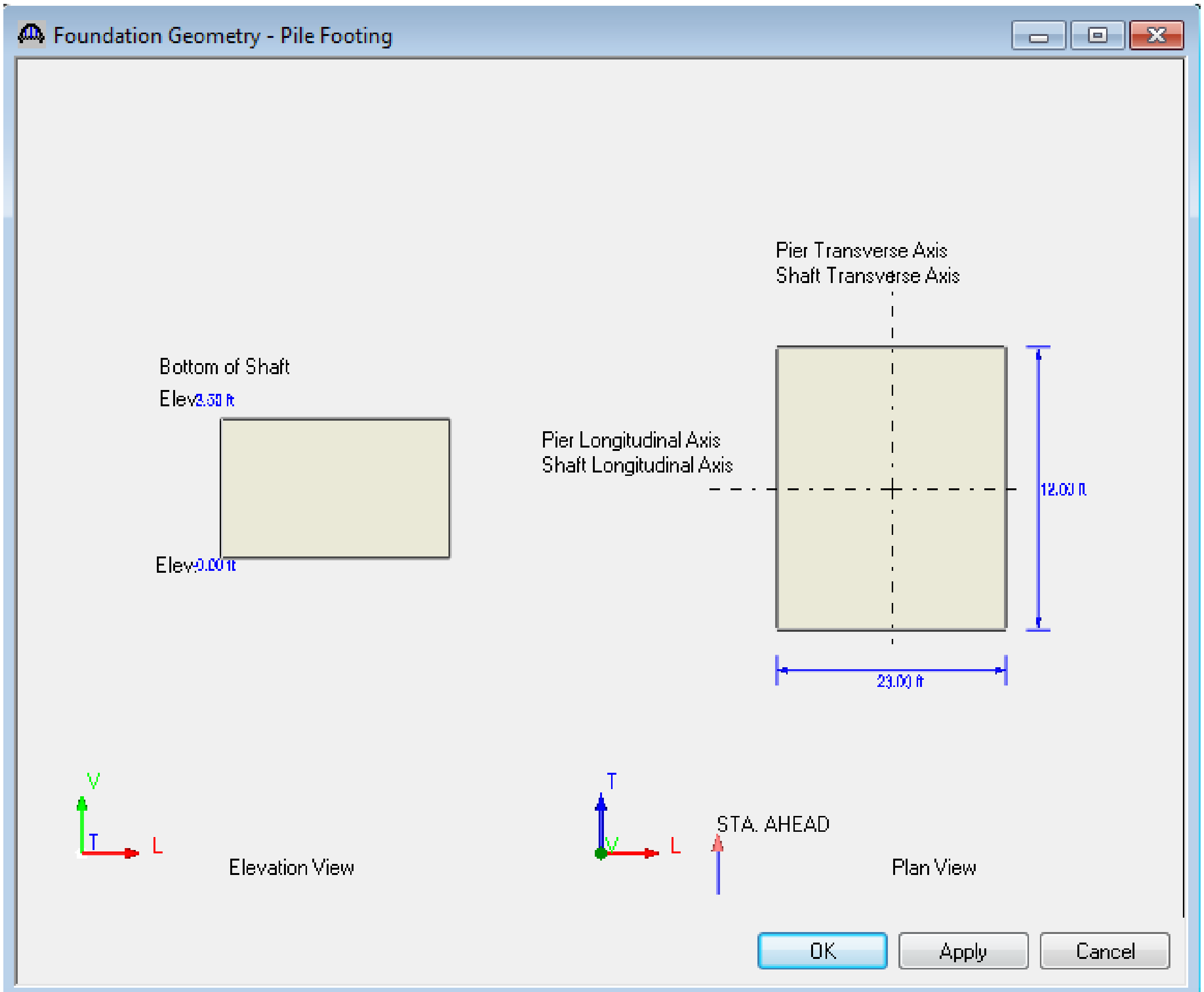

Foundations are not included in the finite element model of the pier but you can describe them in BrD

Select the Piles tab to view the pile information.



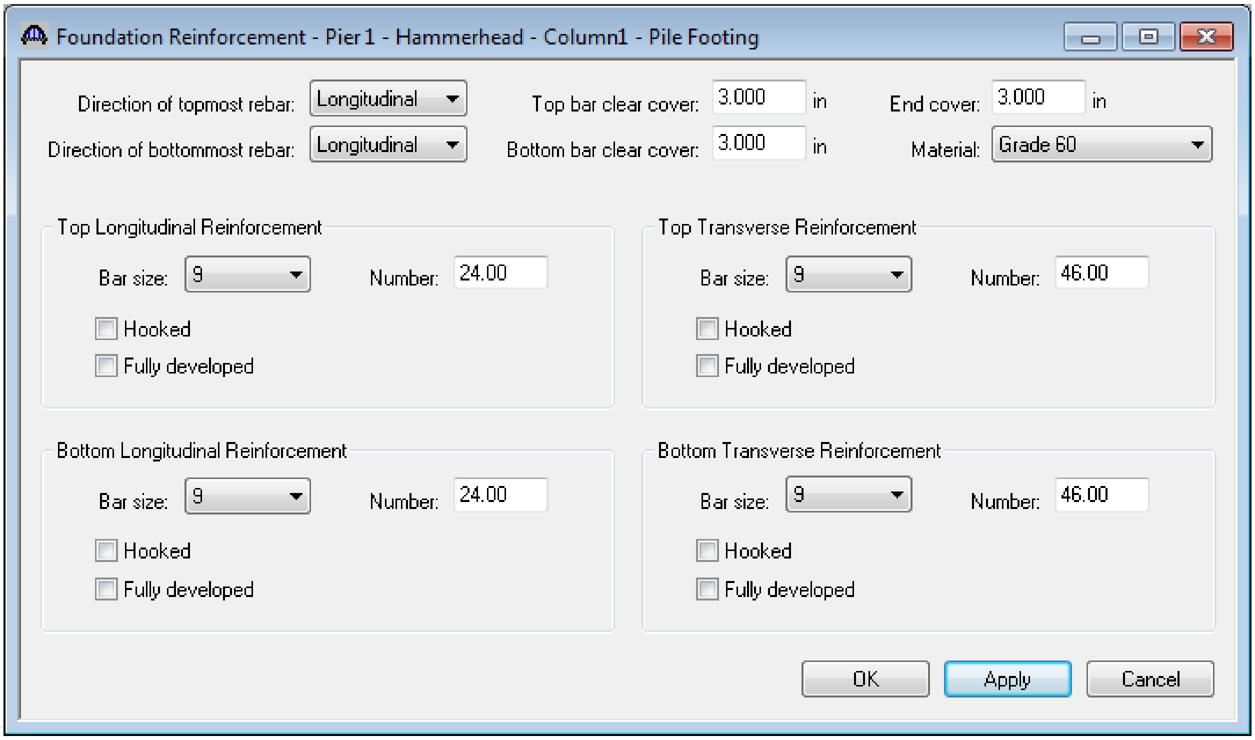
There is no additional information to enter so click the OK button. Do **not** click the Cancel button as that will cause the creation of the new foundation alternative to be canceled.

Open the Foundation Geometry window.



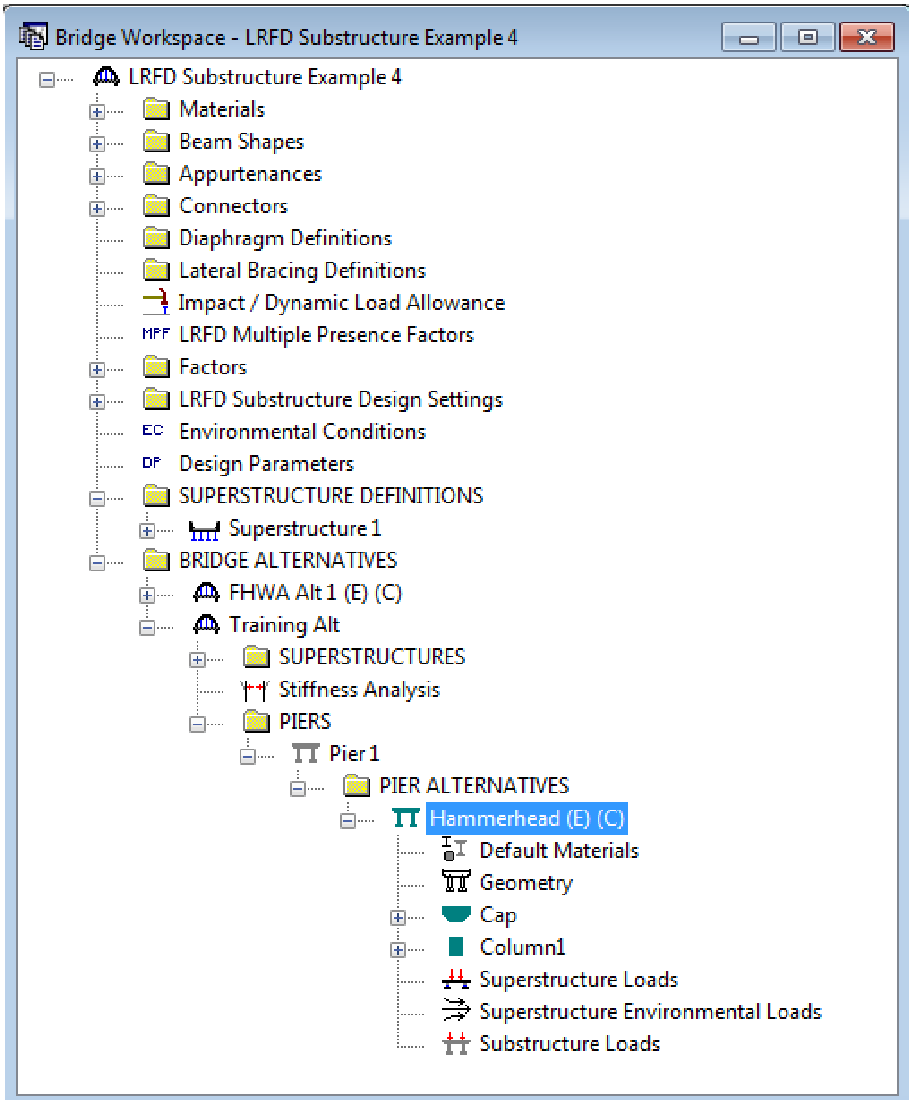

Our bottom of footing elevation is zero feet. Click the OK button to save this data to memory.

Enter the following reinforcement for the footing.



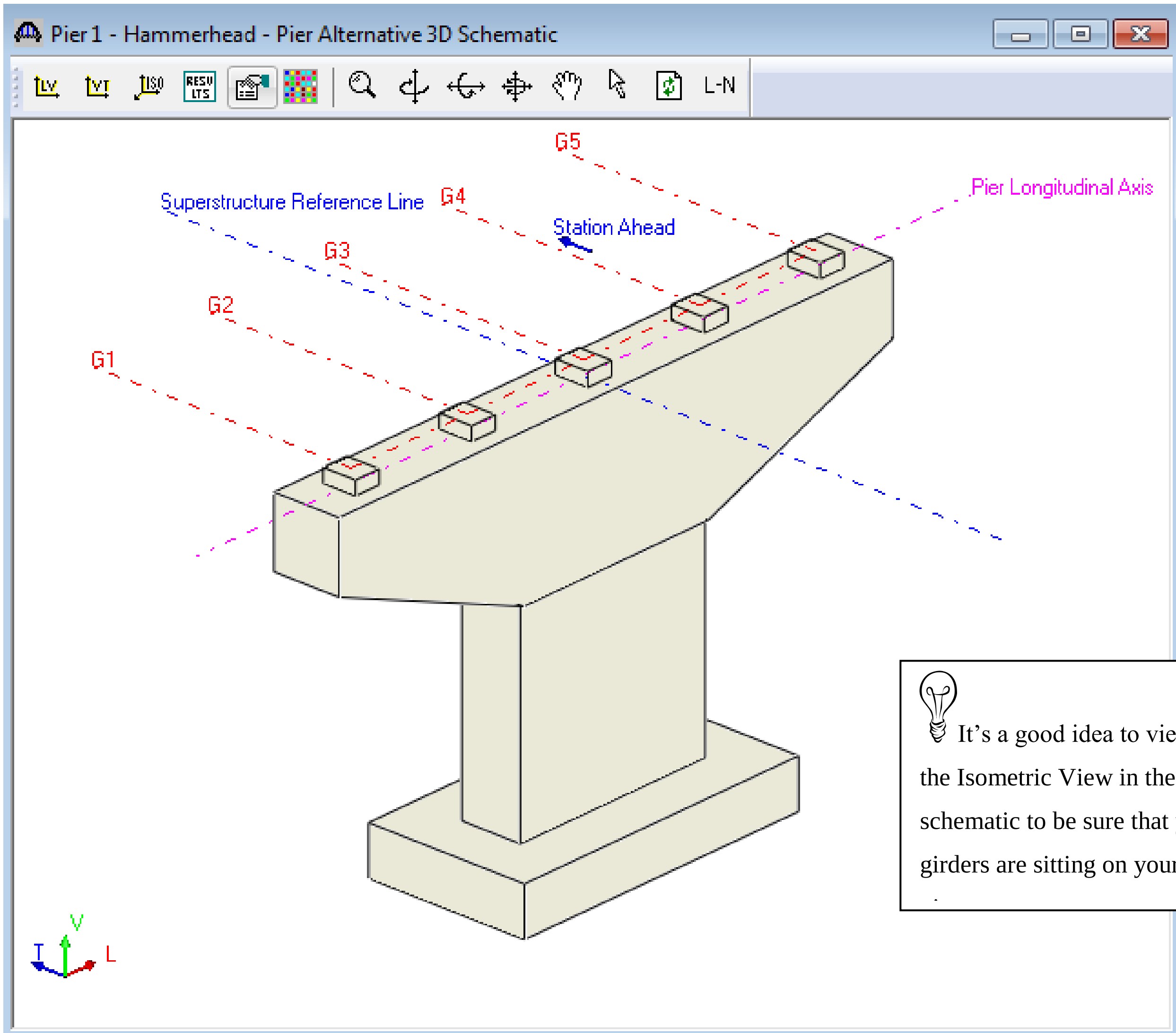
## Pier 3D Schematic

We can now view the 3D schematic of the pier alternative. Select the name of our pier alternative in the bridge workspace tree. The 3D schematic can then be accessed by the "3D" button on the BrD Substructure toolbar shown below.





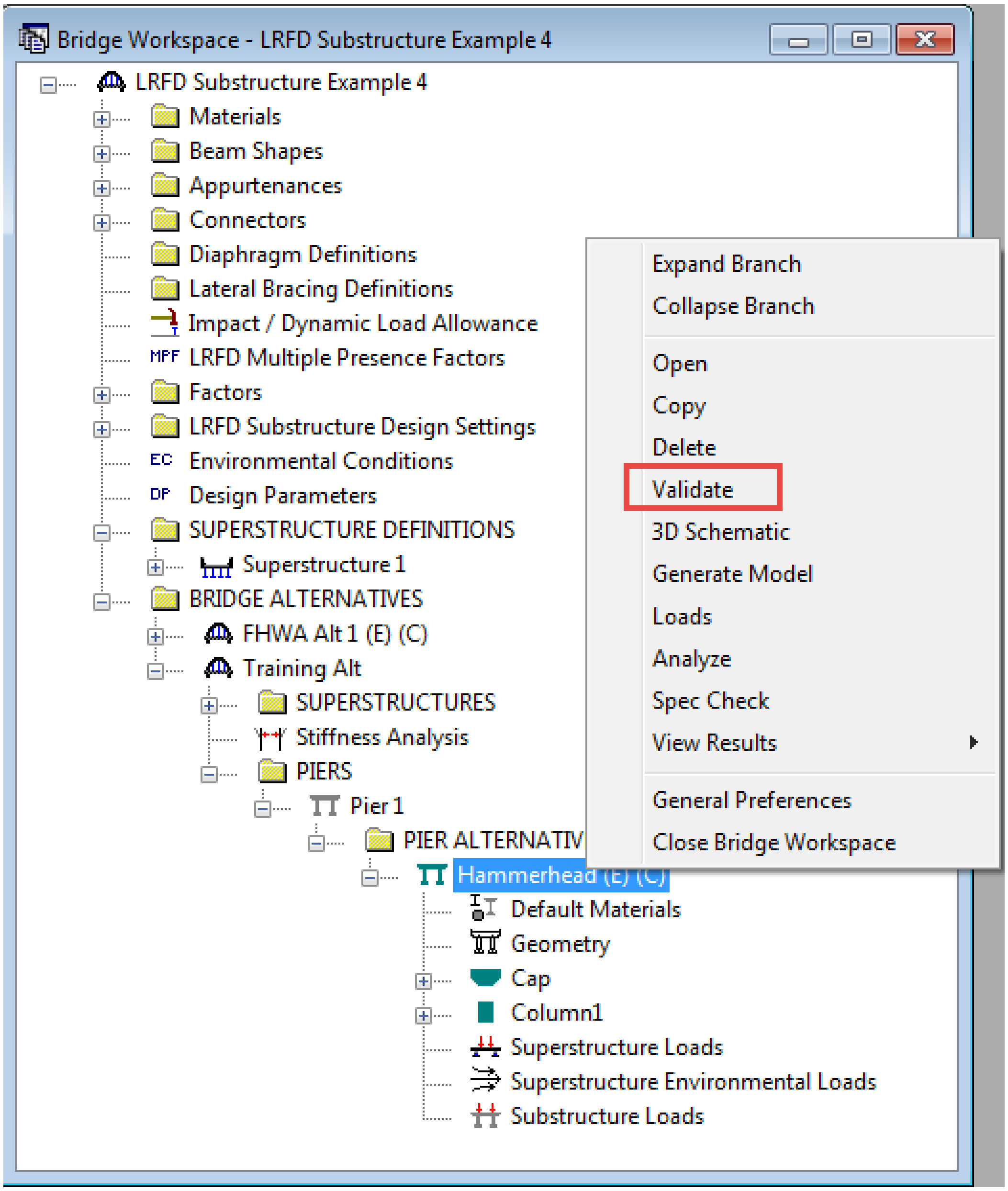
This 3D schematic is a to-scale drawing of the pier alternative. This schematic view has a lot of useful features like rotating, scaling, and dimensioning. Select F1 to open the BrD help topic for this window to review the features available in this schematic window.




It's a good idea to view the Isometric View in the schematic to be sure that your girders are sitting on your

## Validating a Pier Alternative

Another useful feature is to validate your pier alternative once you have the geometry defined. This will alert you to any missing or incorrect data in your pier description. You can access the validation feature from the right-click menu available when your pier alternative is selected in the bridge workspace tree.



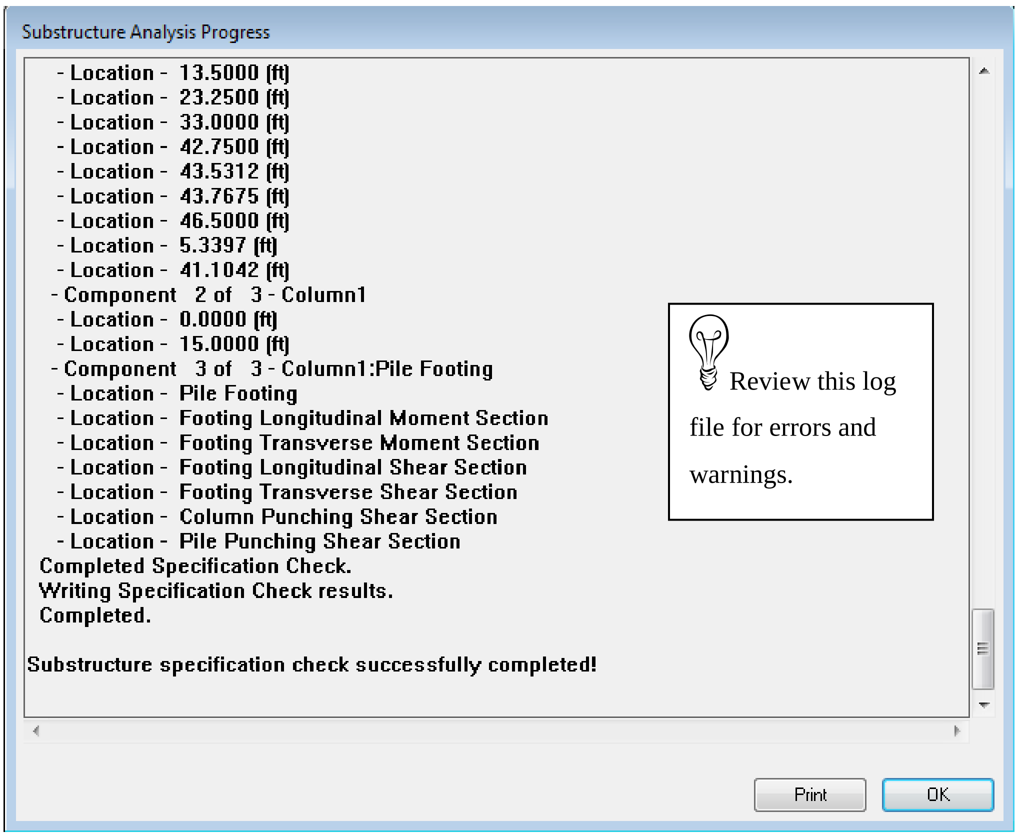

This opens a window which contains warnings and errors if your pier alternative description is in error or missing data.

## Pier Analysis and Specification Checks

We are now ready to analyze our pier. Select the 'Spec Check' toolbar button from the BrD Substructure toolbar.


The superstructure will first be analyzed to determine the superstructure dead load reactions. The remaining loads acting on the pier (such as live load, wind, etc.) are computed and applied to the pier finite element analysis. Load combinations are generated and then the specification checks are processed.

The Substructure Analysis Progress dialog will open as shown below.



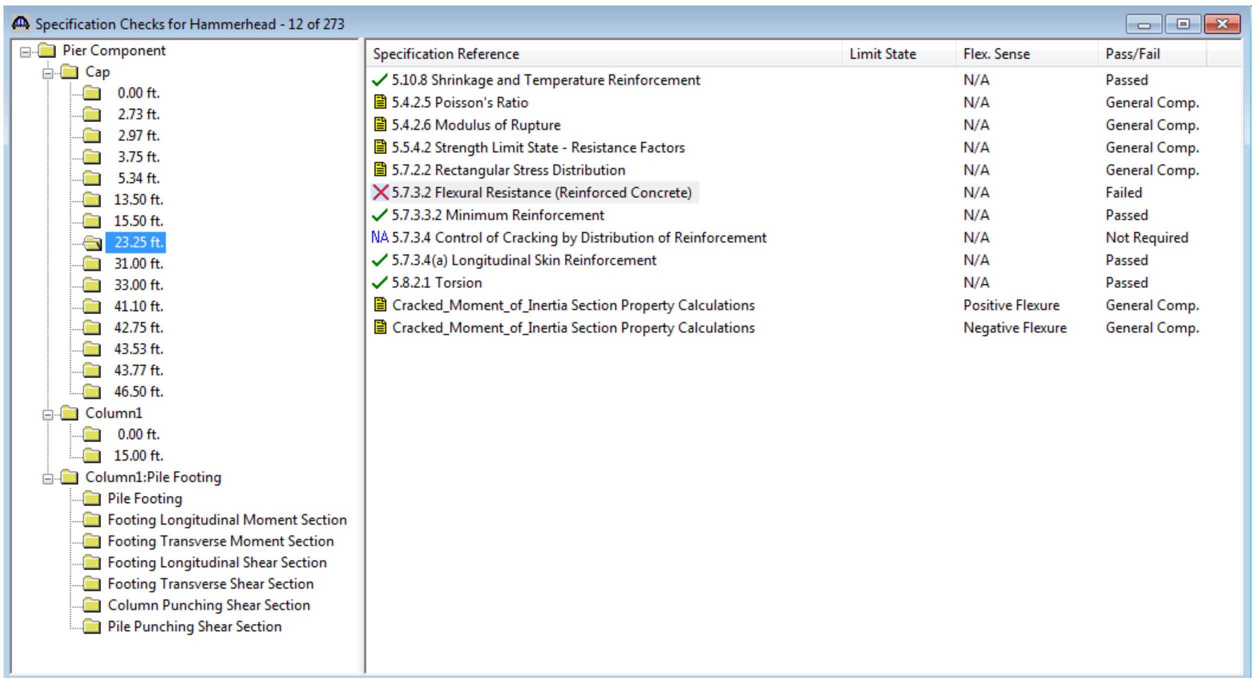

Review this log file for errors and warnings.

If the FE analysis results do not exist on your hard drive when you select to do a Spec Check, BrD will perform the FE analysis automatically. The next time you want to do a Spec Check BrD will use the existing FE analysis results. This allows you to quickly fine tune your reinforcement and geometry without re-doing the FE analysis every time. Once you find reinforcement and geometry that satisfies the spec checks you can do a final FE analysis and then spec check.

## Specification Checking

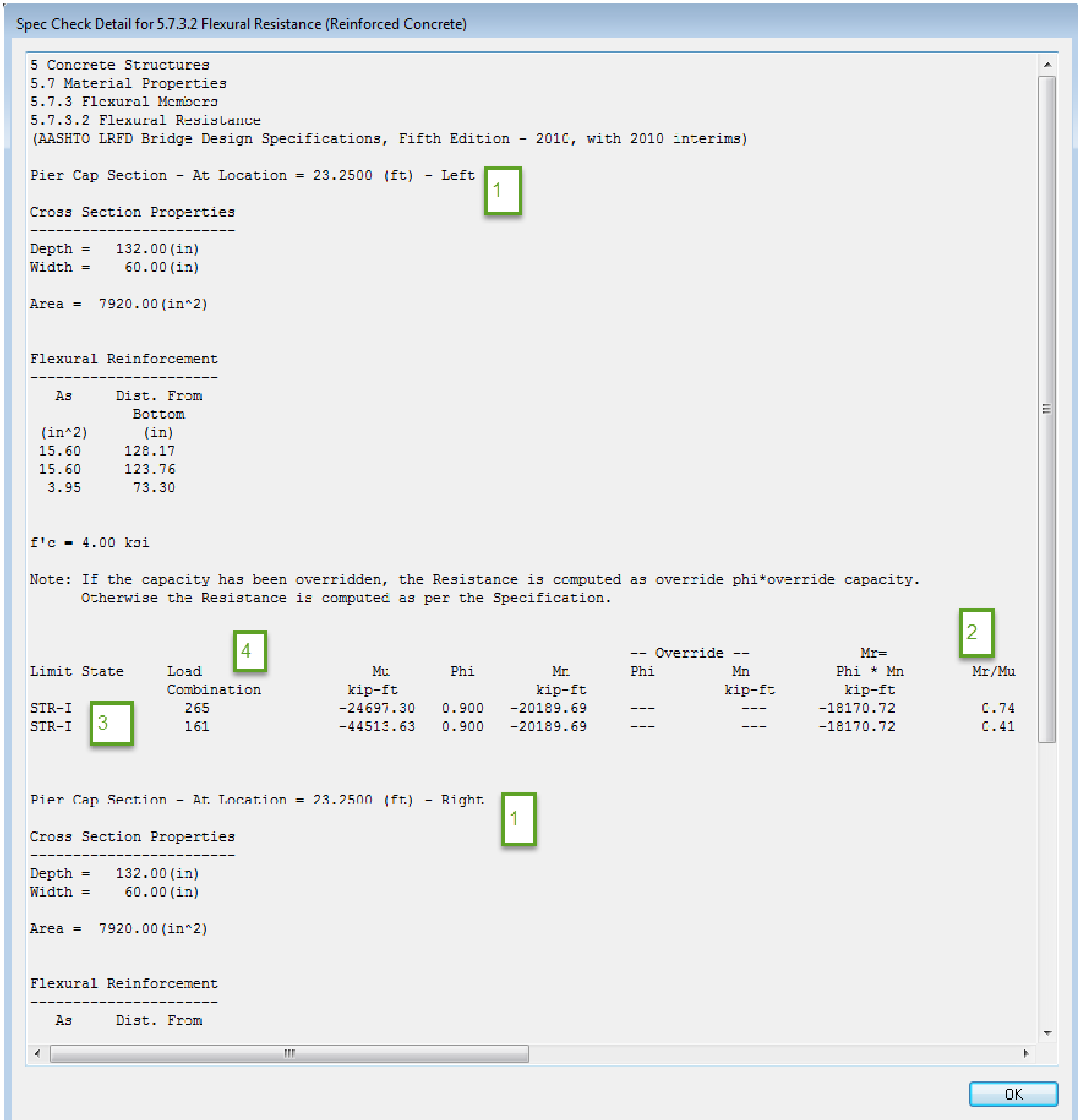
The specification checks can be viewed by selecting the "Spec Check Detail" button.


BrD performs spec checks at each node in the finite element model along with locations where the reinforcement is developed and at a distance dv from the face of each column.



Open the spec check detail window for the flexural resistance at the center of the cap. The following is noted for this window, other spec articles are similar:

- For each spec check location, both the left and right sides of the point are evaluated. (Note for the example shown below: The LL loading is not symmetric so the left/right sides of the cap midpoint show slightly different max/min load values.)
- The design ratio is printed out for the article. The design ratio is the ratio of capacity to demand. A design ratio less than one indicates the demand is greater than the capacity and the spec article fails. A design ratio equal to 99.0 indicates the section is subject to zero demand.
- The user has control over which limit states are investigated. For our example we are using the Preliminary Design Mode and the default Preliminary Design Setting only contains the Strength-I limit state. For each limit state, the max and min force effect is checked. Thus each limit state shows two rows of data.
- The LL load combination is shown in this column. If the location is not at a node in the FE model (eg, the node is at a point where the rebar is fully developed), this column will list two load combinations separated by a comma. The first load combination is the combination considered at the left end and the second load combination is the combination considered at the right end of the FE element that contains this location. The resulting load displayed is a linear interpolation between the two displayed load cases.



Spec Check Detail for 5.7.3.2 Flexural Resistance (Reinforced Concrete)

5 Concrete Structures
5.7 Material Properties
5.7.3 Flexural Members
5.7.3.2 Flexural Resistance
(AASHTO LRFD Bridge Design Specifications, Fifth Edition - 2010, with 2010 interims)

Pier Cap Section - At Location = 23.2500 (ft) - Left



Cross Section Properties
------------------------
Depth = 132.00(in)
Width = 60.00(in)

Area = 7920.00(in^2)

Flexural Reinforcement
----------------------

| As (in^2) | Dist. From Bottom (in) |
|---|---|
| 15.60 | 128.17 |
| 15.60 | 123.76 |
| 3.95 | 73.30 |

f'c = 4.00 ksi

Note: If the capacity has been overridden, the Resistance is computed as override phi*override capacity.
Otherwise the Resistance is computed as per the Specification.



| Limit State | Load Combination | Mu kip-ft | Phi | Mn kip-ft | -- Override -- Phi | Mn kip-ft | Mr= Phi * Mn kip-ft | Mr/Mu |
|---|---|---|---|---|---|---|---|---|
| STR-I | 265 | -24697.30 | 0.900 | -20189.69 | --- | --- | -18170.72 | 0.74 |
| STR-I | 161 | -44513.63 | 0.900 | -20189.69 | --- | --- | -18170.72 | 0.41 |

Pier Cap Section - At Location = 23.2500 (ft) - Right



Cross Section Properties
------------------------
Depth = 132.00(in)
Width = 60.00(in)

Area = 7920.00(in^2)

Flexural Reinforcement
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As Dist. From