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# BSI NEWSLETTER

Bridge Software Institute

**In this issue, we highlight recently developed features in the release of FB-MultiPier v6.1.0 along with Coupled Vessel Impact Analysis (CVIA), and an announcement of Bridge Software Institute's participation in the upcoming Transportation Research Board (TRB) Annual Meeting 2025.**

Engineers making use of software produced by the Bridge Software Institute (BSI) are encouraged to reach out with suggestions for new features and program improvements. Inquiries ranging from project-specific to general program usage are welcomed. We firmly believe that your feedback is invaluable in shaping the future direction of our software.

The announcement and enhancements featured in this newsletter include:

a) BSI at 2025 TRB Annual Meeting;
b) Minimum Pile Tip Embedment (MPTE);
and;
c) Dynamic Coupled Vessel Impact Analysis (CVIA).

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FB-Deep v3.1.0
GeoStat v1.1.2
Atlas v7.2.0

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# BSI at 2025 TRB Annual Meeting

BSI will be participating in the **2025 TRB Annual Meeting**, hosted in **Washington, DC**, from **January 5th-7th, 2025**. We invite you to **visit us at Booth 427**, where our team will be showcasing live demonstrations of the latest advancements in our software solutions. You'll have the opportunity to explore new features, enhancements, and innovative tools now available to support your projects.

Our experts will be on hand to provide personalized insights into how BSI software can contribute to the success of your projects. Whether you're looking for advice on optimizing program usage or interested in exploring future developments, we welcome all questions and discussions.

We look forward to seeing you at Booth 427 to discuss innovative solutions and advancements that drive progress in software development for the transportation and engineering sectors.

# Minimum Pile Tip Embedment (MPTE)

In this section, we address frequently asked questions regarding the FB-MultiPier MPTE option. Additional information can be found at FB-MultiPier Help Manual (Section 2.5.2, and Section 5.6.1) and in the Spring 2018, and Fall 2019 Newsletters.

This option, developed with funding from Florida Department of Transportation (FDOT), provides a convenient, automated routine to establish the minimum driven pile embedment for an individual pile or foundation pile group.

The required axial capacity may be reached during pile driving at an embedment shorter than anticipated. When an MPTE is specified in the construction documents, other factors may govern the final embedment requirement. These conditions are well-documented in the **AASHTO LRFD Bridge Design Specifications (Section 10.7.6)** and typically relate to lateral soil resistance and, possibly axial soil tension resistance (pile pull-out).

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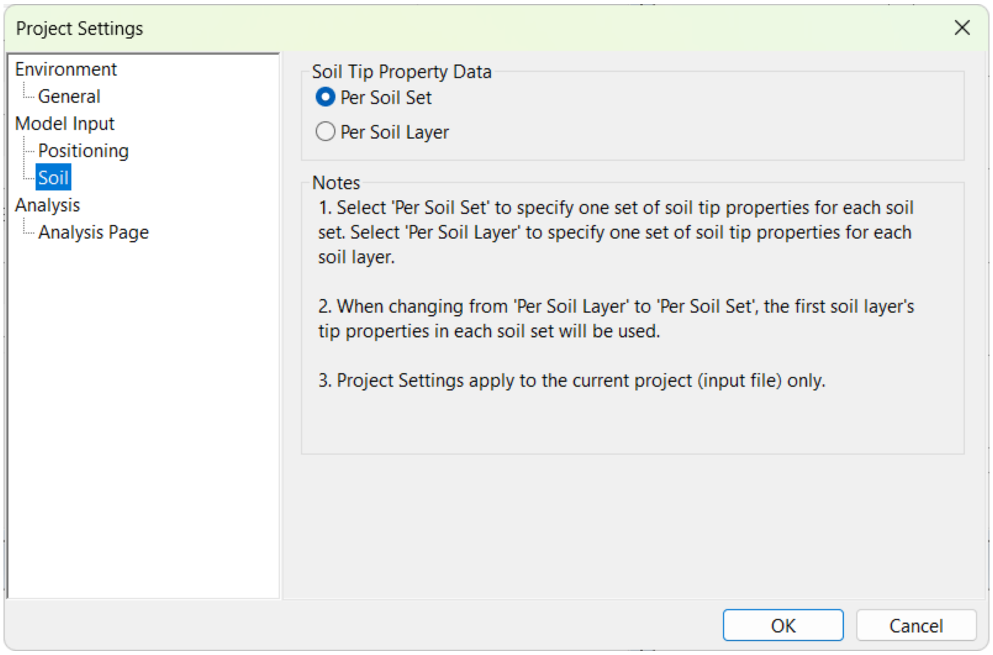
Following the **FDOT Structures Manual (Section 3.5.9)**, a design procedure for determining MPTE is outlined. A high tip end bearing compression resistance for the pile(s) is input to prevent axial compression failure. This high tip resistance is maintained during all embedment lengths as the software steps through the automated reduction of the embedment length. It is recommended that engineers check Project Settings dialog for Soil Tip Property Data selected as ‘Per Soil Set”, as shown in **Fig. 1**.



Soil Tip Property Data
● Per Soil Set
○ Per Soil Layer

Notes
1. Select 'Per Soil Set' to specify one set of soil tip properties for each soil set. Select 'Per Soil Layer' to specify one set of soil tip properties for each soil layer.

2. When changing from 'Per Soil Layer' to 'Per Soil Set', the first soil layer's tip properties in each soil set will be used.

3. Project Settings apply to the current project (input file) only.

**Figure 1. Project Settings dialog**

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To demonstrate this procedure, consider a substructure where the pier is supported at cap level by a spring representing the superstructure resistance with a stiffness of 350 kip/inch and a vessel impact load of 3500 kips is applied as shown **Fig. 2**.

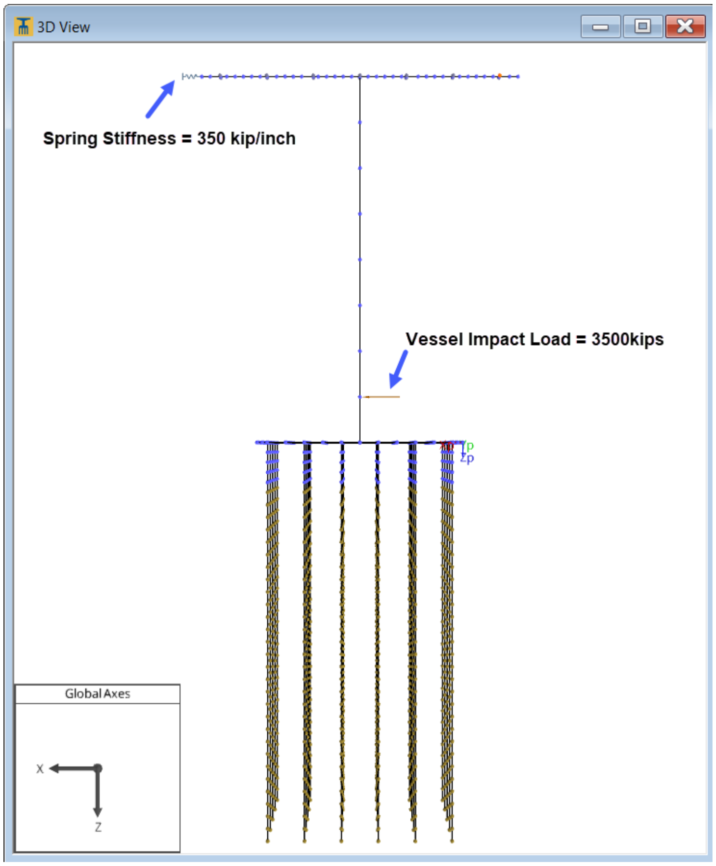

**Figure 2. 3D View window**

If the FB-MultiPier model contains multiple load cases, it is advisable to identify the key load cases which control lateral movement and run a separate model analysis. The MPTE analysis can be time-consuming due to the number of trial cases considered.

From the Model Data window, select Lateral Stability (**Fig. 3**) and check the box for Run Minimum Pile Tip Embedment Analysis. Note that the pile's original embedment length is 70 ft, with a final embedment depth of 20 ft and 11 trial embedments are selected. The analysis will be conducted over a 50 ft length (assuming all trials converge on a solution), subdivided into 5 ft long pile element sections. The first analysis uses the original pile length, followed by 10 trial lengths, thus 50/10 = 5 ft pile length increments.

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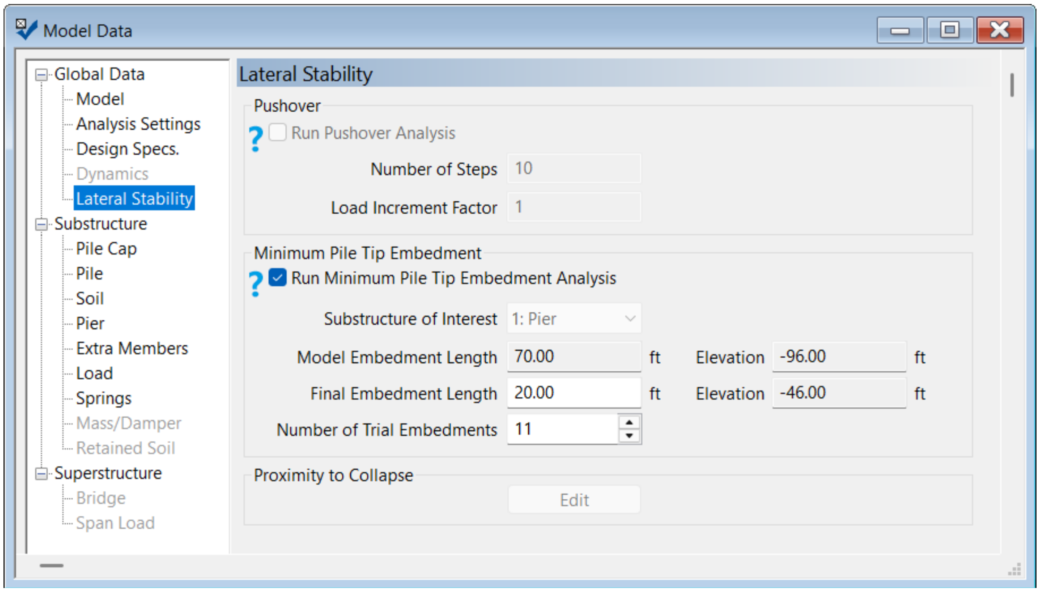


- Global Data
  - Model
  - Analysis Settings
  - Design Specs.
  - Dynamics
  - Lateral Stability
- Substructure
  - Pile Cap
  - Pile
  - Soil
  - Pier
  - Extra Members
  - Load
  - Springs
  - Mass/Damper
  - Retained Soil
- Superstructure
  - Bridge
  - Span Load

Lateral Stability

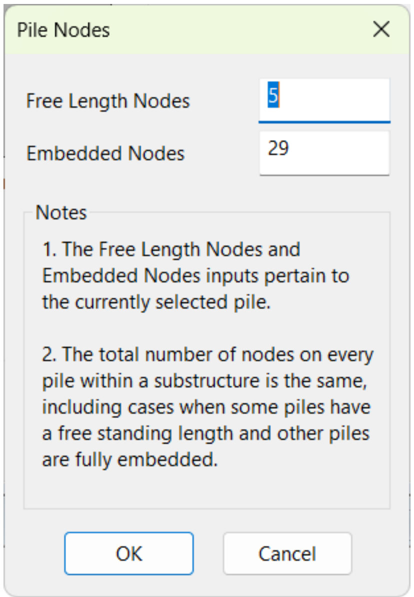
Pushover
☐ Run Pushover Analysis
Number of Steps 10
Load Increment Factor 1

Minimum Pile Tip Embedment
☑ Run Minimum Pile Tip Embedment Analysis
Substructure of Interest 1: Pier
Model Embedment Length 70.00 ft Elevation -96.00 ft
Final Embedment Length 20.00 ft Elevation -46.00 ft
Number of Trial Embedments 11

Proximity to Collapse

**Figure 3. Lateral Stability Page**

By selecting 29 nodes (**Fig. 4**) for the embedded pile length, the node spacing is calculated as 2.5 ft (70/(29-1)). The 5 ft segment lengths for the trials match the current geometry. While the software attempts to keep pile segments reasonably equal in length to maintain comparable stiffnesses and soil resistance within embedment trials, this is considered good practice.



Free Length Nodes 5
Embedded Nodes 29

Notes

1. The Free Length Nodes and Embedded Nodes inputs pertain to the currently selected pile.

2. The total number of nodes on every pile within a substructure is the same, including cases when some piles have a free standing length and other piles are fully embedded.

**Figure 4. Pile Nodes dialog**

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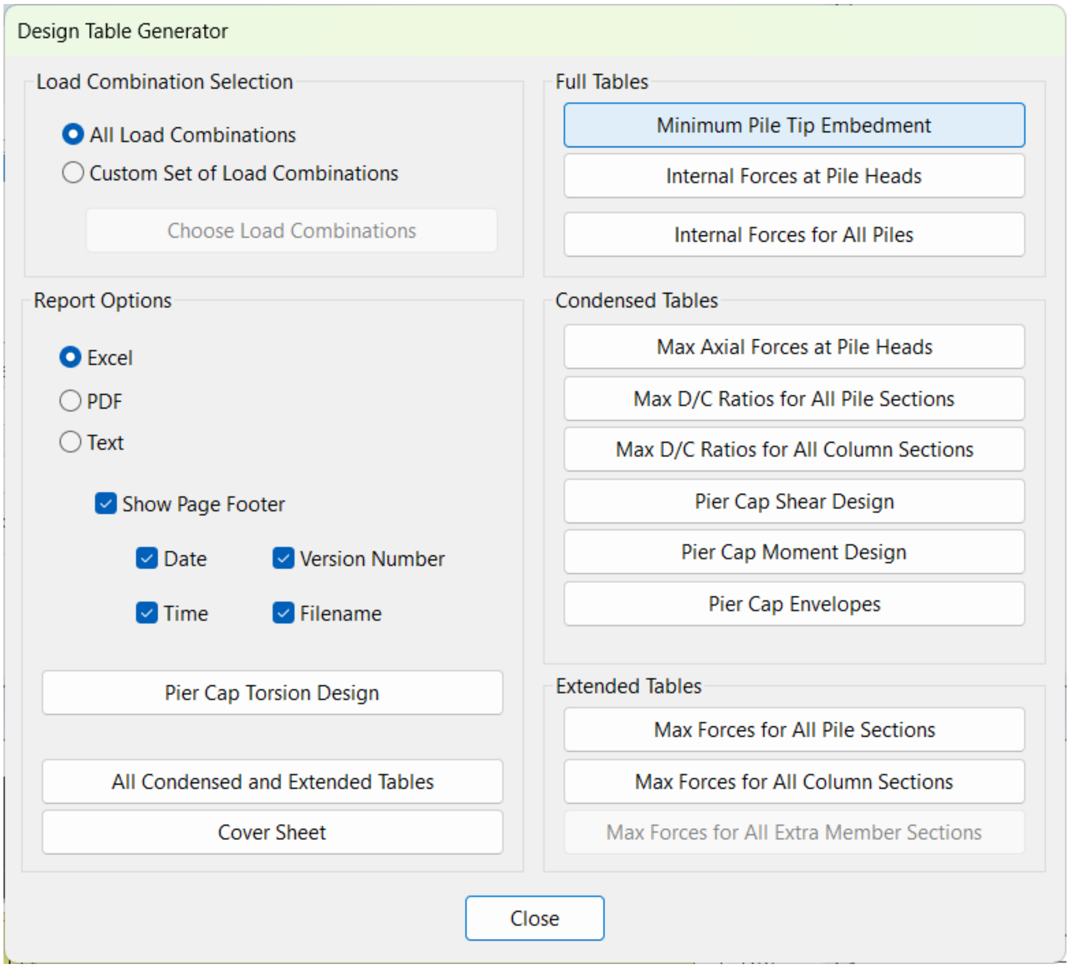
After completing this analysis, we can review a plot of the maximum pile head movement relative to pile embedment, as shown in **Fig. 5** and **Fig. 6**.



Design Table Generator

Load Combination Selection
● All Load Combinations
○ Custom Set of Load Combinations

Report Options
● Excel
○ PDF
○ Text
☑ Show Page Footer
☑ Date ☑ Version Number
☑ Time ☑ Filename

**Figure 5. Design Table Generator dialog**

It is useful to review the analysis with only 20 ft of embedment to evaluate the failure mode. A quick way to do this is to run the model with 20 ft of embedment and review the UI graphical output. From the Axial pile results (**Fig. 7**), we observe no tension (+) values, indicating that the failure mode is not related to loss of soil skin friction (pull-out).

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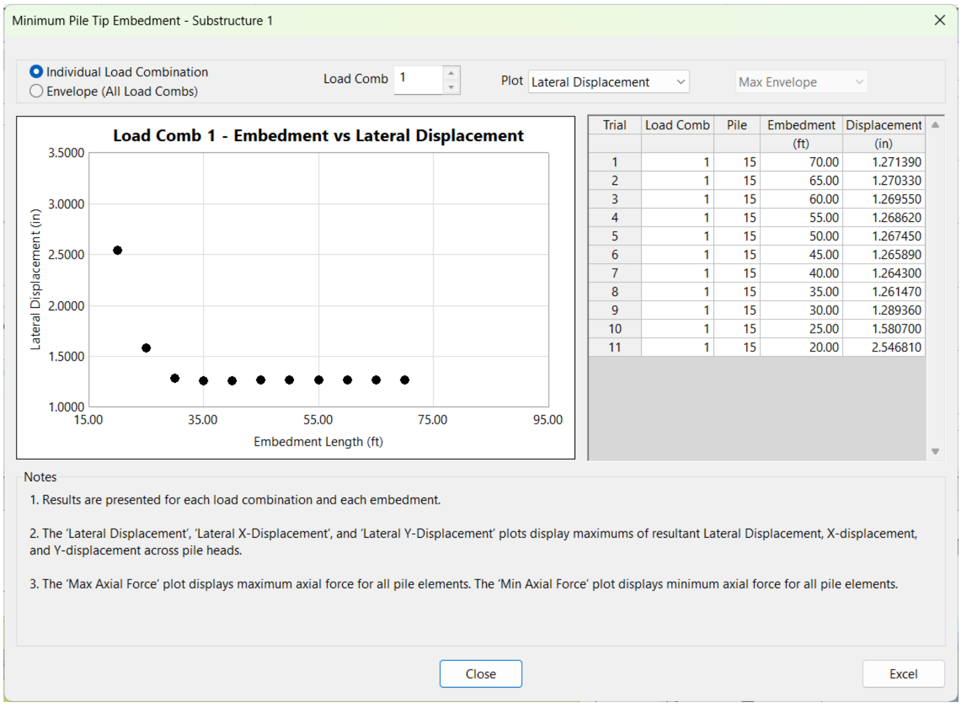

● Individual Load Combination
○ Envelope (All Load Combs)

Load Comb 1

Plot Lateral Displacement

Max Envelope

| Trial | Load Comb | Pile | Embedment (ft) | Displacement (in) |
|---|---|---|---|---|
| 1 | 1 | 15 | 70.00 | 1.271390 |
| 2 | 1 | 15 | 65.00 | 1.270330 |
| 3 | 1 | 15 | 60.00 | 1.269550 |
| 4 | 1 | 15 | 55.00 | 1.268620 |
| 5 | 1 | 15 | 50.00 | 1.267450 |
| 6 | 1 | 15 | 45.00 | 1.265890 |
| 7 | 1 | 15 | 40.00 | 1.264300 |
| 8 | 1 | 15 | 35.00 | 1.261470 |
| 9 | 1 | 15 | 30.00 | 1.289360 |
| 10 | 1 | 15 | 25.00 | 1.580700 |
| 11 | 1 | 15 | 20.00 | 2.546810 |

Notes

1. Results are presented for each load combination and each embedment.

2. The 'Lateral Displacement', 'Lateral X-Displacement', and 'Lateral Y-Displacement' plots display maximums of resultant Lateral Displacement, X-displacement, and Y-displacement across pile heads.

3. The 'Max Axial Force' plot displays maximum axial force for all pile elements. The 'Min Axial Force' plot displays minimum axial force for all pile elements.

**Figure 6. Minimum Pile Tip Embedment dialog**

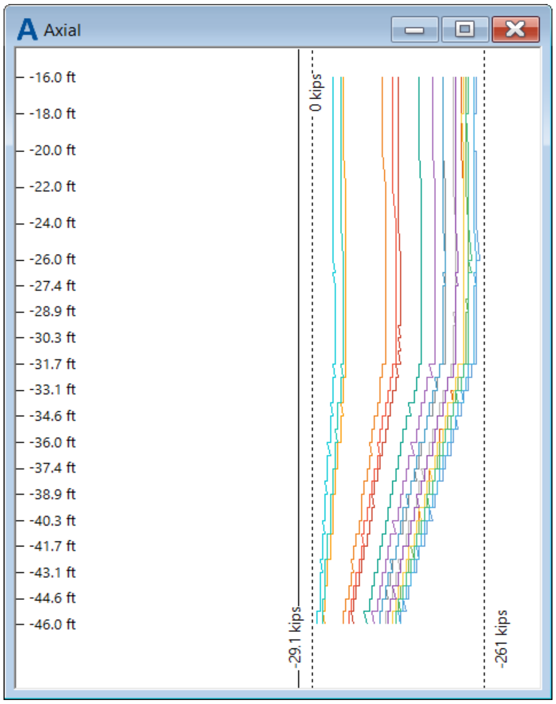

**Figure 7. Pile Results – Axial Force along all Piles (20ft embedment trial)**

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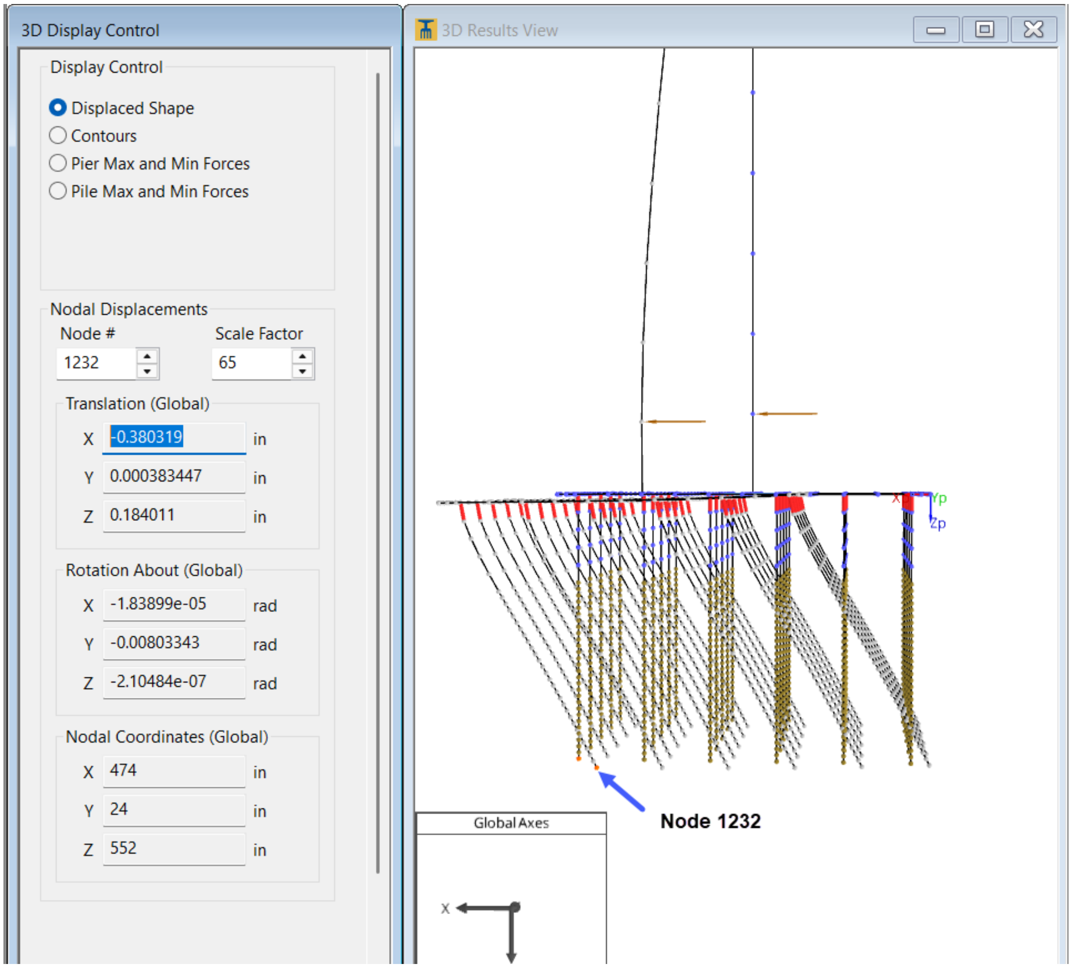
From the 3-D results view (**Fig. 8**), we can observe that the pile tips are beginning to move laterally, and all the pile heads are now hinged.



Display Control
● Displaced Shape
○ Contours
○ Pier Max and Min Forces
○ Pile Max and Min Forces

Nodal Displacements
Node # 1232
Scale Factor 65

Translation (Global)
X -0.380319 in
Y 0.000383447 in
Z 0.184011 in

Rotation About (Global)
X -1.83899e-05 rad
Y -0.00803343 rad
Z -2.10484e-07 rad

Nodal Coordinates (Global)
X 474 in
Y 24 in
Z 552 in

Node 1232

**Figure 8. 3D Results View – Displaced Shape (20ft embedment trial)**

From **Fig. 6** and the table, we observe that at approximately 32 ft of embedment, pile displacements begin to increase between trial embedments. To determine the minimum embedment for the contract documents, we utilize the FDOT procedure:

- 20% of 32 feet is 6.4 ft.
- Therefore, 5 ft is added to the 32 ft, resulting in an MPTE of 37 ft.

Review the 3-D results (**Fig. 9**) with the required 37 ft embedment. When the minimum embedment of 37 ft is input, we can observe that the pile hinging is no longer present. The pile tip movement is reduced to 0.00035 inches, and the pile curvature shows reversal. The piles are stable and meet both FDOT Structures Manual and AASHTO LRFD specifications.

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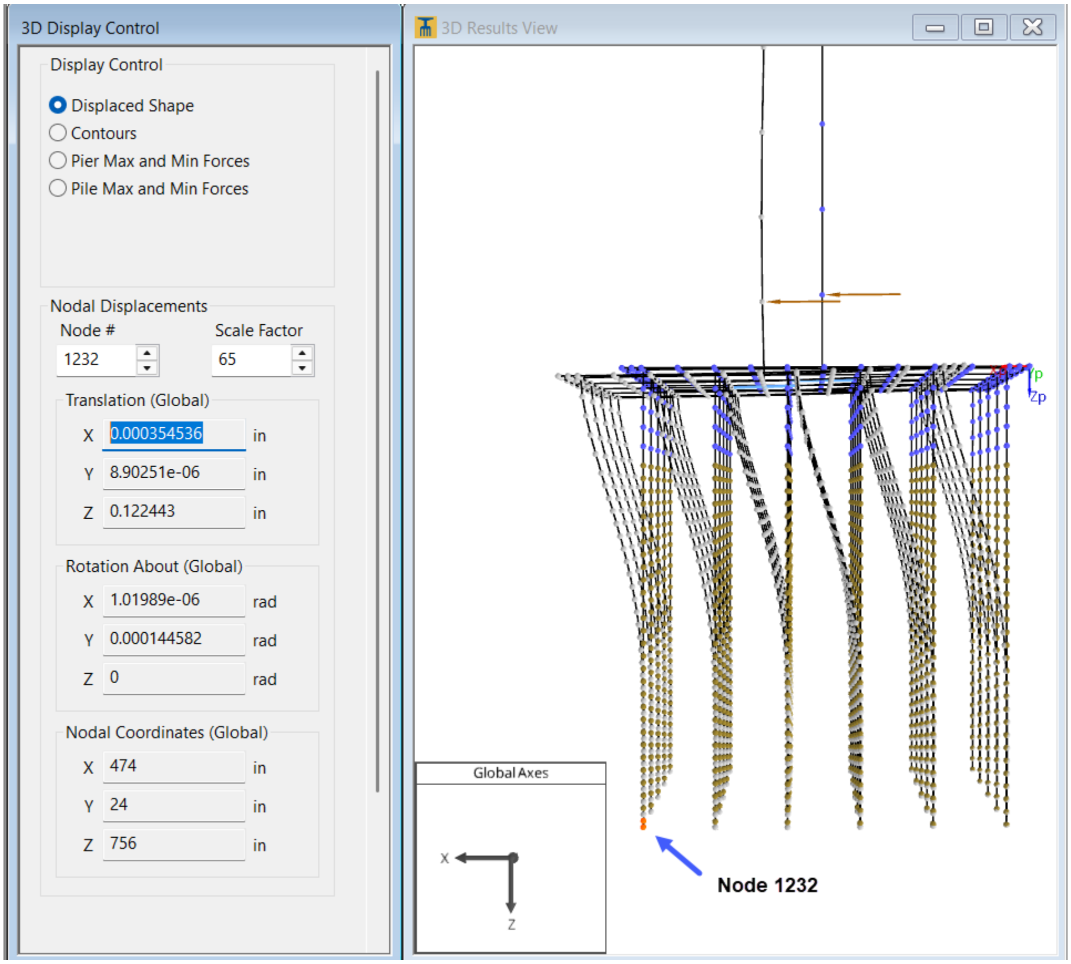

3D Display Control

Display Control

● Displaced Shape
○ Contours
○ Pier Max and Min Forces
○ Pile Max and Min Forces

Nodal Displacements

Node # 1232
Scale Factor 65

Translation (Global)

X 0.000354536 in
Y 8.90251e-06 in
Z 0.122443 in

Rotation About (Global)

X 1.01989e-06 rad
Y 0.000144582 rad
Z 0 rad

Nodal Coordinates (Global)

X 474 in
Y 24 in
Z 756 in

**Figure 9. 3D Results View – Displaced Shape (37ft embedment trial)**

# Dynamic Vessel Collision Impact Analysis (CVIA)

The Spring 2016 newsletter demonstrated the use of FB-MultiPier for dynamic analysis, which may be referenced for a step-by-step procedure. In this newsletter, we will conduct a dynamic analysis for a channel pier of the Bryant Patton Memorial Bridge (Saint George Island Bridge), Franklin County, Florida.

We have selected a 3191 ton barge with 260 ton push boat, resulting in a combined displacement weight being 3451 tons (or 6902 kips). The barge is 53 ft wide and 250 ft long, and the push boat is 25 ft wide and 75 ft long. They are assumed to be traveling at 11.8 ft/sec (8 miles/hour) when colliding with a channel pier.

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The **Fig. 10**, **Fig. 11**, and **Fig. 12** depict the 12 span bridge section and the OPTS model for channel pier 3.

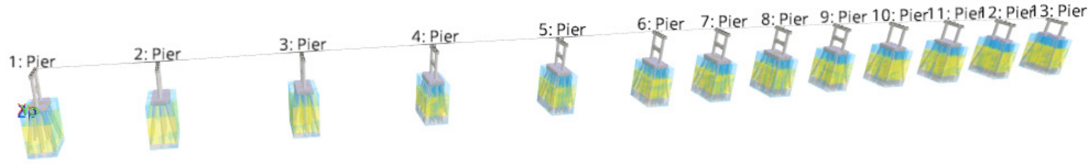

**Figure 10. 12 Span Bridge Section**

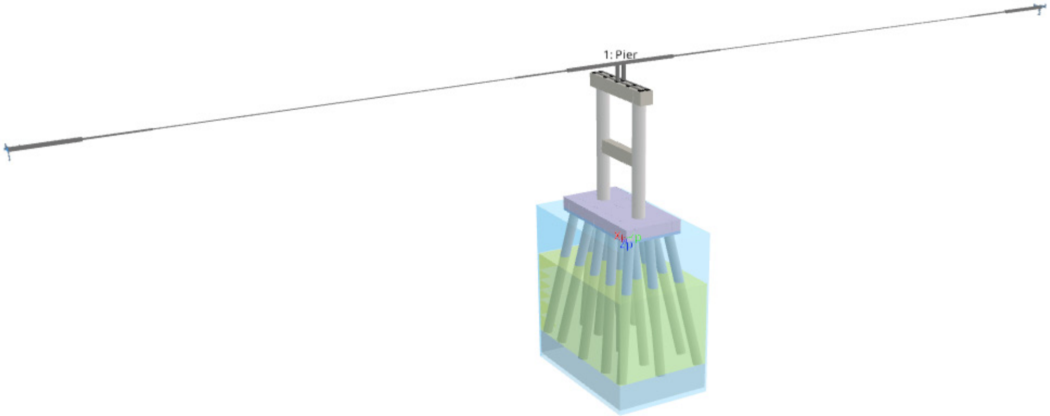

**Figure 11. OPTS (One Pier Two Span) model for channel pier 3**

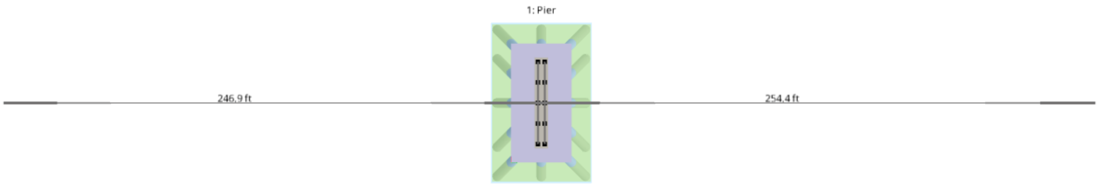

**Figure 12. Bridge Plan View for the OPTS model**

We will apply the vessel impact at Node 15 as a transverse loading to the bridge pile footing as shown in **Fig. 13** and **Fig. 14**.

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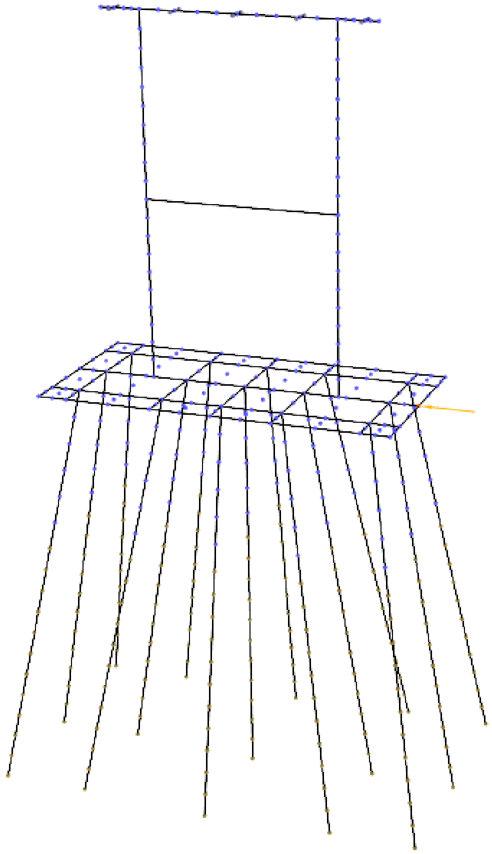

Figure 13. Vessel Impact Load at Node 15

We have selected a 14 ft collision width to represent a reasonable Flat Surface collision. While the footing is 28 ft wide, using engineering judgement we can assume that the complete contact over the entire width is not realistic. The Vessel Bow Force Deformation Relationship is automatically generated by the software and used in the analysis. As **Fig. 14** illustrates, for a collision width of 14 ft, vessel deformation and impact force are linearly related to each other up to 2 inches of barge deformation and 3250 kips of impact force. For vessel deformation levels that exceed 2 inches, the impact force remains constant. That is, the overall force-deformation curve is elastic (at low vessel deformation levels) and plastic (at higher vessel deformation levels).

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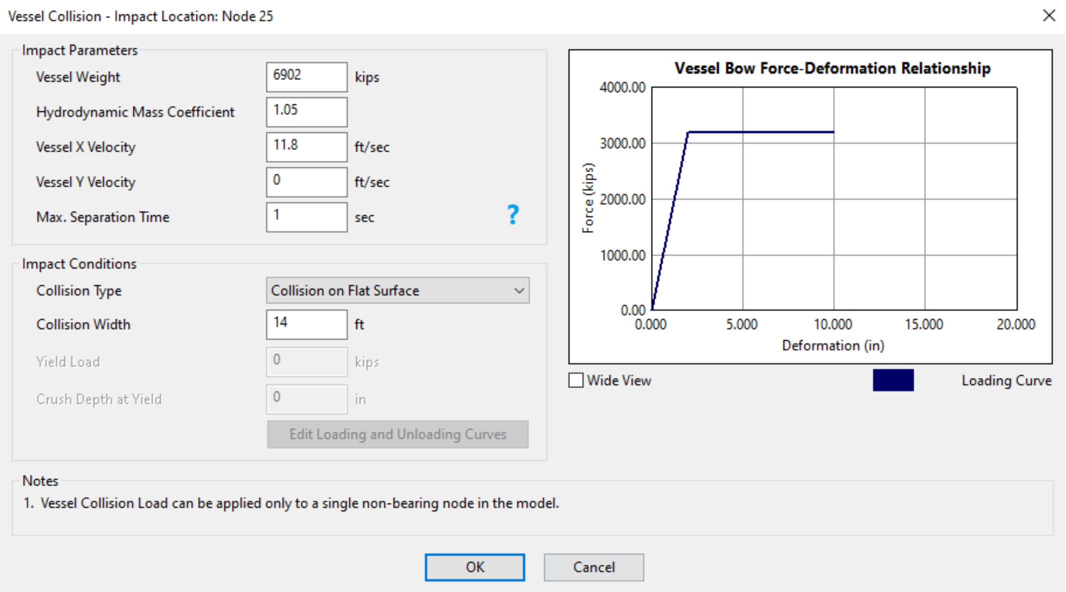


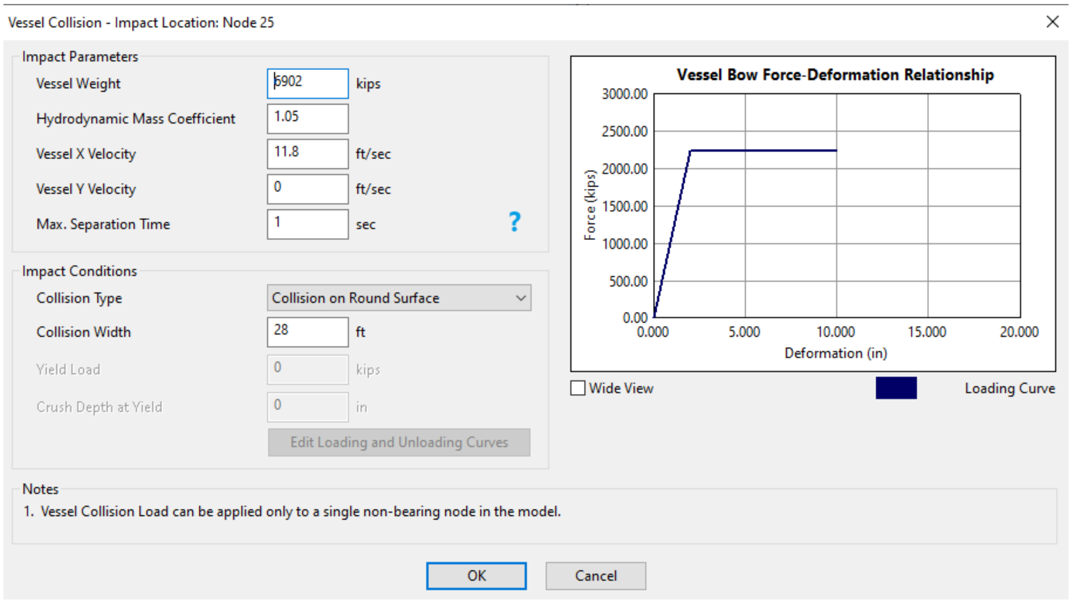
Impact Parameters
Vessel Weight: 6902 kips
Hydrodynamic Mass Coefficient: 1.05
Vessel X Velocity: 11.8 ft/sec
Vessel Y Velocity: 0 ft/sec
Max. Separation Time: 1 sec

Impact Conditions
Collision Type: Collision on Flat Surface
Collision Width: 14 ft
Yield Load: 0 kips
Crush Depth at Yield: 0 in

Notes
1. Vessel Collision Load can be applied only to a single non-bearing node in the model.

**Figure 14. Vessel Collision Dialog (Flat Surface Collision)**

It is also of interest to observe the form of the barge force-deformation curve if a collision on a round surface had instead been selected, and applied over the full footing width of 28 ft (that is, the full pile cap width). As shown in **Fig. 15**, this change results in a dramatic reduction of maximum force developed, with the maximum force being only 2250 kips due to the hull deformation on the rounded surface.



Impact Parameters
Vessel Weight: 6902 kips
Hydrodynamic Mass Coefficient: 1.05
Vessel X Velocity: 11.8 ft/sec
Vessel Y Velocity: 0 ft/sec
Max. Separation Time: 1 sec

Impact Conditions
Collision Type: Collision on Round Surface
Collision Width: 28 ft
Yield Load: 0 kips
Crush Depth at Yield: 0 in

Notes
1. Vessel Collision Load can be applied only to a single non-bearing node in the model.

**Figure 15. Vessel Collision Dialog (Round Surface Collision)**

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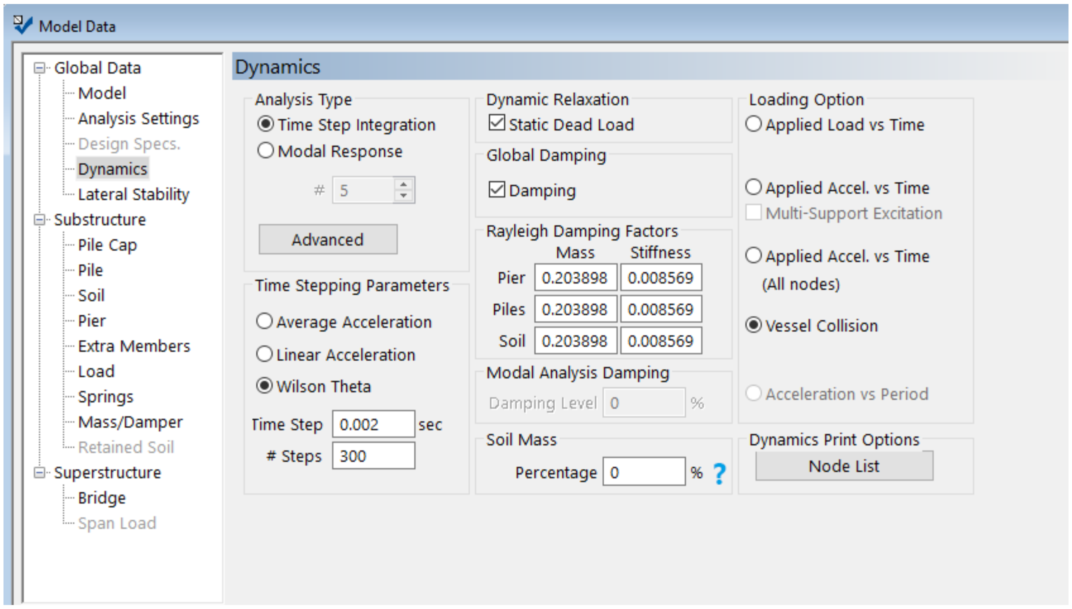
In the Model Data window (**Fig. 16**), we input parameters for the dynamic analysis. The damping coefficients are automatically calculated, a time step of 0.002 seconds is selected, and 300 steps are specified. The analysis will terminate at 300 * 0.002 = 0.6 seconds. The channel pier substructure is relatively stiff and the maximum hull crushing force of 3199 kips is reached at just 0.016 seconds, as shown in **Fig. 17**. The hull crushing force (impact force on the bridge) versus time is displayed in the text "vessel" output in a file, with '.VES' extension (**Fig. 17** and **Fig. 18**).



Dynamics

Analysis Type
● Time Step Integration
○ Modal Response
\# 5

Time Stepping Parameters
○ Average Acceleration
○ Linear Acceleration
● Wilson Theta
Time Step 0.002 sec
\# Steps 300

Dynamic Relaxation
☑ Static Dead Load

Global Damping
☑ Damping

Rayleigh Damping Factors

| | Mass | Stiffness |
|---|---|---|
| Pier | 0.203898 | 0.008569 |
| Piles | 0.203898 | 0.008569 |
| Soil | 0.203898 | 0.008569 |

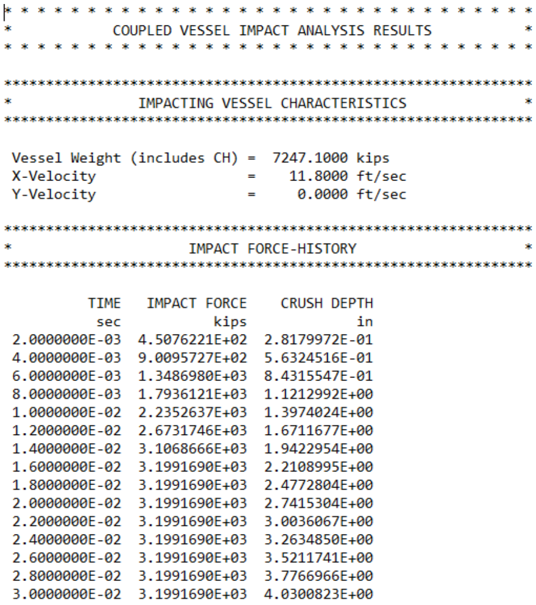
Modal Analysis Damping
Damping Level 0 %

Soil Mass
Percentage 0 %

Loading Option
○ Applied Load vs Time
○ Applied Accel. vs Time
☐ Multi-Support Excitation
○ Applied Accel. vs Time (All nodes)
● Vessel Collision
○ Acceleration vs Period

Dynamics Print Options

**Figure 16. Dynamic Page**



```
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
*             COUPLED VESSEL IMPACT ANALYSIS RESULTS          *
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

***************************************************************
*                 IMPACTING VESSEL CHARACTERISTICS            *
***************************************************************

 Vessel Weight (includes CH) =  7247.1000 kips
 X-Velocity                  =    11.8000 ft/sec
 Y-Velocity                  =     0.0000 ft/sec

***************************************************************
*                       IMPACT FORCE-HISTORY                  *
***************************************************************

          TIME    IMPACT FORCE    CRUSH DEPTH
           sec            kips             in
 2.0000000E-03  4.5076221E+02  2.8179972E-01
 4.0000000E-03  9.0095727E+02  5.6324516E-01
 6.0000000E-03  1.3486980E+03  8.4315547E-01
 8.0000000E-03  1.7936121E+03  1.1212992E+00
 1.0000000E-02  2.2352637E+03  1.3974024E+00
 1.2000000E-02  2.6731746E+03  1.6711677E+00
 1.4000000E-02  3.1068666E+03  1.9422954E+00
 1.6000000E-02  3.1991690E+03  2.2108995E+00
 1.8000000E-02  3.1991690E+03  2.4772804E+00
 2.0000000E-02  3.1991690E+03  2.7415304E+00
 2.2000000E-02  3.1991690E+03  3.0036067E+00
 2.4000000E-02  3.1991690E+03  3.2634850E+00
 2.6000000E-02  3.1991690E+03  3.5211741E+00
 2.8000000E-02  3.1991690E+03  3.7766966E+00
 3.0000000E-02  3.1991690E+03  4.0300823E+00
```

**Figure 17. Coupled Vessel Impact Analysis Results (.VES)**

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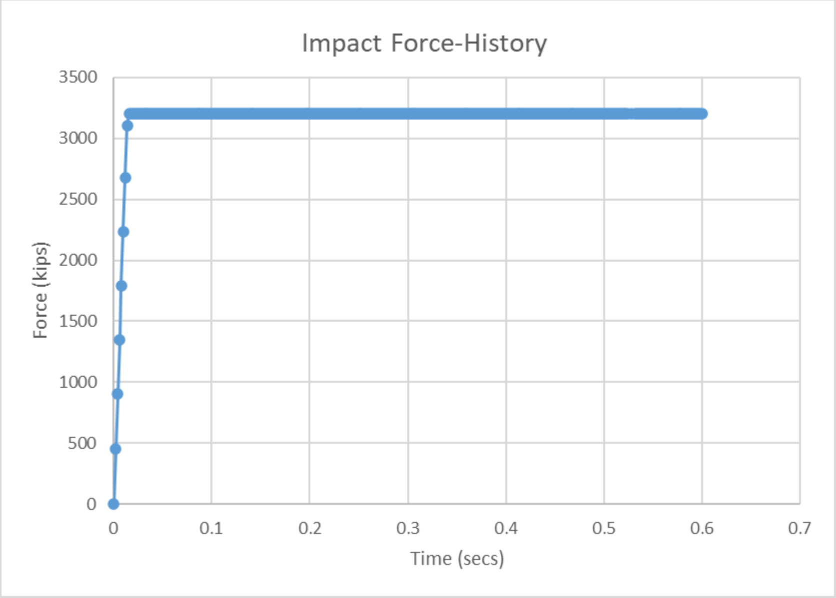

**Figure 18. Impact Force-History**

Upon observing the impact force versus time (**Fig. 17**, and **Fig. 18**), it is interesting to note that the maximum impact force is reached at just 0.016 seconds. After this, the impact force 3199 kips remains constant, as the barge hull is deformed into the plastic region. At 0.184 seconds (time step 92), the maximum footing displacement of 2.15 inches is reached, as shown in **Fig. 19**, and **Fig. 20**. From the graphical output we are able to observe the translation through time of the pier footing (**Fig. 19**).

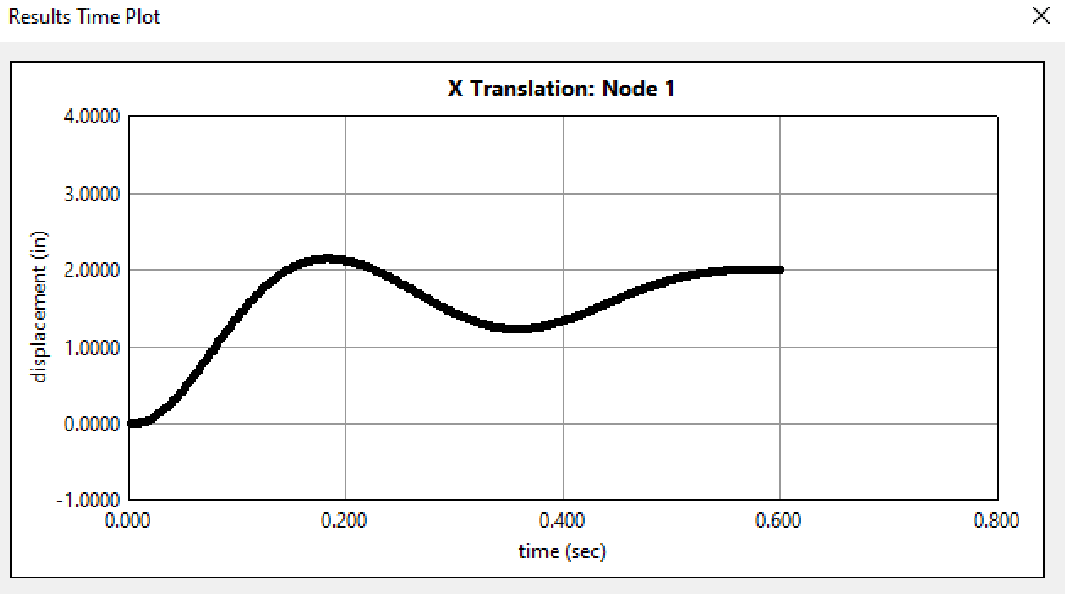

**Figure 19. X Translation through time of the pier footing**

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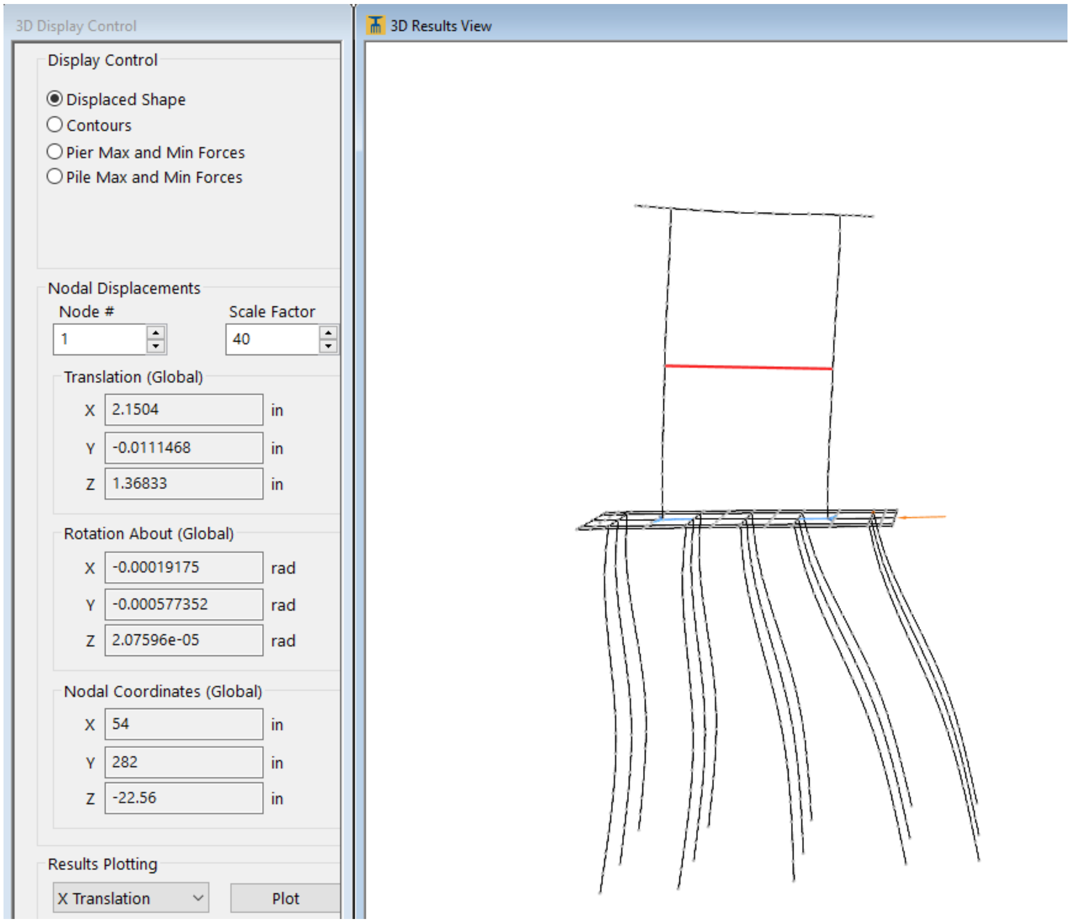


Display Control
● Displaced Shape
○ Contours
○ Pier Max and Min Forces
○ Pile Max and Min Forces

Nodal Displacements
Node # 1
Scale Factor 40

Translation (Global)
X 2.1504 in
Y -0.0111468 in
Z 1.36833 in

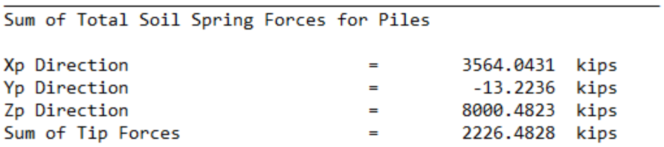
Rotation About (Global)
X -0.00019175 rad
Y -0.000577352 rad
Z 2.07596e-05 rad

Nodal Coordinates (Global)
X 54 in
Y 282 in
Z -22.56 in

Results Plotting
X Translation

**Figure 20. 3D Results Window**

The total lateral force applied to the piles is conveniently obtained from the sum of total soil forces at time step 92, which equals 3564 kips (**Fig. 21**).



```
Sum of Total Soil Spring Forces for Piles

Xp Direction                    =       3564.0431  kips
Yp Direction                    =        -13.2236  kips
Zp Direction                    =       8000.4823  kips
Sum of Tip Forces               =       2226.4828  kips
```

**Figure 21. Sum of Total Soil Forces at Time Step 92 in .out file**

The sum of the bearing forces (or sum of the shears in the columns) results in a force being transmitted to the superstructure, 806 kips. Therefore, the total lateral force on the substructure is 3564 + 806 = 4370 kips, which is approximately 37% larger than the constant applied force of 3199 kips, generated by the barge and applied over time.

This demonstrates the dynamic nature of impact-momentum analysis.

## Index Table

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# BSI Program Status

### FB-MultiPier v6.1.0 Download a FREE demo today!

Released July 2024 - Continuing Development - Technical Support Available

FB-MultiPier allows for the modeling of bridges, bridge piers, pile bents, and other foundation structures. In addition to allowing for multiple load cases and AASHTO load combinations, FB-MultiPier is also capable of performing dynamic analysis (time-history and RSA). For more information about FB-MultiPier, click here.

### FB-Deep v3.1.0 Download a FREE demo today!

Released Feb 2022 - Continuing Development - Technical Support Available

FB-Deep is used to estimate the static axial capacity of drilled shafts and driven piles. The methodology is based upon Federal Highway Administration (FHWA) reports. FB-Deep guides the user through pile and shaft materials data, shape and dimensional inputs, soil properties, and boring log info. For more information about FB-Deep, click here.

### GeoStat v1.1.2

Released Dec 2020 - Continuing Development - Technical Support Available

GeoStat allows engineers to leverage statistical methods when estimating pile/shaft axial resistance quantities, variability, and uncertainty. GeoStat accepts collections of borings/corings, performs both spatial variability analysis and method error estimation, and then generates through-depth profiles of both factored resistance and associated variability. For more information about GeoStat, click here.

### Atlas v7.2.0

Released Dec 2021 - Limited Web Support Available

Atlas is a finite element analysis program that is used for the design/analysis of cable supported traffic signal systems. The Atlas program models dual cable supported systems including single-point, and two-point attachments systems. For more information about Atlas, click here.

## Index Table

FB-MultiPier v6.1.0
FB-Deep v3.1.0
GeoStat v1.1.2
Atlas v7.2.0

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