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BSI Newsletter

Bridge Software Institute

In this issue we discuss features that were implemented in FB-MultiPier v5.4.

The Bridge Software Institute (BSI) encourages correspondence from all engineers making use of the program, particularly when suggestions for new features come to light. These suggestions may be general in nature or very specific to the needs of a given project. We firmly believe that you are in the best position to know what those needs are!

In this release of FB-MultiPier (v5.4), the enhancements listed below were all a result of YOUR suggestions:

a) Liqueified sand p-y model.
b) Simplified hybrid liquefied sand p-y model.
c) Soil with both cohesion and internal friction p-y model.
d) Loess p-y model.
e) Piedmont residual soil p-y model.
f) Massive rock p-y model.
g) Linear (constant subgrade modulus) p-y model.
h) Exclusion of skin friction for embedded casing lengths of drilled shafts.

Please contact BSI at **bsi@ce.ufl.edu** with your ideas.

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What's New at BSI

We are pleased to announce the release of FB-MultiPier v5.4. This program and other bridge design software are available for download from the **BSI** website. The new version of FB-MultiPier (v5.4) contains fixes to the latest reported errors and also includes a number of new features.

Program Enchancements

Lateral Resistance (p-y) models

To provide engineers with more options in characterizing lateral resistance of deep foundations in a variety of soils and rocks, seven new p-y curves have been implemented in FB-MultiPier. Shown in **Fig. 1** are comparisons of the p-y relationships, relative to manually generated p-y curves, based on the references indicated below. Excellent agreement is achieved for all cases. For manual curve generation, all studied piles and shafts were 2 ft in diameter and the results are presented at a depth of 3 ft beneath the ground surface elevation. Additional examples can be found here. Listed below are brief descriptions of the newly implemented p-y models.

a) Liquefied Sand
The p-y relationship for liquefied sand was developed by Rollins et al. (2005a) and Rollins et al. (2005b). The initial curve portions are concave-up (the slope of the curve increases as deflection increases). This p-y curve is presented in **Fig. 1a** and models the lateral resistance of a pile in a liquefied sand at 3 ft depth.

b) Simplified Hybrid Model for Liquefied Sand
The simplified hybrid model for liquefied sand (p-y relationship) was developed by Franke and Rollins (2013). This p-y relationship is applicable to a wide range of soil types, relative densities, pile/shaft diameters, and loading conditions. An example p-y curve is presented in **Fig. 1b** and models the lateral resistance of a pile in a liquefied sand with 0.9 psi residual strength.

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c) Soil with Both Cohesion and Internal Friction

The "c-ϕ" p-y relationship was implemented by drawing upon on the work of Ismael (1990) on cemented soils having both components of shear strength, c and ϕ. The implemented p-y curve is plotted in **Fig. 1c** and models the lateral resistance of a pile in a c - ϕ soil with 21 psi undrained shear strength and 30° internal friction angle.

d) Loess

The p-y relationship for Loess was originally developed and proposed by Johnson et al. (2006). An example p-y curve for Loess is displayed in **Fig. 1d** and models the lateral resistance of a shaft in loess with CPT tip resistance of 153 psi.

e) Piedmont Residual Soil

A p-y relationship for Piedmont residual soils was proposed based on physical tests conducted by Simpson and Brown (2003). An example p-y curve is presented in **Fig. 1e** for a pile in a Piedmont residual soil with modulus (E_{si}) of 1739 psi.

f) Massive Rock

This p-y relationship was developed by Liang et al. (2009) for a rock mass. It is presented in **Fig. 1f** and models the lateral resistance of a shaft in a rock mass with unconfined compressive strength and intact modulus of 5671 psi and 590014 psi, respectively.

g) Linear Soil (Constant Subgrade Modulus)

A linear relationship for lateral resistance (p) versus pile lateral deflection relative to the soil (y) has also been implemented in FB-MultiPier.

References:

Franke, K. W., and Rollins, K. M. (2013). "Simplified Hybrid p-y Spring Model for Liquefied Soils." Journal of Geotechnical and Geoenvironmental Engineering, 139(4), 564-576.

Ismael, N. F. (1990). "Behavior of Laterally Loaded Bored Piles in Cemented Sands." Journal of Geotechnical Engineering, 116(11), 1678-1699.

Johnson, R. M., Parsons, R. L., Dapp, S. D., and Brown, D. A. (2006). "Soil Characterization and p-y Curve Development for Loess." Kansas Department of Transportation, Bureau of Materials and Research.

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Liang, R., Yang, K., and Nusairat, J. (2009). "p-y Criterion for Rock Mass." Journal of Geotechnical and Geoenvironmental Engineering, 135(1), 26-36.

Rollins, K., Gerber, T., Lane, J., and Ashford, S. (2005a). "Lateral Resistance of a Full-Scale Pile Group in Liquefied Sand." Journal of Geotechnical and Geoenvironmental Engineering, 131(1), 115-125.

Rollins, K., Hales, L. J., Ashford, S., and Camp III, W. M. (2005b). "P-Y Curves for Large Diameter Shafts in Liquefied Sand from Blast Liquefaction Tests." Seismic Performance and Simulation of Pile Foundations in Liquefied and Laterally Spreading Ground.

Simpson, M., and Brown, D. A. (2003). "Development of P-Y Curves for Piedmont Residual Soils." Highway Research Center, Harbert Engineering Center, Auburn University.

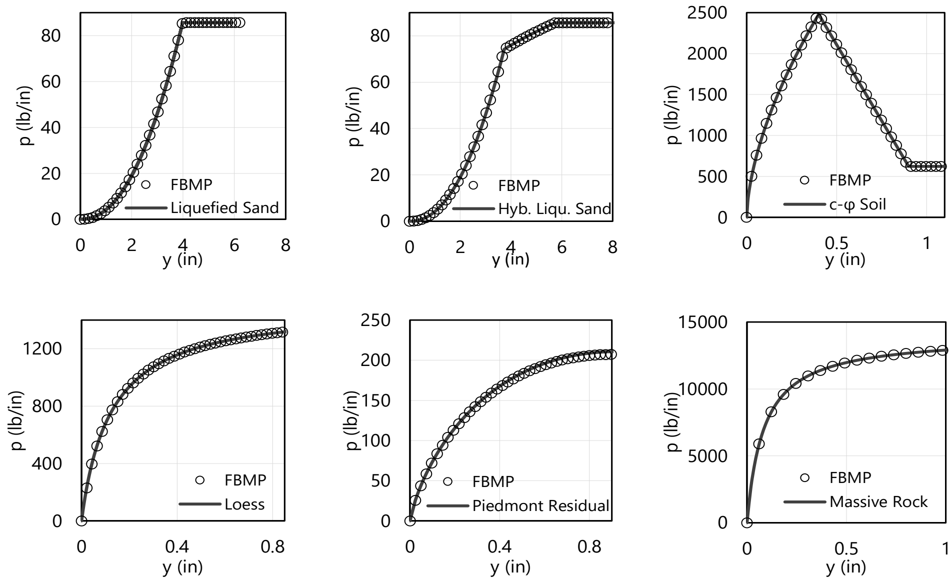

Figure 1. Lateral soil resistance models (p-y curves): a) liquefied sand (Rollins et al. 2005a; Rollins et al. 2005b); b) hybrid liquefied sand (Franke and Rollins 2013); c) c-ϕ soil (Ismael 1990); d) Loess (Johnson et al. 2006); e) Piedmont residual (Simpson and Brown 2003); f) massive rock (Liang et al. 2009)

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Exclusion of Skin Friction for Embedded Casing Lengths of Drilled Shafts

An option has been added to the "Analysis Settings" window, **Fig. 2**, which allows engineers to exclude soil skin friction from the embedded portions of drilled shafts fitted with casings.

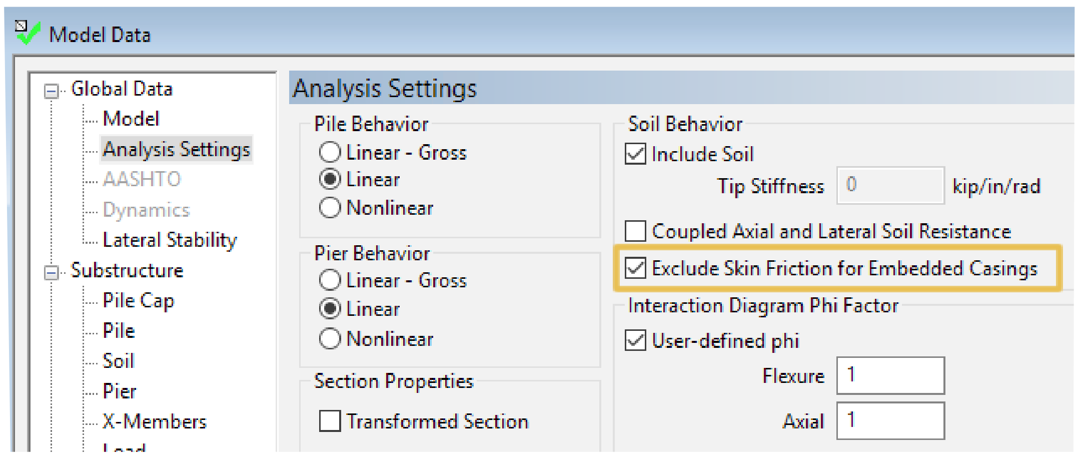

Figure 2. Exclude Skin Friction for Embedded Casings option on Analysis Settings page

The following example illustrates the process of excluding soil skin friction resistance along the embedded casing length of drilled shafts. Consider the hammerhead pier depicted in **Fig. 3**. This substructure consists of a single drilled shaft fitted with casing from the bottom of the sand layer up to the water surface elevation. A column extends concentrically up beyond the drilled shaft, and the overall substructure is topped with tapered pier cap cantilevers. In this example, the substructure is subjected to self-weight loading.

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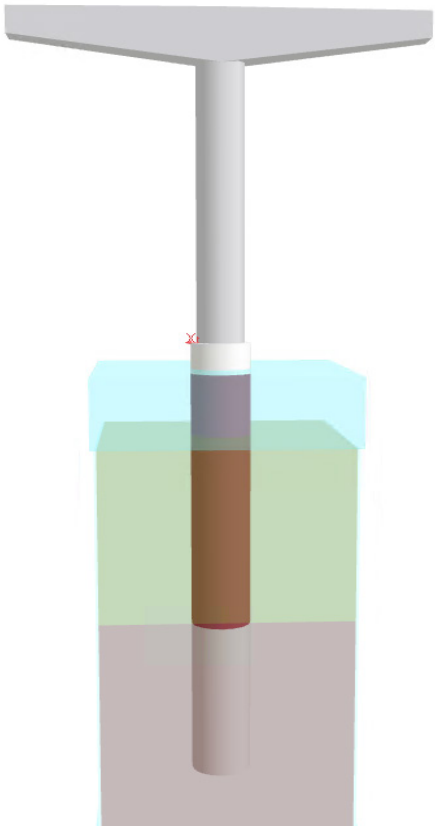

Figure 3. Elevation view of hammerhead pier configuration

After enabling the exclusion of skin friction for embedded casing lengths (recall **Fig. 2**), the Pile Force Results windows can be accessed to review reactions along the shaft. This can be done by clicking the Pile Force Results button (**Fig. 4**, top), selecting the shaft in the Pile Plan View window, and checking the "Soil Reaction Zp (kips)" checkbox. These actions will open the Printable Forces dialog (**Fig. 4**, bottom), which tabulates vertical soil reactions along the shaft. As expected, only a nominal soil reaction is generated along the embedded casing length (elevations -18ft to -56ft).

FALL
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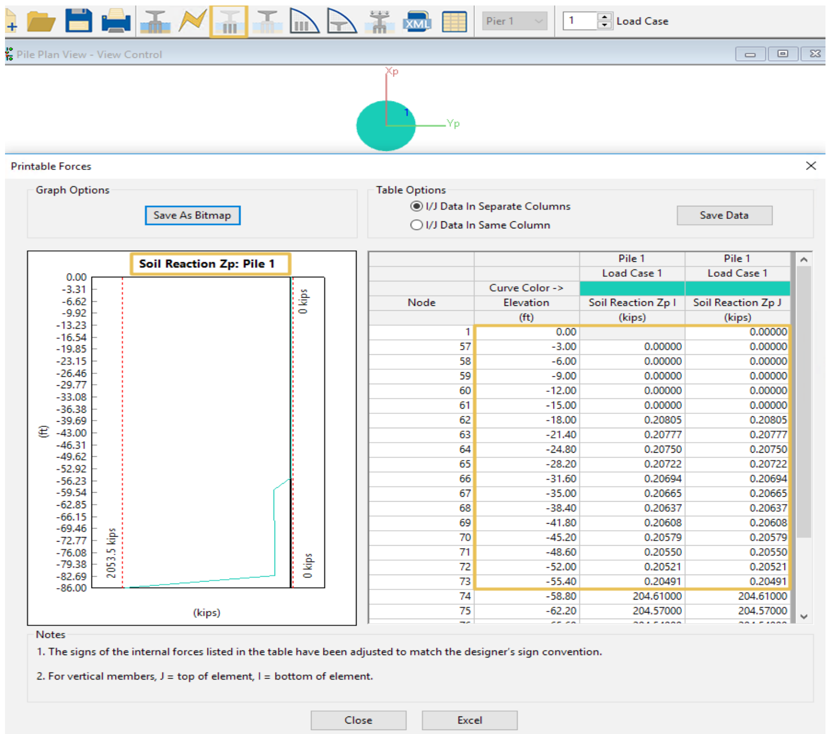

Figure 4. Printable Forces dialog for Soil Reaction (Zp)

Modeling Tips

Hammerhead Piers

The hammerhead pier from **Fig. 3** can be easily modeled in FB-MultiPier. A tip for creating such a model with a single pile or shaft support is simply to supply a 1 x 1 grid line mesh from within the Pile Cap model data window (**Fig. 5**), which indicates to the program that no pile cap is present within the substructure. Further, for this type of model, the pile and column are directly connected end-to-end.

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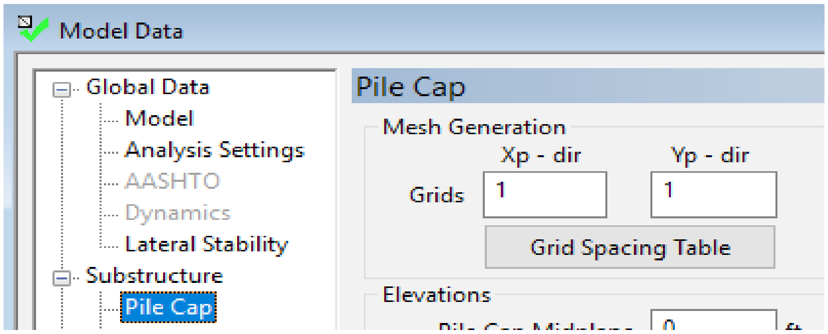

Figure 5. Pile cap mesh discretization of 1x1 for use in modeling hammerhead configurations

In FB-MultiPier, the pier cap can also be sloped or tapered from within the Pier page. For example, the pier cap cantilever for the example configuration from **Fig. 3** is tapered across 19 increments

Technical Support

Cary Peterson
Technical Support, Bridge Software Institute

Location of model files: When running an analysis with FB-MultiPier, the input file should always be located on the local machine, and not on a network server. If an input file is located on a server, network latency can disrupt reading and writing of analysis files, and cause the program to crash. Thus, it is best practice to create a folder on the local machine and save the input file to this location. Once the model has been analyzed, the input (.in) and output (.out) files can be copied back to the server location (for permanent storage, or access by other engineers).

Identifying the program version: To leverage all program features and revisions, engineers are encouraged to make use of the most currently available versions of BSI software. To identify the current version of program installed on your computer, open the program and go to Help -> About to see the program version number.

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BSI Program Status

FB-MultiPier v5.4 **Download a FREE demo today!**

Released November 2018 - 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 v2.05 **Download a FREE demo today!**

Released January 2018 - 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.

Atlas v7.0

Released June 2017 - 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.

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