Dynapile 2016 – User's Manual

Dynamic analysis of pile and drilled shafts under dynamic loading

by

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CHAPTER 1. Introduction

1.1 General Description

Piles and drilled shafts are frequently used as deep foundations to support large and heavy superstructures. The static and dynamic response of these foundations, under static and dynamic loading, is of great importance among engineers and designers.

Static response of piles may be approximated through beam on Winkler foundations and using well-established means of approximating the behavior of soil media through a series of nonlinear springs. Stiffness of these springs are approximated through empirical force-displacement relations referred to as $t-z$ (axial resistance) and $p-y$ curves (lateral resistance) proposed to correlate pile capacity to soil strength.

While $t-z$ and $p-y$ curves provide adequate approximation of soil behavior under static loading, they do not provide means of including inertial effects, dynamic interaction of piles, as well as damping under time-varying loads for dynamic analyses of pile foundations.

Dynapile was developed as a computational tool to fill the gap by providing means of computing dynamic stiffness of pile foundations. Dynapile is a finite-element computational software and consistent boundary method (CBM) for the dynamic analysis of foundations in finite or semi-infinite multi-layered media. Dynapile computes the dynamic stiffness of pile foundations, dynamic response, group reduction factors, and time-history response of foundations under seismic motion.

1.2 Features of the Program

Dynapile provides an easy to use interface for inputting project information and displaying solution results. Dynapile computes the following results:

1. Dynamic stiffness of pile foundations including
    a. Translational (sway) stiffness of pile foundations $K_{xx}, K_{xy}, K_{yy}, K_{zz}$
    b. Rotational (rocking stiffness of pile foundations $K_{rx\,rx}, K_{ry\,ry}, K_{rz\,rz}$
    c. Translational-rotational (sway-rocking) coupling terms $K_{x\,ry}, K_{y\,rx}, K_{z\,rx}, K_{z\,ry}$
2. Transfer functions (kinematic displacement factors) for single piles as well as pile foundations
    a. Single pile
        i. Ratio of pile-head displacement to base displacement
        ii. Ratio of pile-head displacement to free-field displacement
        iii. Ratio of free-field displacement to base displacement
    b. Pile group
        i. Ratio of pile-head displacement to pile-tip displacement in horizontal and vertical directions
        ii. Ratio of pile-head displacement to free-field displacement in horizontal and vertical directions
3. Dynamic response of foundation and superstructure
4. Time-history response of foundation under external ground excitation

1.3 History of Development

1.3.1 Dynapile 1.0 (1999)

The first release of Dynapile computes the following results:

1. Dynamic stiffness of pile foundations including
    a. Translational (sway) stiffness of pile foundations K_{xx}, K_{zz}
    b. Rotational (rocking) stiffness of pile foundations $K_{rx\,rx}, K_{ry\,ry}$
    c. Translational-rotational (sway-rocking) coupling terms $K_{x\,rx}, K_{x\,ry}, K_{y\,rx}, K_{y\,ry}, K_{z\,rx}, K_{z\,ry}$
2. Transfer functions (kinematic displacement factors) for single piles as well as pile foundations
    a. Single pile
        i. Ratio of pile-head displacement to pile-tip displacement
        ii. Ratio of pile-head displacement to free-field displacement
        iii. Ratio of free-field displacement to pile-tip displacement
    b. Pile group
        i. Ratio of pile-head displacement to pile-tip displacement in horizontal
        ii. Ratio of pile-head displacement to free-field displacement in horizontal

1.3.2 Dynapile 2.0 (2002)

Dynapile 2.0 allows for specification of piles in arbitrary configuration with pile-head coordinates.

1.3.3 Dynapile 3.0 (2016)

Dynapile features a new look and feel, coupled with an improved solver. Some of the new features are highlighted below

- Revamped graphical user interface that features:
    - Three-dimensional view of foundation layout (Figure 3-1)
    - Mix and match units for inputting and viewing data (Figure 3-13)
    - Predefined cross-sectional geometries for rapid model creation (Figure 3-19)
    - Drag and drop to rearrange soil layers (Figure 3-22)
    - Create foundation layouts from templates (Figure 3-24)
    - Import wizard for importing external ground excitation from file (Figure 3-29)
    - Re-organization of solution data in a tree-view for easier navigation and viewing (Figure 3-34)
    - Convert display units of existing solution data on the fly
    - Create and view solution report (Section 3.5.2)
    - Export solution data to Comma Separated Values (.csv) format
    - Export solution report to PDF
    - Copy and paste formatted solution report from Dynapile to external word processors or spreadsheet software while maintaining formatting
- Improved solver which includes:

- Compute additional pile group translational stiffness terms K_{xy}, K_{yy}
- Compute additional pile group rotational stiffness terms $K_{rz\,rz}$
- Compute translational-rotational coupling terms $K_{x\,ry}, K_{y\,rx}, K_{z\,rx}, K_{z\,ry}$
- Specify interaction level amount between piles
- Add two additional degrees of freedom to superstructure (u_y, u_z)
- Compute response of foundation and superstructure in the frequency domain
- Compute time-history response of foundation under external ground excitation

1.4 Organization of Dynapile Manuals

The documentation provided with the computer program Dynapile consists of two volumes. The User's Manual contains full documentation about the operation of the program on personal computers. The User's Manual covers the areas of installation, preparation of input data, program execution, view of computational results, and example applications. The distribution of the User's Manual is made via standard portable document file (PDF) format.

The Technical Manual provides information about the theoretical approach in which Dynapile is based. The Technical Manual includes other helpful references related to concepts utilized in program Dynapile. ENSOFT holds a copyright of the Technical Manual so it is distributed in protected form that can only be opened by licensed users of the Dynapile program.

Both manuals are installed with the Dynapile program and accessible via any one of the following three methods:

1. Windows start menu
2. Ensoft tile in Windows 8 or Windows 10
3. Help menu (Section 3.1.5) within the Dynapile program

1.5 Typographical Conventions

To orient the user to different software features, certain terms are set in typefaces that distinguish them from the body text. The following formatting conventions are used throughout the Manual:

- Commands that are typed directly on the keyboard: "Enter" ; "F1" ; "Esc"
- Commands with keys simultaneously pressed in the keyboard: "Alt + F" ; "CTRL + O"
- Menu items and other text displayed on the screen are in sans serif:
  From the File menu choose Open
- File names and names of directories and folder and icon names are in italics:
  Open the example file *example1.dy3d*
- Internet and electronic mail addresses are underlined:
  Send email to support@ensoftinc.com

1.6 Contents of the Dynapile Package

The standard package sent with Dynapile consists of the following items:

- One USB device (sometimes known as hardware key or dongle),
- One backup CD-ROM (this may be missing in future releases, since the full program is available for free downloading from the www.ensoftinc.com website.

The user-selected installation directory (default directory is *Program Files (x86)\Ensoft\Dynapile2016*) contains the main Windows-program module (*winDynapile2016.exe*), the program engine for direct computations (*DYNAPILE_DLL.dll*), the Help file (*DYNAPILE2016.chm*), and other support files. The User's and Technical Manuals are also included in the installation directory. Several examples of input files (all files with extension **.dy3d*) are installed in a separate *Ensoft/Dynapile2016-Examples* subdirectory in the root Windows drive (usually *C:*).

1.7 Hardware Requirements

To use Dynapile, the user needs the following minimum hardware configuration:

- Any personal computer with an Intel® Pentium® or newer processor.
- A hard disk with at least 200 MB of free space.
- Microsoft Windows®, XP, VISTA or Windows 7/8/10. A newer release of the Microsoft Windows® operating system may need a more recent update of the Dynapile software.
- Drivers for minimum OpenGL 2.0 (typically included in the Microsoft Windows system)
- Minimum of 128 MB of free RAM memory.
- A mouse or similar pointing device.
- Optional: Any windows-compatible printer.

1.8 Technical Support

Although computer program Dynapile was designed to be distinguished by its ease of use and by its helpful User's Manual, some users may still have questions. The technical staff at ENSOFT strongly supports all registered users with questions related to the installation or use of Dynapile, according to the stipulations presented below. The software is provided with free maintenance service for the first year. After the first year the user is encouraged to purchase the yearly maintenance services. The yearly maintenance services include free download of the latest version and free technical support as described below.

1.8.1 Preferred Methods of Software Support

Software support is given, in order of preference, by the following methods:

- Electronic mail to: support@ensoftinc.com
- Fax to: (512) 244-6067
- Telephone call to: (512) 244-6464, extension 2

Users are strongly encouraged to utilize electronic means of support via email. In any event, users should include the following information when requesting for software support: software version (obtain

from the Help/About menu), description of the problem copy, input-data file attachment, contact person and licensed company or user name (or name and office location of the licensed company).

Although immediate answers (less than two hours during regular working hours) are offered on most technical support requests, up to two business days should be expected in case of difficulties or conflict of schedules. The users will be informed of ENSOFT's reception of their electronic mails requesting software support if the problem is complicated and cannot be resolved within two business days.

1.8.2 Support by Telephone

Technical help by means of direct calls to our local telephone number (512-244-6464) is available, but limited. The current policy of ENSOFT is that all telephone calls for software support will be answered free of charge for the first 15 minutes of each call if the user has a current maintenance policy. A charge of $90.00 US dollars per hour ($1.50 US dollars per minute) may come into effect for every additional minute after the initial 15 minutes. Applicable charges will be billed to the user.

Software support by any of the methods (fax, email or telephone) is free for all users that have a current annual maintenance policy.

1.8.3 Upgrade Verification and Internet Site

Starting from Dynapile v2016, the software provides options for the user to check the most recent maintenance release through an internet connection by selecting Help/Check for Updates. This command starts the default internet browser and will display the user's maintenance expiration date, the user's software release number and the most recent release number that is available for downloading.

If the user's version is not the latest version and the maintenance has not been expired, the user can download the latest version from our web server directly (www.ensoftinc.com). Users may also consult our internet site for additional information on software updates, demos, and new applications; technical news; and company information.

1.8.4 Changes of Support Policy

The software support policy and associated expenses are subject to change at ENSOFT's discretion and without specific mailed notices to the users. However, any change of rules will be verbally provided during telephone calls for software support.

CHAPTER 2. Installation

2.1 Installation Procedures

Program Dynapile is distributed with an associated USB key (hardware key or dongle). The hardware key consists of a device that is attached to an empty USB port (or USB hub) of the computer in use (or in the designated software server in the case of local network licenses). This method of software protection has been found to provide compatibility with existing operating systems, better stability than other alternatives, and allows users to obtain software updates or replacements via downloads from the internet.

2.1.1 Installation of Single-User Version

This version of Dynapile has been tested to be compatible with the following versions of the Microsoft Windows® operating systems: 2000, XP, Vista, Windows 7, 8 and 10.

The following guidelines are recommended to be followed during the installation process of Dynapile for single-user licenses.

1. Plug the supplied hardware lock (USB device) into one of the available USB ports in your computer. The USB device is plug-and-play compatible so the operating system will recognize the USB device automatically and a small solid green light should be noticeable at the end of the USB key (a flickering green light or no light indicate problems with the standard windows driver or with the USB key).
2. If the user installs from a distribution USB memory stick and the main installation program does not start automatically upon insertion of the memory stick then click on the Windows Start Menu button and select Run. On the command line, type *d:\setup.exe* or *e:\setup.exe*, where *d:* or *e:* represents the drive that contains the distribution memory stick. Click OK to execute the command and start the main installation program for ENSOFT's software. A screen similar to the one in Figure 2-1 should appear.
3. If the user installs from a downloaded file then please run the downloaded file (double click) and go to instruction #5.
4. Click anywhere on the Dynapile 2016 icon and then click on the Install Standard button to start the installation of Dynapile.
5. The user should read the license agreement shown in Figure 2.2-2. Please click Yes if you agree and would like to proceed.
6. Select Single-User License in Figure 2.2-3 then click Next. For network installations please contact Ensoft support (support@ensoftinc.com).
7. The user will be provided with an option to select a drive and directory for the installation of Dynapile (see Figure 2.2-4); the default is *c:\Program Files (x86)\Dynapile\Dynapile2016*. If the desired directory does not exist, the installation program will automatically create a new directory in the chosen hard drive.

   Most distribution files will be copied to the installation directory (either the default or the one selected by the user). However, certain files are copied to system directories in Windows and some Windows services are started during installation (mainly for Network installations). The name of the system files, their exact locations, and the type of services that are started may change in time and for different versions of the Microsoft Windows® operating system.

Example files are copied to the following subdirectory under the root Windows drive:

(Root Drive)\Ensoft\Dynapile2016-Examples

8. During the installation the user will be asked to set the file extension association for opening Dynapile 2016 input data files (see Figure 2.2-5). If the user agrees (leaves the default check mark) then double clicking (or running) any input data file with extensions of the type *filename.dy3d* will start the installed Dynapile 2016 software.

9. The user will be prompted to confirm the shortcut directory name that will be created in the Windows Start Menu (See Figure 2.2-6). The default is *Start Menu/Programs/Ensoft/Dynapile2016*. Windows 8 will automatically create an Ensoft tile with the same shortcuts.

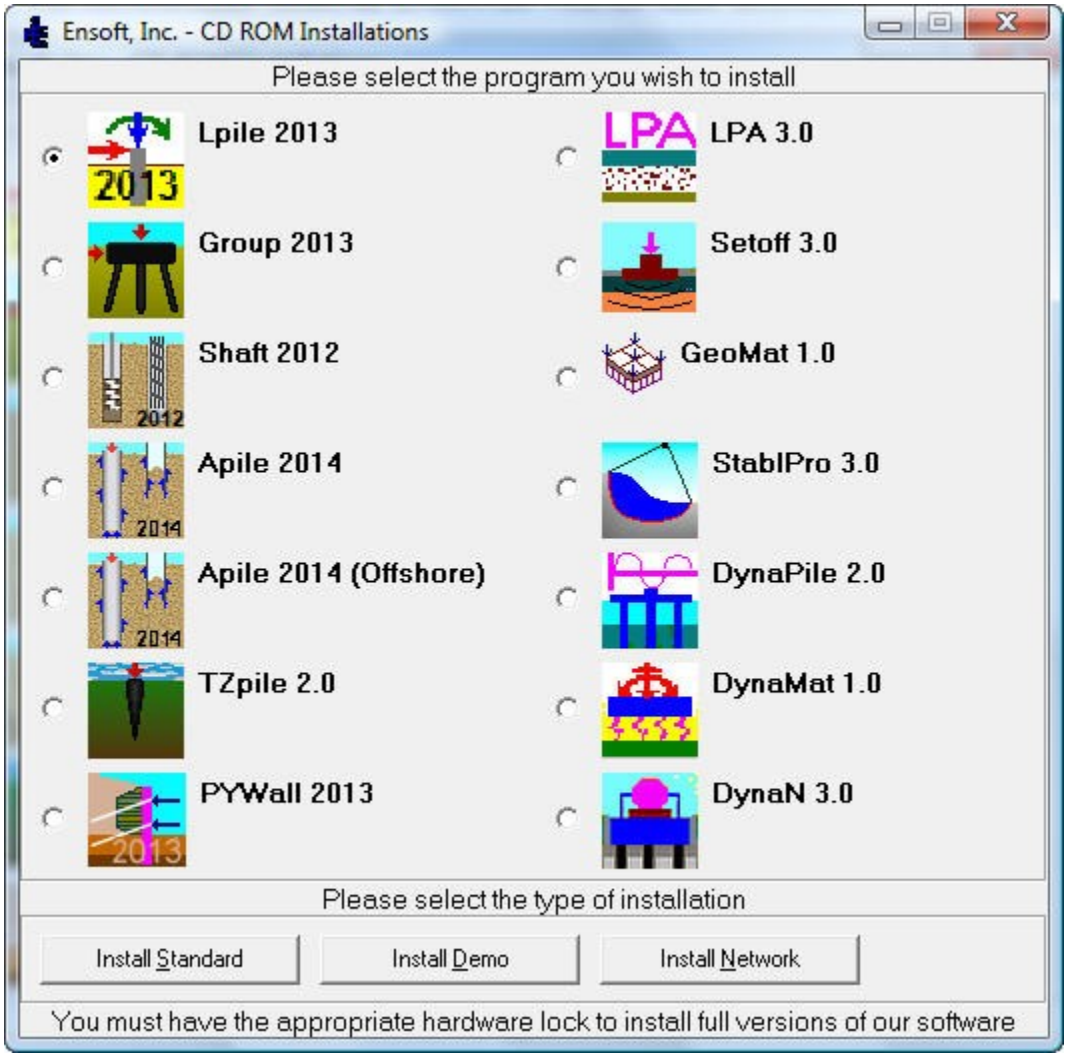


Figure 2-1 Main CD-ROM installation screen for ENSOFT software (may change with time)

After the installation is finished, it is not necessary to reboot Windows for the program to run. The user may run the program by selecting Dynapile v2016 from the standard links installed in the Microsoft Windows® Start Menu: Start Menu > All Programs > Ensoft > Dynapile2016

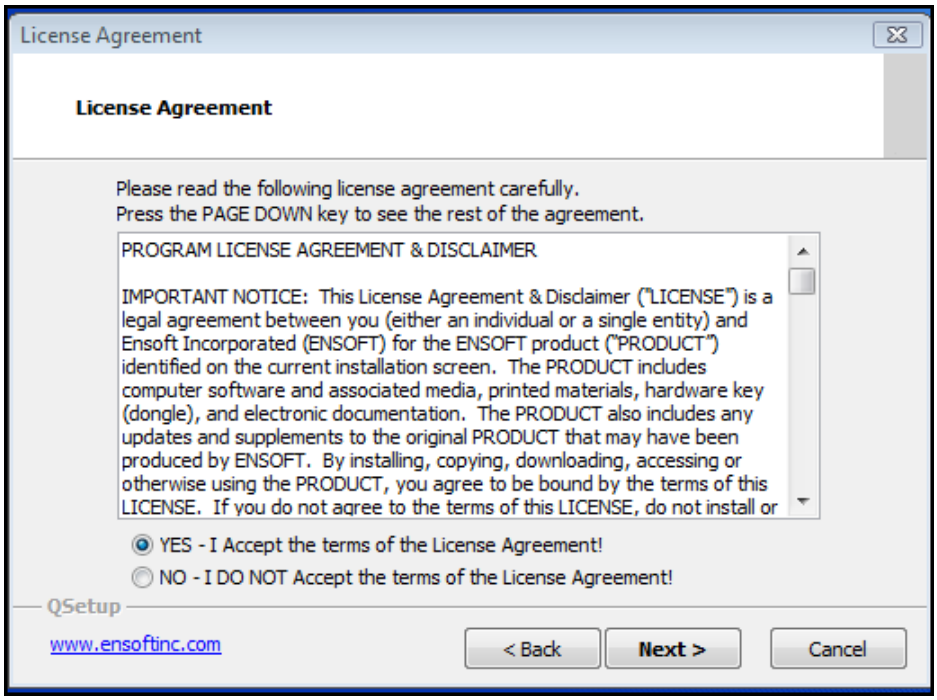


Figure 2.2-2 Installation screen with License Agreement (may change with time)

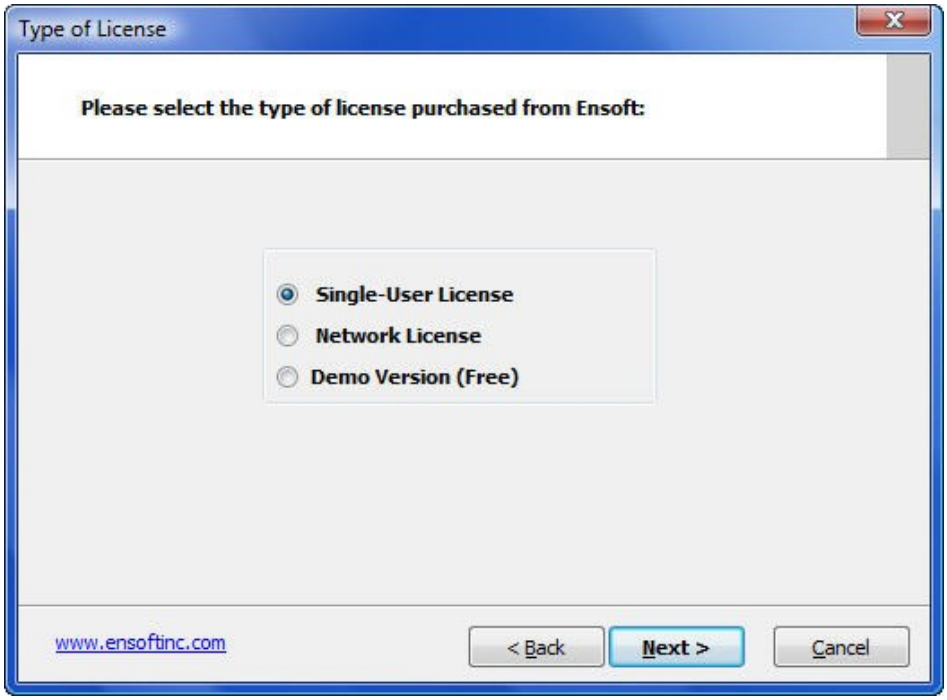


Figure 2.2-3 Selection of Single-User License (may change with time)

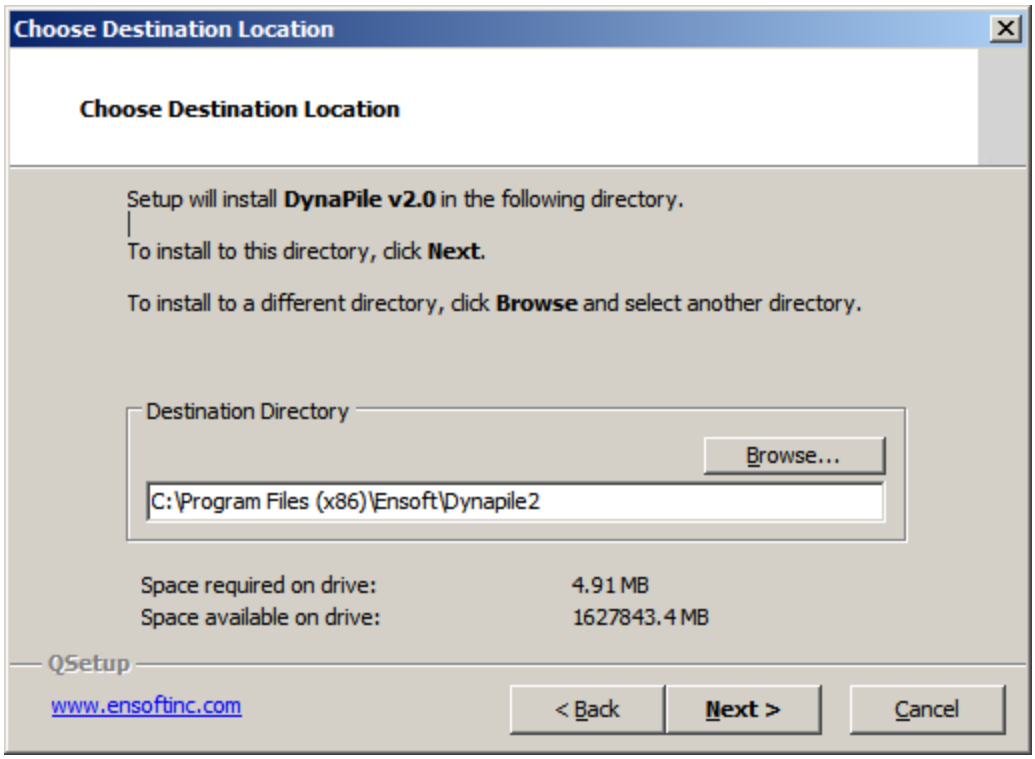


Figure 2.2-4 Default Installation Directory for Program Files (may change with time)

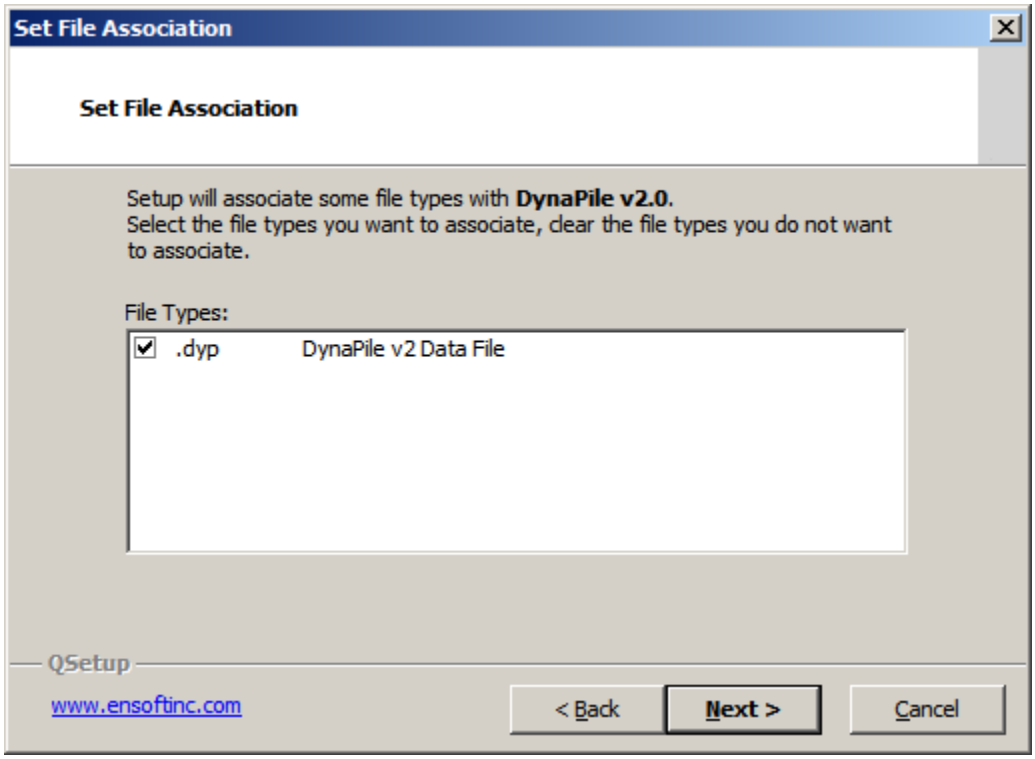


Figure 2.2-5 File Extension Association for Dynapile 2.0 Data Files (may change with time)

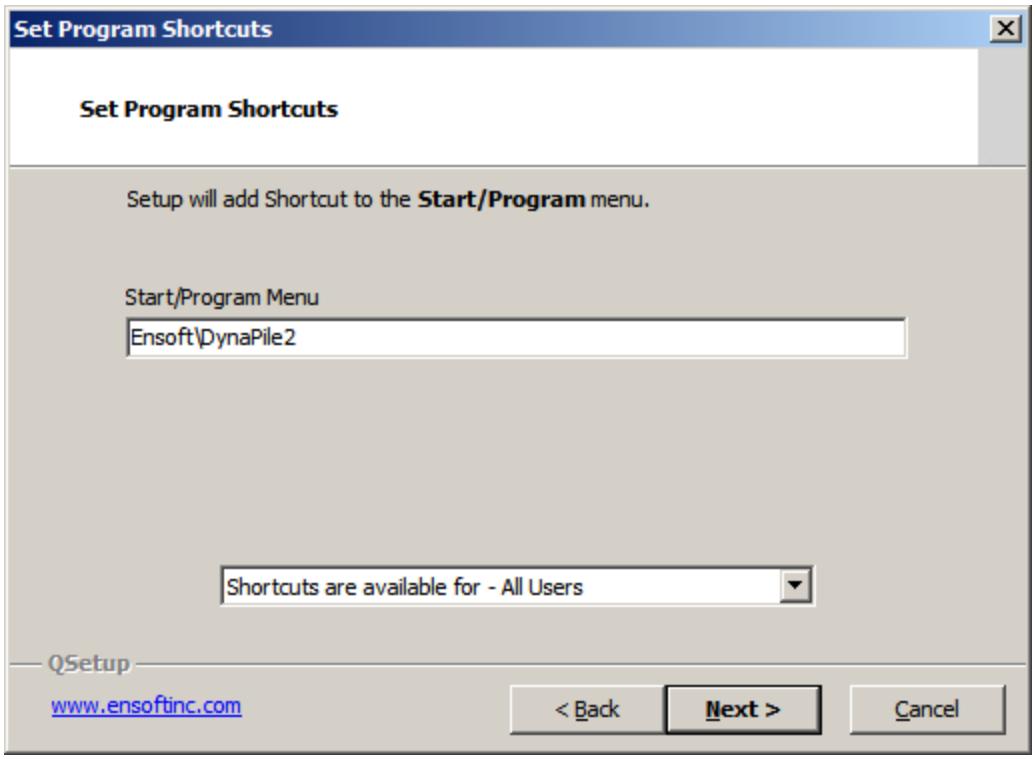


Figure 2.2-6 Default Shortcut Folder in Windows Start Menu (may change with time)

2.1.2 Introduction of Network Version

Special network licenses and USB hardware keys (network keys) are available for users who desire to operate Dynapile on a Windows network. The network version is limited to users with two or more licenses at the same physical site. Discounted rates apply for users purchasing multiple licenses for the same site.

Network versions of Dynapile have special subroutines written for installations in "software servers" and for installations of "individual clients". The "software server" or "license server" is the computer that will be carrying the network USB key provided by ENSOFT, INC. The software server is not necessarily the same as the existing network server. Any computer in the existing Windows network may be designated software server for Dynapile as long as the network key is attached to an available USB port (or through an USB hub) and the "server" version of the software is installed on its local drive. Software "clients" may be all computers of the licensed site that have the program installed as client. Software clients do not need any hardware key attached to their computers. The program installed in software clients will be allowed to run if their IP are within the allowable (licensed) IP ranges and if the computer designated as software server is accessible on the network with the proper operating system and with its network key secured in place.

Users of the network version of Dynapile are allowed to have the software installed in as many computers as desired within the licensed IP ranges of their local Windows network. However, only a number of users equal to the total number of purchased licenses will be able to operate the program at the same time.

2.1.2.1 *Installation of Network Version*

Installers of network licenses should refer to a separate booklet with installation instructions for the Network version of this product. The document can be downloaded from the Ensoft web site:

http://www.ensoftinc.com/updates/Ensoft Network Installation Notes.pdf

Alternatively, the document can be requested via email to support@ensoftinc.com

2.1.2.2 *Silent Installations on Client Computers*

For installation of network licenses on local client computers there is an option for command-based installations that are completely silent (performed without other user input). Instructions for silent installations on client computers can be downloaded from the Ensoft web site using the following link:

http://www.ensoftinc.com/updates/Silent Install on Client Computers.pdf

Alternatively, the document can be requested via email to support@ensoftinc.com

2.1.3 Backup of Original Software

The distributed software may be copied for backup purposes. The program may be installed in several computers at the same time. However, unless network licenses are purchased, the program will only operate in computers that carry the appropriate hardware key.

2.1.4 Software Updates on the Internet

Occasionally, ENSOFT will produce software improvements and/or fixes and place the latest software programs on ENSOFT's internet site. Users can check for available updates by selecting Help/Check for Updates from the Dynapile menu. Software users may freely download the latest program update from the following site: *http://www.ensoftinc.com*

CHAPTER 3. Using Dynapile

The full layout of dynapile, loaded with a project, is shown below in Figure 3-1. The menu bar houses the program's functionality, while the menu bars provide convenience access to some of these functionalities.

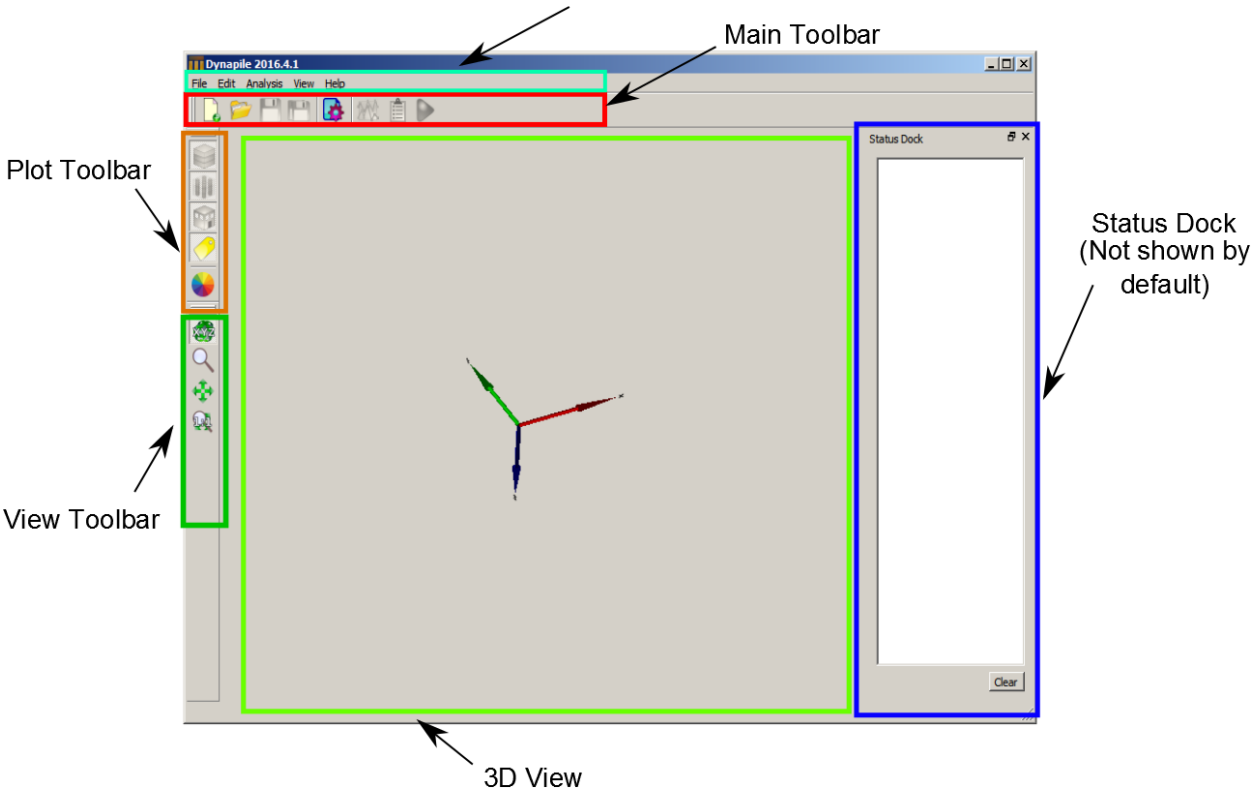


Figure 3-1 Dynapile layout overview

Dynapile runs under either Licensed or demonstration (Demo) mode. If the hardware USB security key is not found, Dynapile will run under Demo mode. Table 3-1 compares the availability of some of the core functionalities of Dynapile under these two modes.

Table 3-1 Dynapile running mode and available functionalities

	Licensed	Demo
Open	✓	✓
Edit	✓	✓
View existing results	✓	✓
View User's Manual	✓	✓
View Technical Manual	✓	✗
Save / Save As	✓	✗
Run analysis	✓	✗

Throughout this chapter, the full functionality of Dynapile is discussed (i.e. Dynapile running under Licensed mode).

The typical steps followed in analyzing a foundation system are as follows (see e.g. Example 1 in Section 4.1.1):

1. Open Dynapile
2. Enter required project data (Section 3.3)
3. Save project to a file on local drive
4. Run Analysis (Section 3.4)
5. View/save results (Section 3.5)

This chapter is organized as follows. In Section 3.1 and Section 3.2, the menu bars and the toolbars, respectively, are highlighted. In Section 3.3, editing the project data is discussed in detail. Finally, viewing and exporting of the solution data are discussed in the remaining sections

3.1 Menu Bars

Functionalities of Dynapile are organized in menus as listed in the below

Menu	Functionality
File	Filing of project, e.g. new file, save, import, etc.
Edit	Editing of data and view
Analysis	Starting analysis and viewing results
View	Manipulating toolbars and view in Dynapile
Help	Accessing information about Dynapile

In the following subsections, the available actions within each menu is highlighted.

3.1.1 File Menu

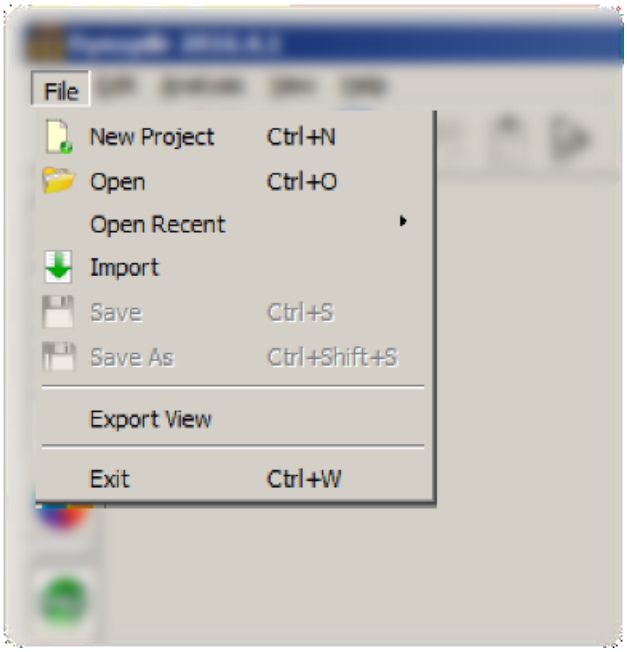


Figure 3-2 File menu

The File menu is shown in Figure 3-2, and corresponding functionality of each option is discussed in the below:

Icon	Action	Description
	New project	Discard current project data (if any) and start a new project from scratch
	Open	Discard current project data (if any), locate a file from local drive, and open it
	Open Recent	Discard current project data (if any) and open the selected file
	Import	Discard current project data, and import from local drive a Dynapile Version 2.0 input file with extension .dyd
	Save	Save project under existing file. If no file has been specified, will prompt for a file name. Otherwise, existing file will be overwritten. If the project has not been altered, this button will be disabled. Dynapile 2016 input files have extension .dy3d
	Save As	Save project under a different name. If the project has not been altered, this button will be disabled.
	Export View	Export the current 3D view (Figure 3-1) as a PNG file
	Exit	Exit Dynapile

3.1.2 Edit Menu

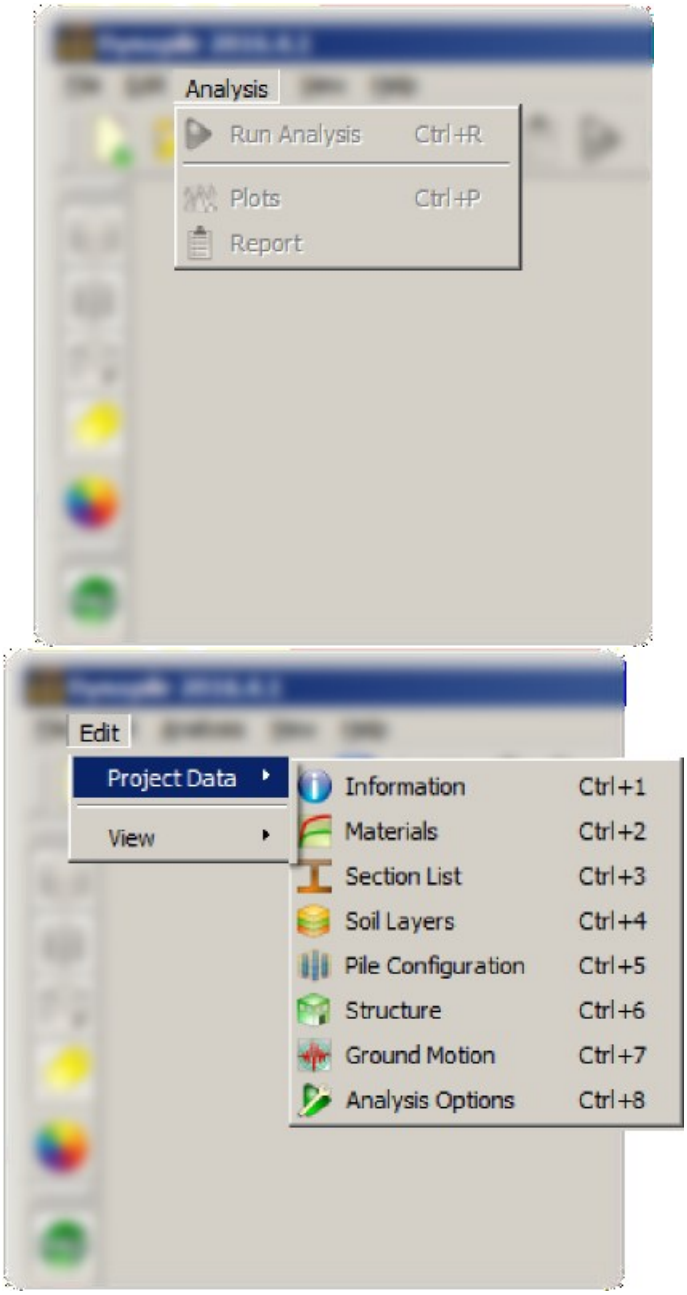


Figure 3-3 Edit menu

The Edit menu is shown in Figure 3-3, and corresponding functionality of each option is discussed in the below:

Icon	Action	Description
	Information	Open the project data window and show Project information
	Materials	Open the project data window and show Material library list (Section 3.3.2)
	Section List	Open the project data window and show Section library list (Section 3.3.3)
	Soil Layers	Open the project data window and show soil layer data (Section 3.3.4)
	Pile Configuration	Open the project data window and show pile layout (Section 3.3.5)
	Structure	Open the project data window and show superstructure data (Section 3.3.6)
	Ground Motion	Open the project data window and show ground motion data (Section 3.3.7)
	Analysis Options	Open the project data window and show analysis options data (Section 3.3.8)
	Background Color	Change 3D view background color by toggling open the color section window (Figure 3-4)

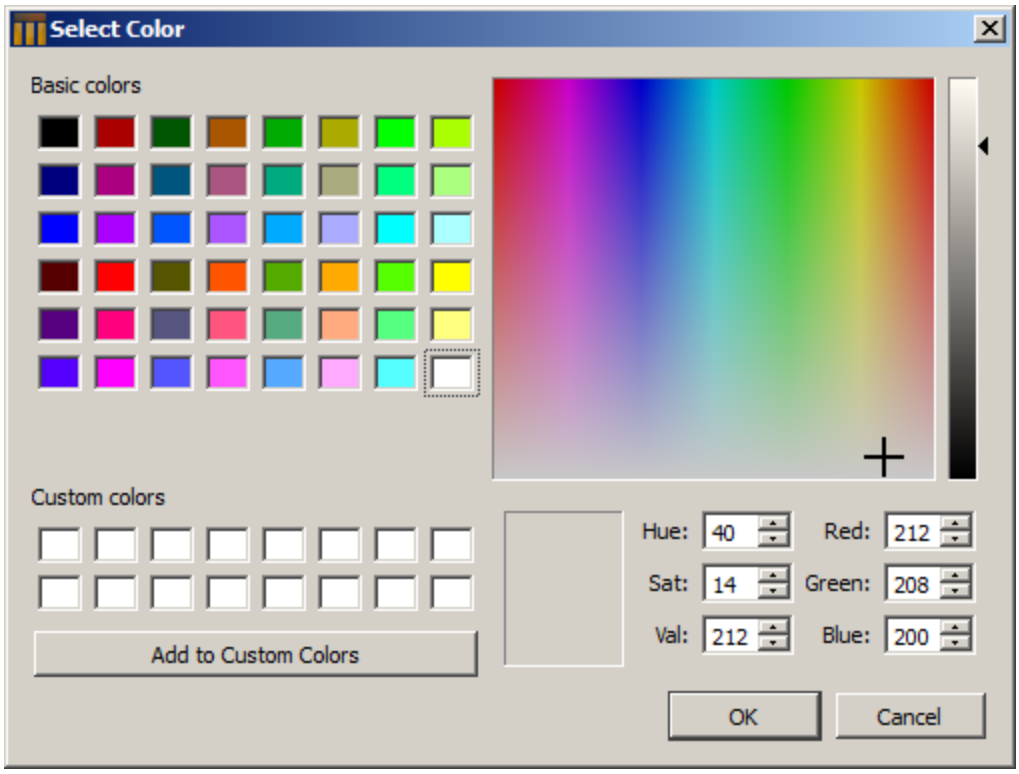


Figure 3-4 Selecting new color

3.1.3 Analysis Menu

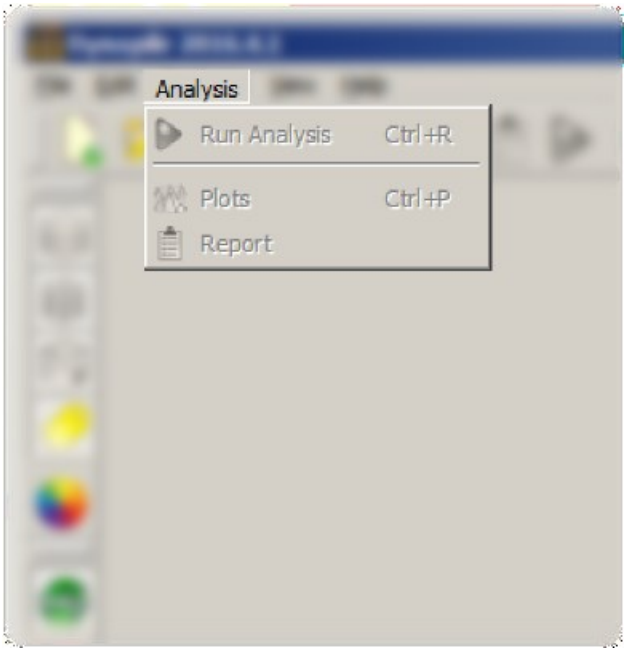


Figure 3-5 Analysis menu

The Analysis menu is shown in Figure 3-5, and the corresponding functionality of each option is discussed in the below:

Icon	Action	Description
	Run Analysis	Start the computation using the specified sets of data. If an analysis had been performed at a prior time, the data will be overwritten. For the analysis button to become available, project must be saved (or resaved if altered). Also, see Section 3.4
	Plots	Open plot window and show solution plots. This button is disabled unless a plot file with extension .dy3p exist in the project directory. Also see Section 3.5.1
	Report	Open summary window and show input and output data. This button is disabled unless a plot file with extension .dy3p exist in the project directory. Also see Section 3.5.2.

3.1.4 View Menu

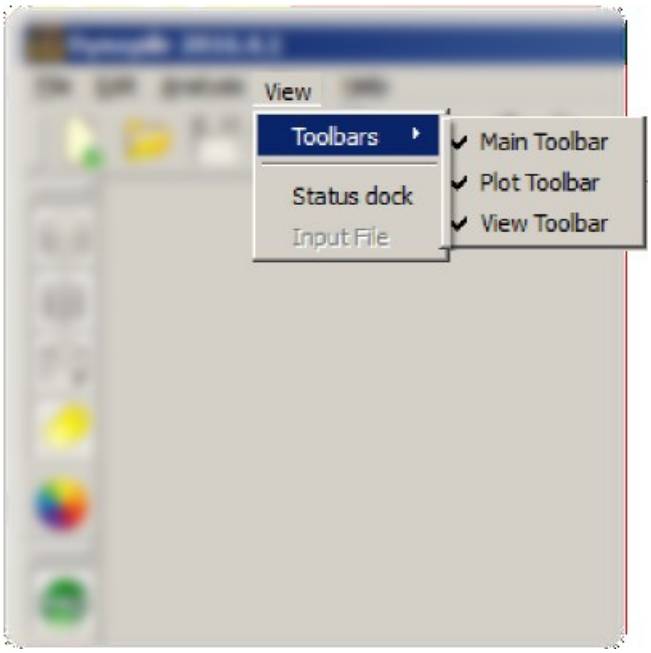


Figure 3-6 View menu

The View menu is shown in Figure 3-6, and corresponding functionality of each option is discussed in the below:

Icon	Action	Description
	Main Toolbar	Toggle the visibility of main toolbar (Figure 3-1)
	Plot toolbar	Toggle the visibility of plot toolbar (Figure 3-1)
	View Toolbar	Toggle the visibility of the view toolbar (Figure 3-1)
	Status dock	Toggle the visibility of the status dock (Figure 3-1)
	Input file	Show the input file

3.1.5 Help Menu

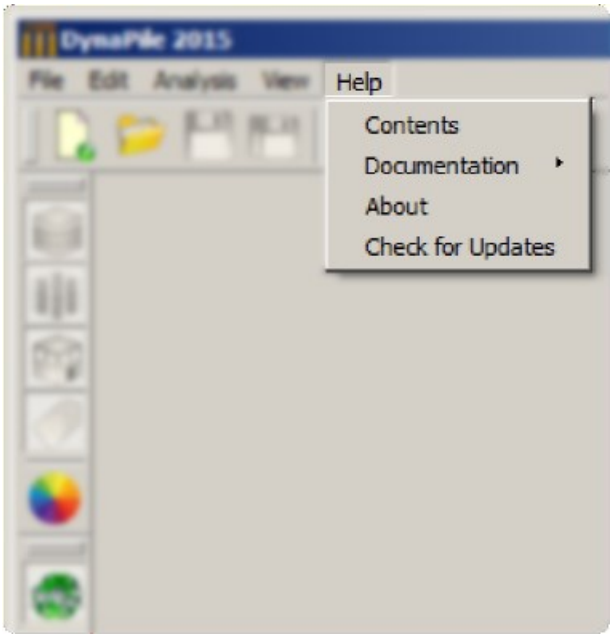


Figure 3-7 Help menu

The Help menu is shown in Figure 3-7, and corresponding functionality of each option is discussed in the below:

Icon	Action	Description
	Contents	Open Dynapile's user's manual file in compiled html format
	Documentation	Open Dynapile's User's Manual (this document) or Technical Manual in PDF format.
	About	Open About window of Dynapile to view information including license information
	Check for Updates	Open default web-browser and check for Dynapile updates

3.2 Toolbars

Dynapile has a total of three toolbars presented (Figure 3-8): Main Toolbar, Plot Toolbar, and View Toolbar. These toolbars serve as a convenient way to access commonly used functionality, most of which are available from the Menu bar.

The visibility of the toolbars may be toggled at any time by either:

- Right-clicking the menu bar and selecting the name of the toolbar
- Or, Navigating to

  View → Toolbars

  and selecting the name of the toolbar

Additionally, the location of the toolbars may be changed by clicking and dragging them with the mouse (Figure 3-8).

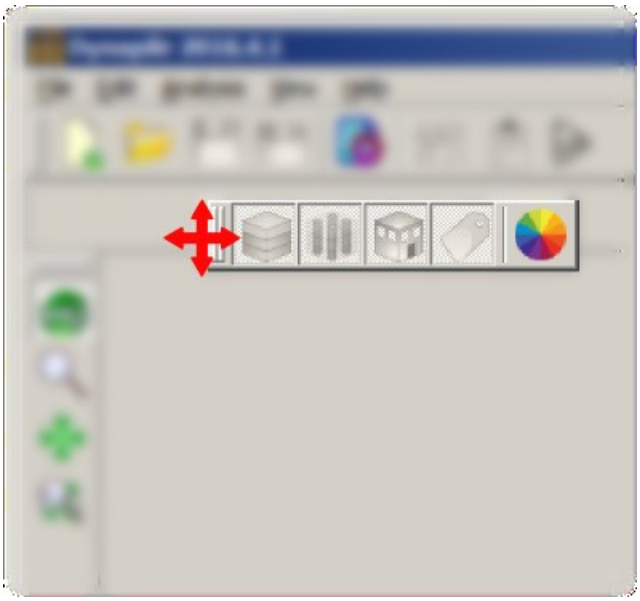


Figure 3-8 Toolbars can be moved around using the mouse

In the subsections below, the corresponding action associated to each icons in the toolbars are discussed. Note that information about each icon may be obtained by hovering the mouse over the icon.

3.2.1 Main Toolbar

Figure 3-9 Main toolbar

The main toolbar (Figure 3-9) houses the most commonly used buttons for convenience action. All buttons, except the Project Data button (), are contained in the menu bar of the program. In the below, the function of each button is summarized

Icon	Action
	Start a new project by deleting all existing project data. The Project Data window () will then prompted open
	Locate an existing project file with extension .dy3d from local drives and open it. Prior to importing the project data, all existing project data are removed.
	Save the current project under the existing name with extension .dy3d. If no filename has been previously specified, a dialog will prompt for a filename.
	Save current project under a different name with extension of .dy3d
	Open project data window. Selecting this option will initially display the Project Information dialog. Note: changing the project data will result in automatic deletion of all existing solution data.
	View solution plot window. If no solution file exists with extension .dy3p, this button will not be enabled
	View summary of solution data. If no solution file exists with the extension .dy3p, this button will not be enabled
	Start the analysis. Any existing solution data will be overwritten. This button will be disabled until current project has been saved under a filename, or resaved if altered.

3.2.2 Plot Toolbar

The plot toolbar (Figure 3-10) contains buttons to manipulate the 3D view of pile group system (Figure 3-1). In the below, the functionality of each button is discussed.

Figure 3-10 Plot toolbar

Icon	Action
	Toggle the visibility of soil layers (if available) in the 3D view
	Toggle the visibility of the piles (if available) in the 3D view
	Toggle the visibility of the superstructure (if available) in the 3D view
	Toggle the visibility of the axes labels and frame in the 3D view
	Change background color of the 3D view

3.2.3 View Toolbar

Figure 3-11 View toolbar

The View Toolbar (Figure 3-11) contains tools to manipulate the 3D view. In the below, the functionality of each button is discussed.

Icon	Action
	This is the preferred, and most versatile way of manipulating the 3D view. The functionality of the left mouse button is toggled by holding modifier keys as discussed in the below: • **Rotation**: Hold the left mouse button and drag on the screen to rotate the 3D view about the y and z axes • **Rotation**: Hold down the CTRL key on the keyboard, and drag on the screen to rotate about the x and y axes • **Translation**: Hold down the middle mouse key, and drag on the screen to translate (move) the 3D view around the screen • **Zooming In**: Using the mouse wheel, scroll up to zoom in • **Zooming Out**: Using the mouse wheel, scroll down to zoom out
	When selected, move the mouse up and down on the screen whiling holding the LEFT mouse button to zoon in and out, respectively. This is equivalent to selecting  and scrolling up and down using the mouse wheel button.
	When selected, move the mouse around while holding the LEFT mouse button to move the 3D view on the screen. This is equivalent to selecting  and using the middle button
	Reset view to original view

3.3 Project Data

Project data window holds the entire project data and is used to view and/or edit the data. Data associated to the project is organized in a total of 8 subcategories as displayed on top of the window (Figure 3-12) as icons, and can be navigated to by clicking the icons.

All changes made in these categories are immediately updated, and can navigate between the different categories by clicking the icons at any time. When finished, the changes can updated by clicking the "OK" button. Notice that clicking "OK" will result in deletion of all existing solution results that may have been previously computed.

Alternatively, all changes made can be discarded by clicking the "CANCEL" button.

It is suggested that, for new projects, data in each category to be filled from starting from left to right, i.e. starting with Project Information (discussed in Section 3.3.1), and progressing to Analysis Options (discussed in Section 3.3.8).

Each subcategory and the corresponding data will be described in the following.

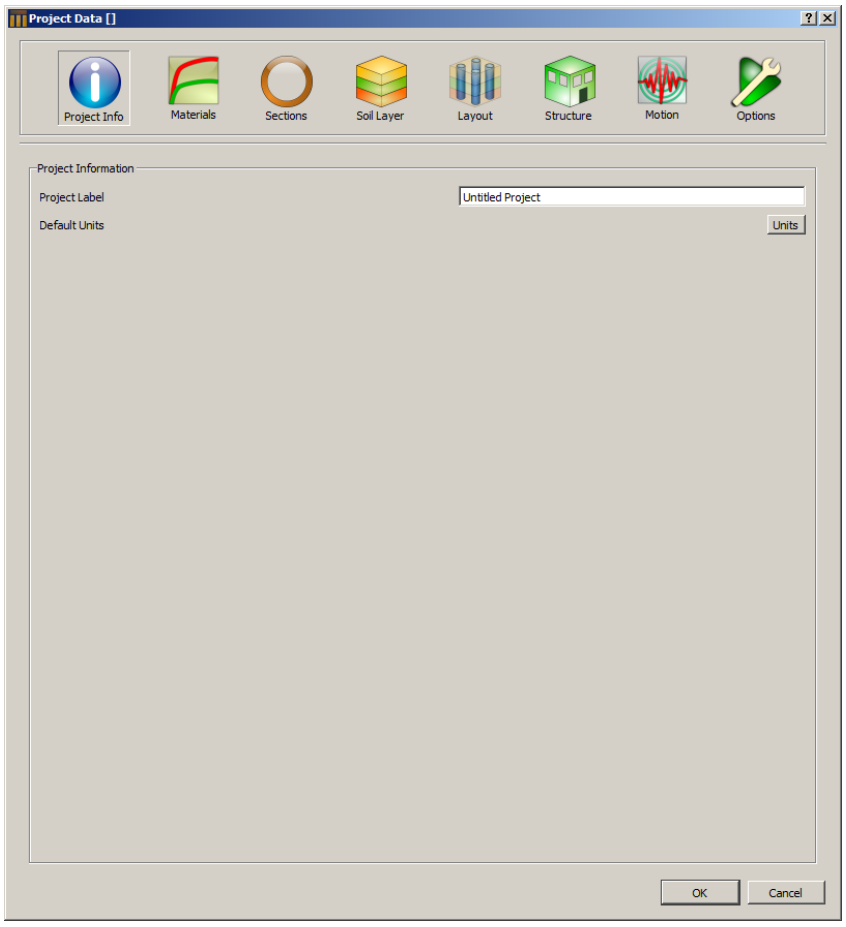


Figure 3-12 Project Information

3.3.1 Project Information

General project information including project title as well as the default display units are specified in this tab. Available data to modify is as follows:

- **Project Label**: An optional string of text to describe the project
- **Units**: Prompt open unit window (Section 3.3.1.1) and change the default display of units in other windows and widgets. The specified units serve merely as the default displayed units in all input. In input fields and tables, the units can be changed on-the-fly by right-clicking containing input widget (see, for instance, Figure 3-13 and Figure 3-14) with the mouse. Upon selection of a new unit, existing value will be converted.

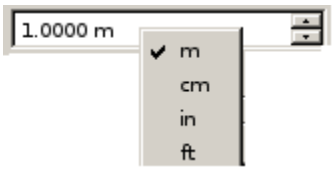


Figure 3-13 Changing units in a spinbox

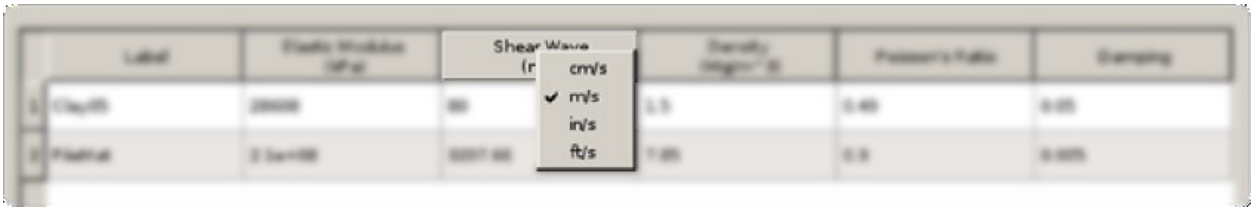


Figure 3-14 Click headers to change units on a table column

3.3.1.1 Units

Individual units can be changed from the drop down menus (Figure 3-15). The unit symbols (m, kN, slugs, etc) correspond to the globally used symbols for the units, and ^ denotes the superscript operator (for instance, m^2 implies m^2, in^4 implies in^4, etc.). In Table 3-2, the full name for each available unit of measurement in Dynapile is tabulated.

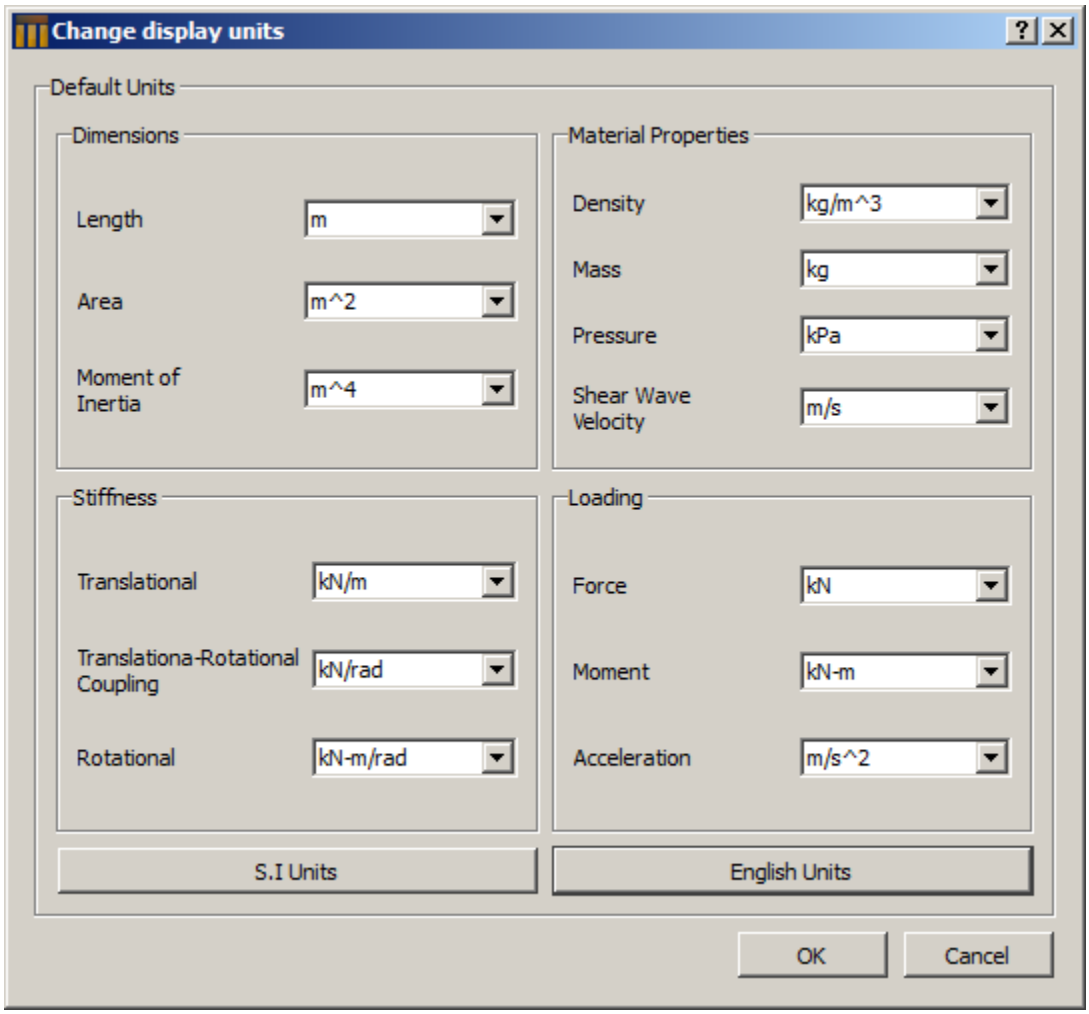


Figure 3-15 Display unit window

Table 3-2 Unit symbols used throughout Dynapile

Symbol	Unit name
m	Meter
cm	Centimeter
in	Inches
ft	Feet
kg	Kilograms
Mg	Megagram
Pa	Pascal
kPa	Kilopascal
MPa	Megapascal
GPa	Gigapascal
psi	Pound-force per square inch
psf	Pound-force per square feet
N	Newton
kN	Kilonewton
lb	Pound-force
kip	Kip-force
rad	Radians
Hz	Hertz

For convenience, the two buttons on the lower window (Figure 3-15) can be used to change the units of length, force, and mass in all drop-down menus to the ones tabulated in Table 3-3. The conversion units between the available units are tabulated in Table 3-4 through Table 3-14.

Table 3-3 Preconfigured unit sets

	S.I Units Button	English Units Button
Length	Meters (m)	Inches (in)
Force	Kilonewton (kN)	Pound-force (lb)
Mass	Kilogram (kg)	Slugs

Table 3-4 Length unit conversion table (shown to four decimal places)

From\To	m	cm	in	ft
m	1.	100.	39.3701	3.2808
cm	0.0100	1.	0.3937	0.0328
in	0.0254	2.5400	1.	0.0833
ft	0.3048	30.4800	12.0000	1.

Table 3-5 Area unit conversion table

From\To	m^4	cm^4	in^4	ft^4
m^4	1.0000	1.0000E-08	2.403E+06	115.8618
cm^4	1.000E+08	1.0000	0.0240	1.1586E-06
in^4	4.1623E-07	41.6231	1.0000	4.8225E-05
ft^4	8.6310E-03	8.631E+05	2.074E+04	1.0000

Table 3-6 Area moment of inertia conversion table

From\To	m^4	cm^4	in^4	ft^4
m^4	1.0000	1.0000E-08	2.403E+06	115.8618
cm^4	1.000E+08	1.0000	0.0240	1.1586E-06
in^4	4.1623E-07	41.6231	1.0000	4.8225E-05
ft^4	8.6310E-03	8.631E+05	2.074E+04	1.0000

Table 3-7 Density unit conversion table

From\To	kg/m^3	kg/cm^3	Mg/m^3	Mg/cm^3	$slugs/ft^3$	$slugs/in^3$
kg/m^3	1.000E+00	1.000E-06	1.000E-03	1.000E-09	1.940E-03	1.123E-06
kg/cm^3	1.000E+06	1.000E+00	1.000E+03	1.000E-03	1.940E+03	1.123E+00
Mg/m^3	1.000E+03	1.000E-03	1.000E+00	1.000E-06	1.940E+00	1.123E-03
Mg/cm^3	1.000E+09	5.154E-04	1.000E+06	1.000E+00	1.940E+06	1.123E+03
$slugs/ft^3$	5.154E+02	5.154E-04	5.154E-01	5.154E-07	1.000E+00	5.787E-04
$slugs/in^3$	8.906E+05	8.906E-01	8.906E+02	8.906E-04	1.728E+03	1.000E+00

Table 3-8 Pressure unit conversion table

From\To	Pa	kPa	MPa	GPa	psi	psf
Pa	1	1.000E-03	1.000E-06	1.000E-09	1.450E-04	2.089E-02
kPa	1.000E+03	1	1.000E-03	1.000E-06	1.454E-01	2.089E+01
MPa	1.000E+06	1.000E+03	1	1.000E-03	1.450E+02	2.089E+04
GPa	1.000E+09	1.000E+06	1.000E+03	1	1.450E+05	2.089E+07
psi	6.895E+03	6.879E+00	6.895E-03	6.895E-06	1	1.440E+02
psf	4.788E+01	4.788E-02	4.788E-05	4.788E-08	6.944E-03	1

Table 3-9 Velocity unit conversion table

From\To	m/s	cm/s	in/s	ft/s
m/s	1.0000	0.0100	39.3701	3.2808
cm/s	100.0000	1.0000	0.3937	0.0328
in/s	0.0254	2.5400	1.0000	0.0833
ft/s	0.3048	30.4800	12.0000	1.0000

Table 3-10 Acceleration conversion table

From\To	m/s^2	cm/s^2	in/s^2	ft/s^2
m/s^2	1.0000	0.0100	39.3701	3.2808
cm/s^2	100.0000	1.0000	0.3937	0.0328
in/s^2	0.0254	2.5400	1.0000	0.0833
ft/s^2	0.3048	30.4800	12.0000	1.0000

Table 3-11 Force unit conversion table

From\To	N	kN	lb	kip
N	1.0000	1000.0000	0.2248	0.0002
kN	0.0010	1.0000	224.8089	0.2248
lb	4.4482	0.0044	1.0000	0.0010
kip	4448.2205	4.4482	1000.0000	1.0000

Table 3-12 Translational stiffness conversion table

From\To	N/m	kN/m	N/cm	kN/cm	lb/in	lb/ft	kip/in	kip/ft
N/m	1.000E+00	1.000E-03	1.000E-02	1.000E-05	5.710E-03	6.852E-02	5.710E-06	6.852E-05
kN/m	1.000E+03	1.000E+00	1.000E+01	1.000E-02	5.710E+00	6.852E+01	5.710E-03	6.852E-02
N/cm	1.000E+02	1.000E-01	1.000E+00	1.000E-03	5.710E-01	6.852E+00	5.710E-04	6.852E-03
kN/cm	1.000E+05	1.000E+02	1.000E+03	1.000E+00	5.710E+02	6.852E+03	5.710E-01	6.852E+00
lb/in	1.751E+02	1.751E-01	1.751E+00	1.751E-03	1.000E+00	1.200E+01	1.000E-03	1.200E-02
lb/ft	1.459E+01	1.459E-02	1.459E-01	1.459E-04	8.333E-02	1.000E+00	8.333E-05	1.000E-03
kip/in	1.751E+05	1.751E+02	1.751E+03	1.751E+00	1.000E+03	1.200E+04	1.000E+00	1.200E+01
kip/ft	1.459E+04	1.459E+01	1.459E+02	1.459E-01	8.333E+01	1.000E+03	8.333E-02	1.000E+00

Table 3-13 Rotational stiffness conversion table

From\To	N/rad	kN/rad	lb/rad	kip/rad
N/rad	1.0000	1000.0000	0.2248	0.0002
kN/rad	0.0010	1.0000	224.8089	0.2248
lb/rad	4.4482	0.0044	1.0000	0.0010
kip/rad	4448.2205	4.4482	1000.0000	1.0000

Table 3-14 Moment stiffness conversion table

From\To	N-m/rad	kN-m/rad	N-cm/rad	kN-cm/rad	Lb-in/rad	Lb-ft/rad	Kip-in/rad	Kip-ft/rad
N-m/rad	1.000E+00	1.000E-03	1.000E+02	1.000E-01	8.851E+00	7.376E-01	8.851E-03	7.376E-04
kN-m/rad	1.000E+03	1.000E+00	1.000E+05	1.000E+02	8.851E+03	7.376E+02	8.851E+00	7.376E-01
N-cm/rad	1.000E-02	1.000E-05	1.000E+00	1.000E-03	8.851E-02	7.376E-03	8.851E-05	7.376E-06
kN-cm/rad	1.000E+01	1.000E-02	1.000E+03	1.000E+00	8.851E+01	7.376E+00	8.851E-02	7.376E-03
Lb-in/rad	1.130E-01	1.130E-04	1.130E+01	1.130E-02	1.000E+00	8.333E-02	1.000E-03	8.333E-05
Lb-ft/rad	1.356E+00	1.356E-03	1.356E+02	1.356E-01	1.200E+01	1.000E+00	1.200E-02	1.000E-03
Kip-in/rad	1.130E+02	1.130E-01	1.130E+04	1.130E+01	1.000E+03	8.333E+01	1.000E+00	8.333E-02
Kip-ft/rad	1.356E+03	1.356E+00	1.356E+05	1.356E+02	1.200E+04	1.000E+03	1.200E+01	1.000E+00

3.3.2 Material List Library

The material library (Figure 3-16) window contains the full list of available material library for the project. All materials in Dynapile (individual soil layers, as well as pile properties) are linear elastic, homogeneous, and isotropic. The list defined here serves as a library, and the order in which the materials are defined is not important. Following their definitions, these materials can be then assigned to piles (Section 3.3.5) as well as soil layers (Section 3.3.4).

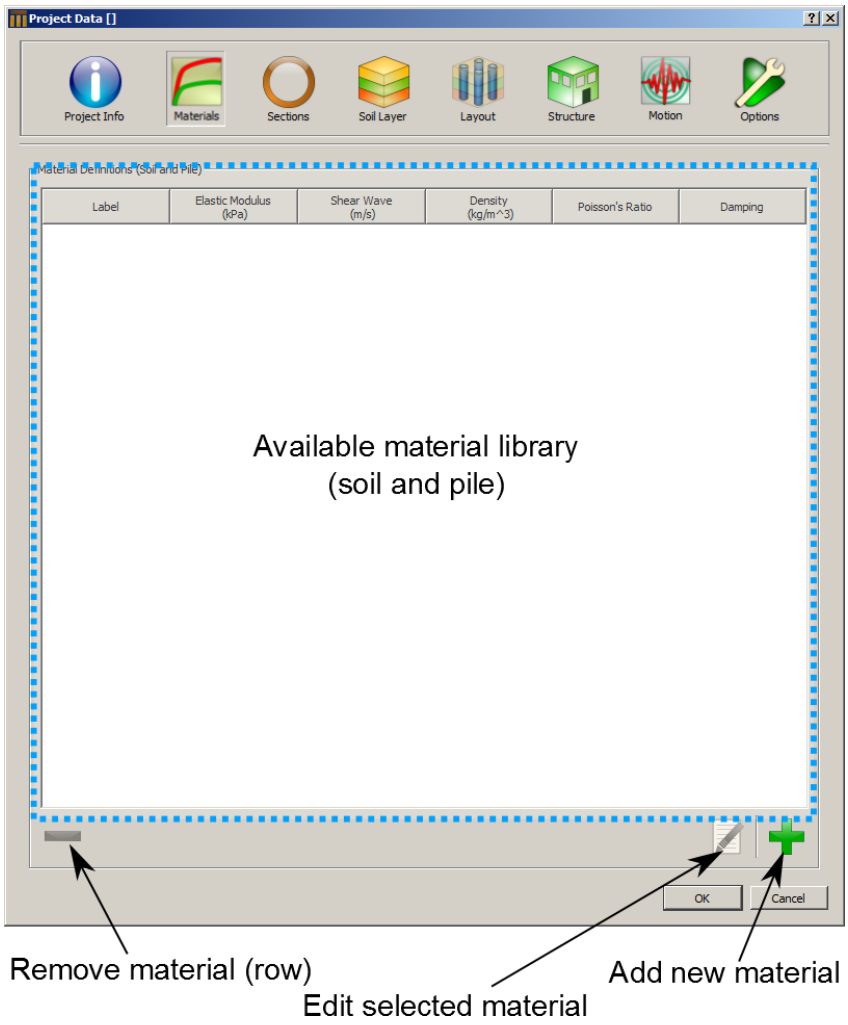


Figure 3-16 Material list library

In general, the analysis of pile foundations in a soil stratum with n soil-layers generally requires the definition of $(n + 1)$ materials: n materials for soil-layers, and 1 to serve as material property of the pile. As an example, consider the analysis of pile foundations in homogeneous soil ($n = 1$). Then a total of 2 material properties need to be defined: 1 for soil stratum, and 1 for the pile properties.

The available library can be manipulated through the buttons presented on the bottom of the window:

Icon	Action
	insert a new material by prompting material dialog (Section 3.3.2.1)
	remove the current selected material row. If no element in the table is selected, this button will be disabled
	edit the current selected material by prompting open the material edit button (Section 3.3.2.1). Alternatively, double-clicking anywhere on an existing table value will serve as the same function

3.3.2.1 Inserting/editing new material

When editing or inserting a new material, the Material Properties dialog is presented on the screen (Figure 3-17).

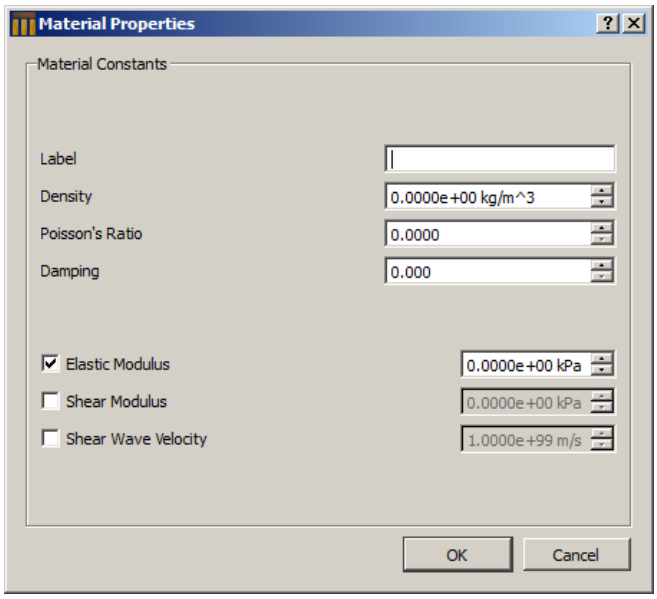


Figure 3-17 New material definition

The parameters that can be inputted are described in the table below

Item	Description	Limit
Label	A *unique* descriptive label to refer to the material. This label will be used in other windows to refer to the material properties specified	No spaces
Density	Volumetric mass-density of the material	$0 < \rho < \infty$
Poisson's Ratio	Poisson's ratio of the material	$0.0 < \nu < 0.5$
Damping	Material damping ratio for the material	$0.0 < \beta < 1.0$
Elastic Modulus	Elastic modulus of the material	$E > 0$
Shear Modulus	Shear modulus of the material	$G > 0$
Shear wave velocity	Shear wave velocity of the material	$0 < v_s < \infty$

The last three terms (namely the elastic modulus, E, shear modulus, G, and the shear wave velocity, v_s) are related through the density, ρ, and Poisson's ratio, ν, of the material:

	$\boldsymbol{E}$	$\boldsymbol{G}$	$\boldsymbol{v_s}$
$\boldsymbol{E} =$	E	$2G(1+\nu)$	$2(1+\nu)\rho v_s^2$
$\boldsymbol{G} =$	$\dfrac{E}{2(1+\nu)}$	G	ρv_s^2
$\boldsymbol{v_s} =$	$\sqrt{\dfrac{E}{2(1+\nu)\rho}}$	$\sqrt{\dfrac{G}{\rho}}$	v_s

Thus, only one of the three parameters needs to be specified, and other two are computed automatically.

3.3.3 Section List Library

The Sections List (Figure 3-18) contains the full set of cross-sections which may be assigned to piles. Any number of sections can be defined, and a minimum of one cross-section is required to be defined for each project. All sections are assumed to be doubly symmetric.

There are four required properties to be assigned for a given section:

1. **Section label**: Specify a *unique* label to refer to the section. This label will be used in other windows to refer to the section properties specified
2. **Area**, A: cross-sectional area of the section
3. **Area Moment of Inertia**. I: The area moment of inertia of the section about its neutral axes. Since all sections are assumed to be symmetric about both major axes, only a single value is required
4. **Equivalent diameter**, d: The equivalent diameter of the section (refer to Table 3-15 for examples)

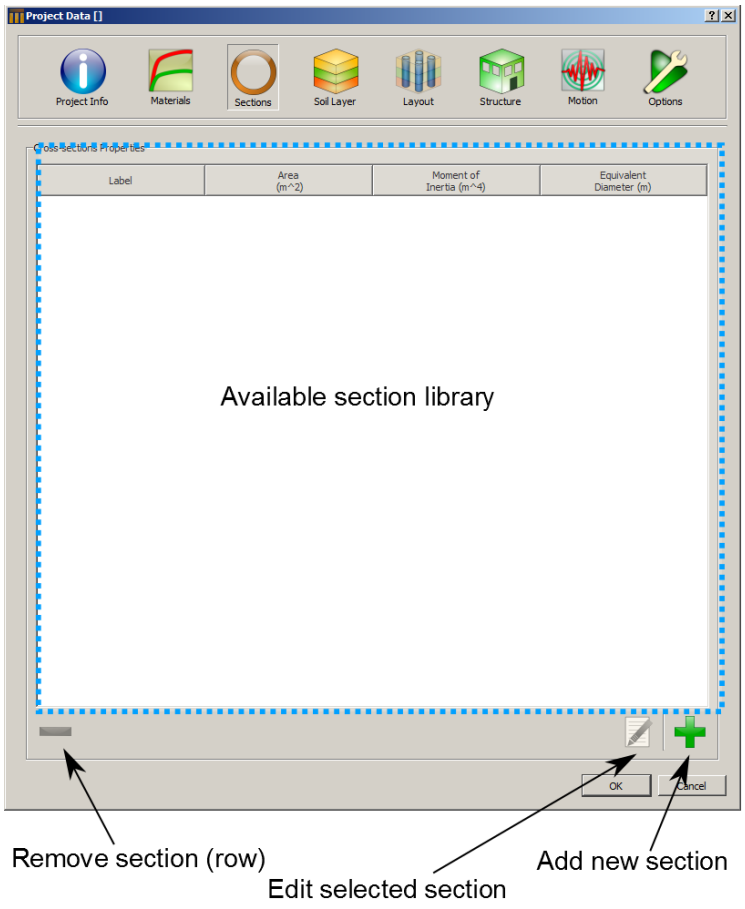


Figure 3-18 Section list library

The available library can be manipulated through the buttons presented on the bottom of the window (Figure 3-18):

Icon	Action
	insert a new section by prompting open the Add Section dialog (Section 3.3.3.1)
	remove the current selected section row. If no element in the table is selected, this button will be disabled
	edit the current selected section. Double clicking an existing value in a table will serve the same function

3.3.3.1 Adding a New Cross-section

Section type can be selected from a total of 5 different sections, described in the below. Upon selecting from the available section list, a new window will be opened to input section properties (Figure 3-19).

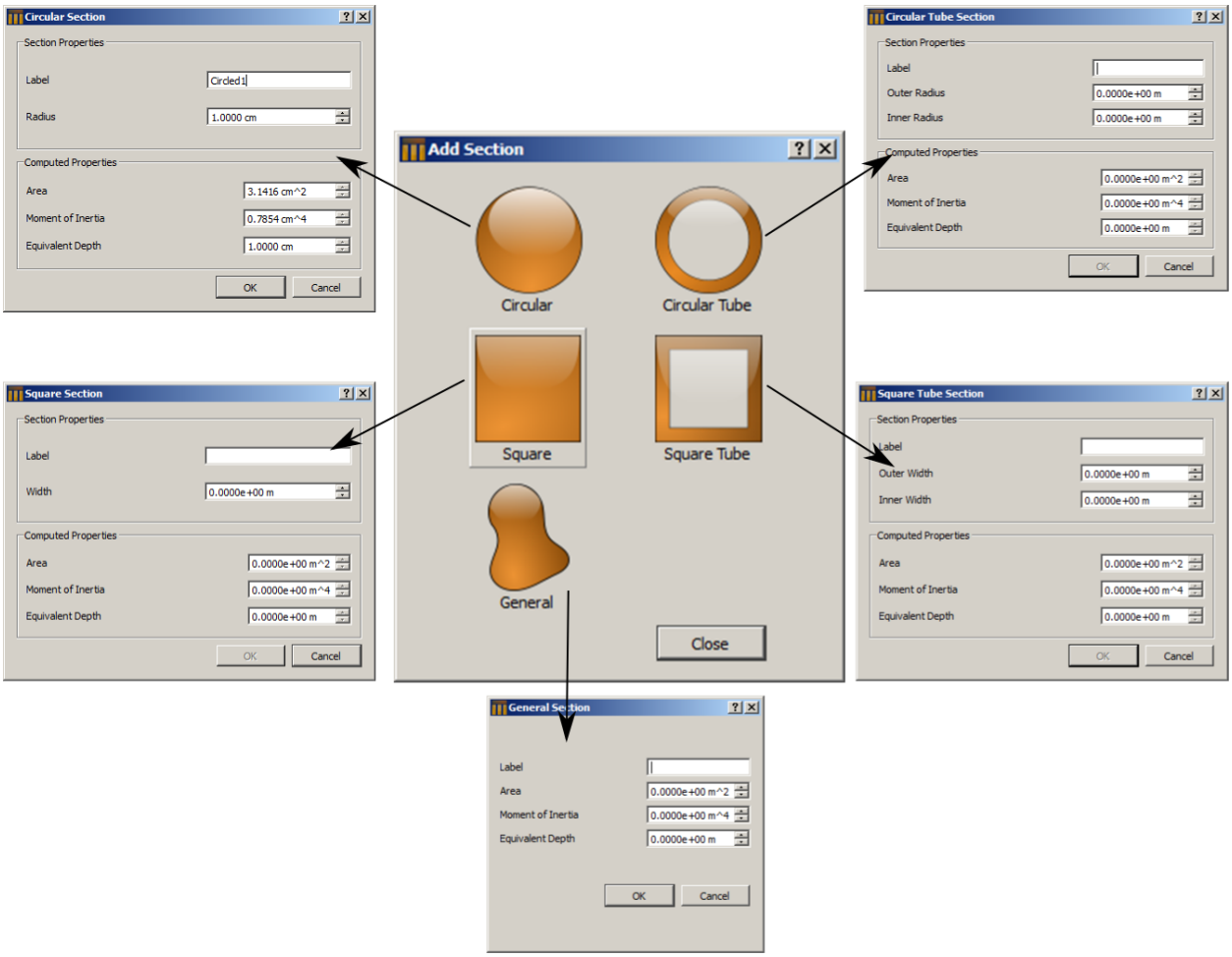


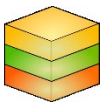
Figure 3-19 Defining new sections

The available section types are tabulated in Table 3-15.

Table 3-15 Available section Types

Icon	Type	Description	Area (A)	Area Moment of Inertia (I)	Equivalent Diameter (d)
	**Circular**	Solid circular section with radius r	πr^2	$\frac{\pi}{4}r^4$	$2r$
	**Circular Tube**	Hollow circular tube with inner and outer radii r_i and r_o, respectively $(0 < r_i < r_o)$	$\pi(r_o^2 - r_i^2)$	$\frac{\pi}{4}(r_o^4 - r_i^4)$	$2r_o$
	**Square**	Solid square section with width w	w^2	$\frac{1}{12}w^4$	w
	**Square Tube**	Hollow square tube with outer and inner widths w_o and w_i, respectively $(0 < w_i < w_o)$	$w_o^2 - w_i^2$	$\frac{1}{12}(w_o^4 - w_i^4)$	w_o
	**General**	Arbitrary section requiring the specification of area, area moment of inertia, and equivalent diameter of section	User-specified	User-specified	User-specified

3.3.4 Soil Layers



Available soil layers in the soil layer stratum are specified from a top-to-bottom fashion in the Soil Layer window (Figure 3-20). There are four required attributes to each soil layer:

1. **Label**: An appropriate descriptive label to refer to the soil layer
2. **Material**: Material label previously defined in the Material Library dialog. Double-clicking the window item will open full list of previously declared materials. If no materials have been defiled, the drop down menu will be empty
3. **Thickness**: the thickness of the specified layer
4. **Number of sublayers**: specify the desired number of discretizations to be performed for the given sublayer. Please note that the current version of Dynapile can handle a maximum number of 46 *total* sublayers.

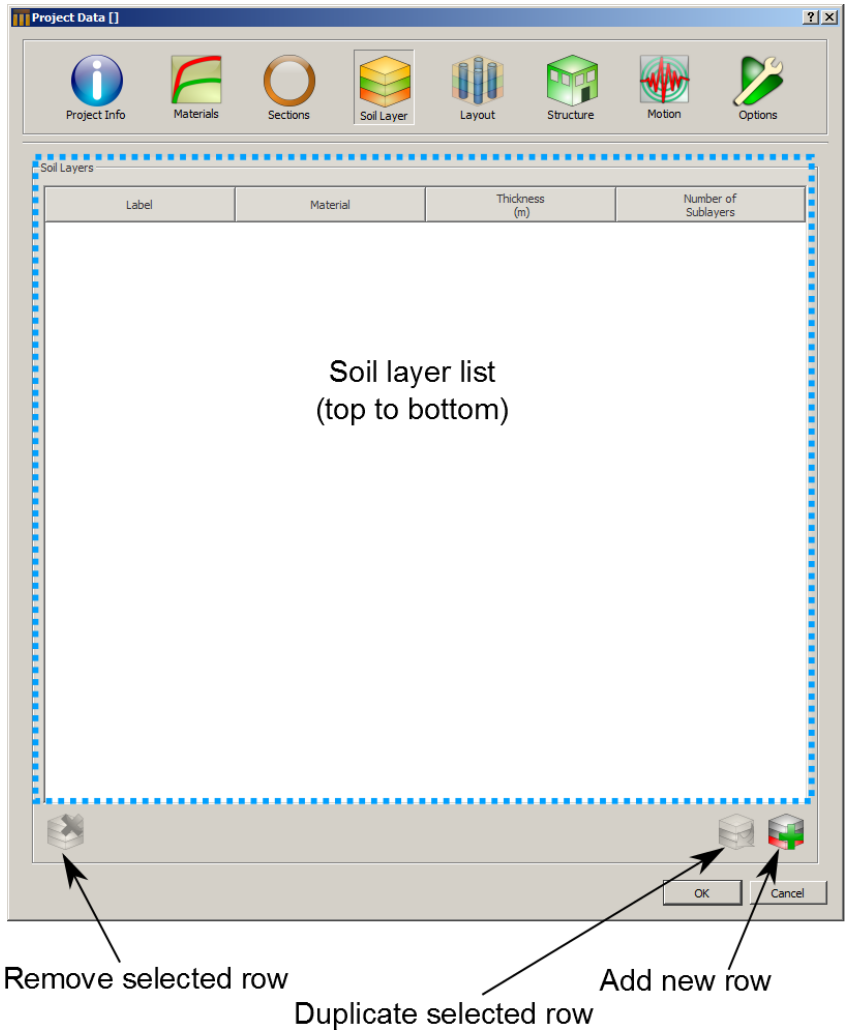


Figure 3-20 Soil layer definition

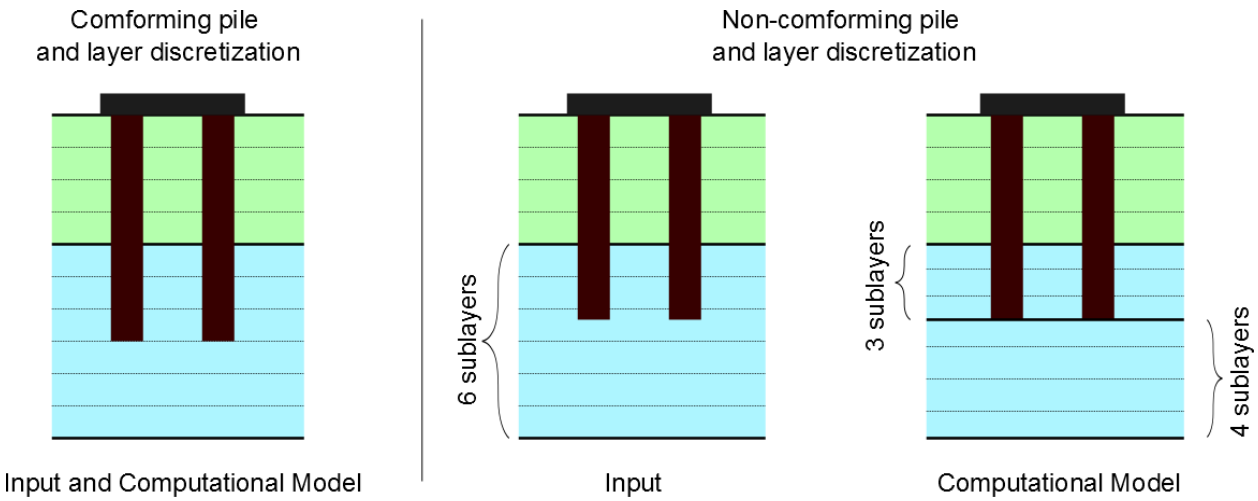


Figure 3-21 Conforming and non-conforming sublayer discretization

Dynapile internally forces the conformity of piles (see Section 3.3.5) with the soil layer discretization (see Figure 3-21). If the inputted pile lengths are not consistent with the underlying soil layer discretization, then an additional sublayer is introduced internally such that conformity is enforced.

The available soil layers can be manipulated through the buttons presented on the bottom of the window:

Icon	Action
	insert a blank row in the soil layer table
	duplicate the current selected soil layer by creating a new soil layer at the end of the list with the same properties as the selected soil layer (disabled if no row is selected)
	remove the row corresponding to the selected soil layer (disabled if no row is selected)

The soil layers can be easily moved around and rearranged. In order to rearrange the order of the soil layers (see Figure 3-22):

1. Select and hold the left-most index number with the left-mouse button
2. Drag to desired location
3. Release the left-mouse button

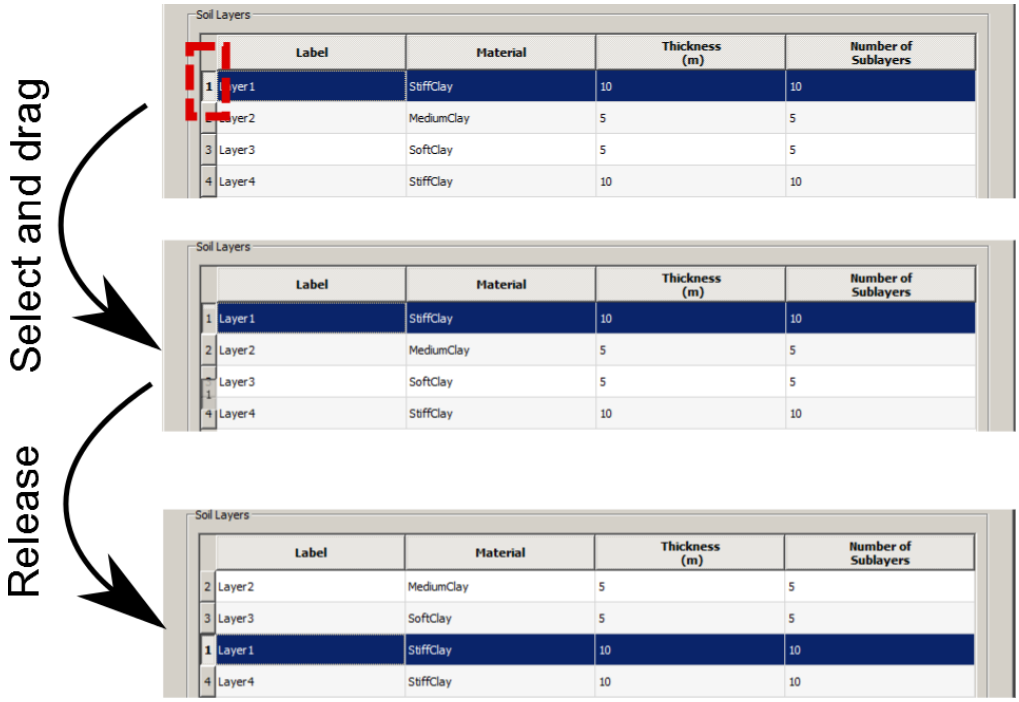
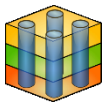


Figure 3-22 Rearranging the order of soil layers

3.3.5 Pile Layout



The pile layer window (Figure 3-23) contains information on the available list of piles. The piles can be specified in an arbitrary manner. The list of piles are presented in a table, while view from the bottom of the pile group is displayed above the table.

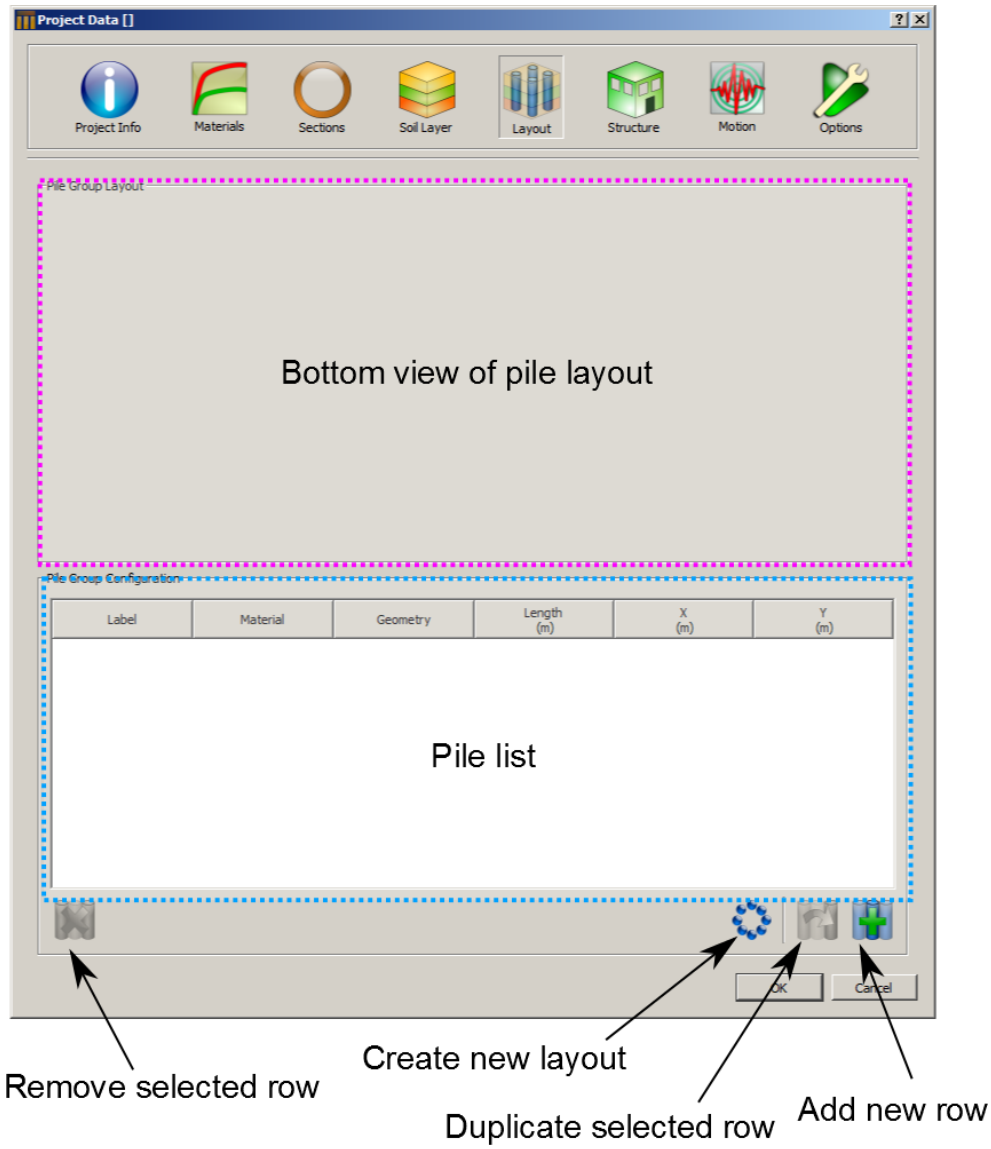


Figure 3-23 Pile configuration window

There are a total of 6 required attributes to be specified for a given pile

1. **Label**: an appropriate label to refer to the given pile
2. **Material**: Material label previously defined in the Material Library  (see Section 3.3.2). Double-click the window to be prompted for the available list of materials. If the material library is empty, the drop-down menu will be empty.
3. **Geometry**: Cross-section label previously defined in the Sections Library  (see Section 3.3.3). Double click the window to be prompted for the available list of cross-sections. If the cross-section library is empty, the drop-down menu will be empty.
4. **Length**: The length of the pile
5. **X**: global x-coordinate of the pile
6. **Y**: global y -coordinate of the pile

The pile layout can be manipulated through the buttons presented on the bottom of the window:

Icon	Action
	Insert a new blank row at the end of the table.
	Create a pile layout from scratch. This will overwrite any existing pile configuration in the table.
	Create a new row at the end of the table, and copy the properties of the selected pile to the row (disabled if no index in the table is selected)
	Remove the selected row (disabled if no index in the table is selected).

Please note that the current version of Dynapile can only handle single pile geometry and material. A change in the material or section property for one pile therefore will automatically propagate to all other piles.

3.3.5.1 Pile Layout Template

Rather than inserting one pile at a time in the layout table, the Pile Layout Template allows for rapid creation of a pile group layout (Figure 3-24). The template can be used to create two different layouts:

1. **Rectangular grid**: A pile group arranged in the form of a rectangular grid. The center-to-center spacing of the piles as well as the number of piles in each direction is required to be specified in the appropriate spaces. Toggling the "Add piles only along the perimeter" will toggle inclusion of piles in the center of the pile group.
2. **Circular Grid**: A pile group arranged in the form of a circle can be specified. In the window, "quantity" refers to the total number of piles, and "foundation radius" refers to the distance from the foundation center to center of a pile.

An overview of the pile layout is automatically updated on the left side of the window when the parameters are changed.

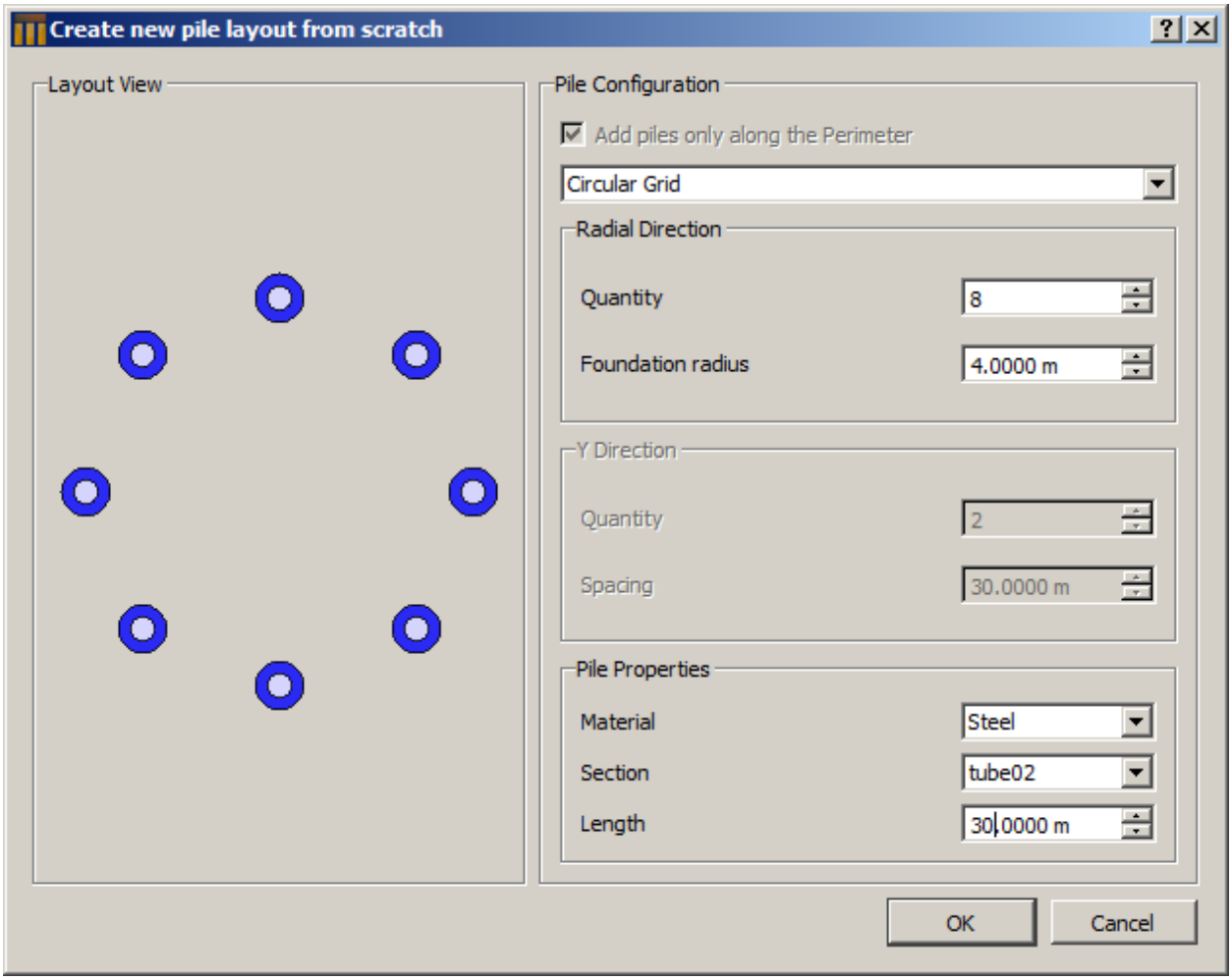


Figure 3-24 Pile layout from template

Note: if no materials have been specified in the material library, the material drop down menu will be empty.

Note: if no cross-sections have been declared previously in the Sections library, the section drop down menu will be empty. The preview of the pile layout in this case will be shown as a set of red crosses.

3.3.6 Superstructure

Superstructure tab (Figure 3.3.6) provides means to enter data regarding a structure placed at the centroid of the pile-cap. When enabled, Dynapile can compute the response of a superstructure (modeled as a mass with three translational degrees of freedom, see Figure 3-26) in the frequency domain. Filling the Superstructure tab is optional.

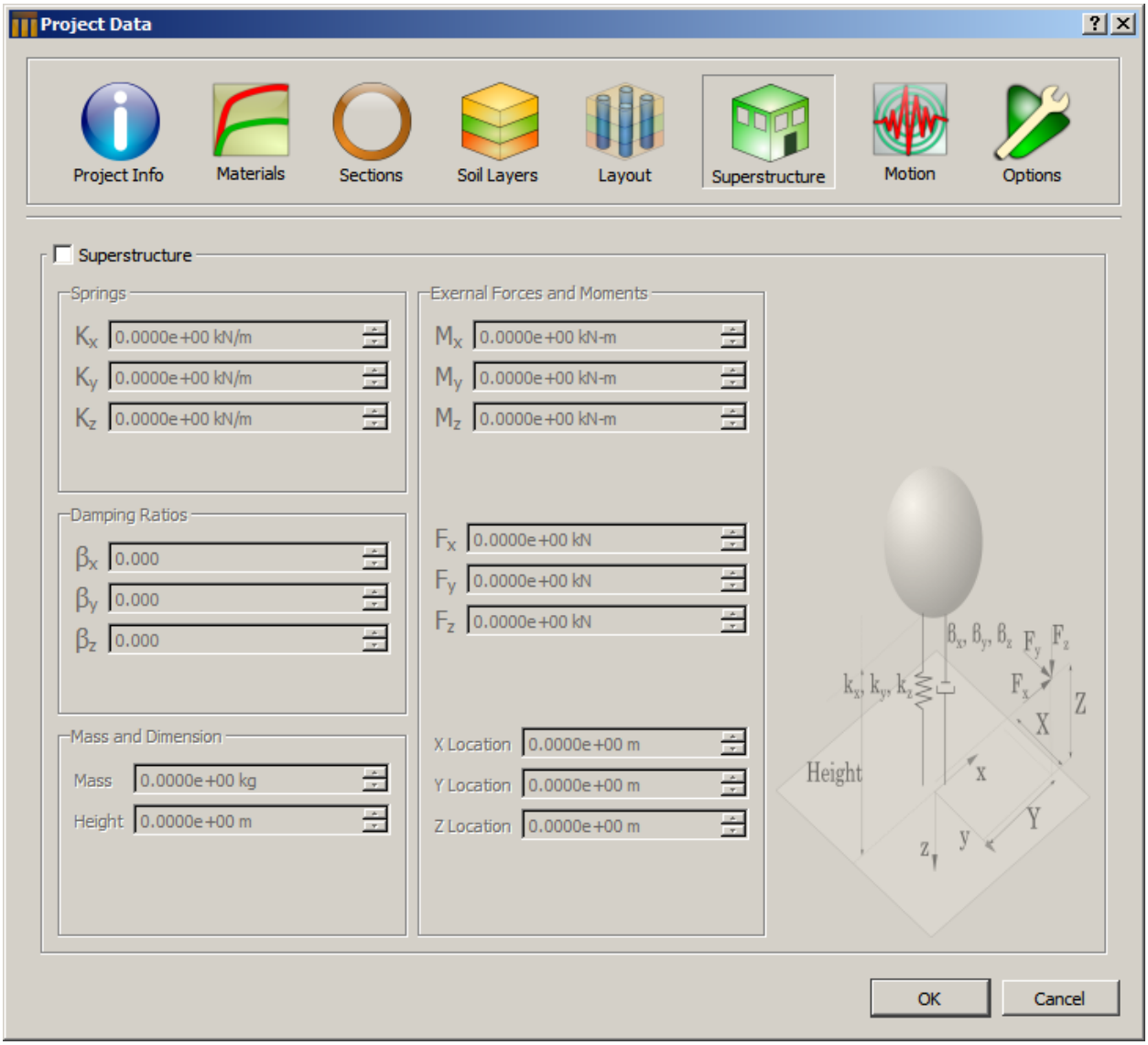


Figure 3-25 Superstructure dialog

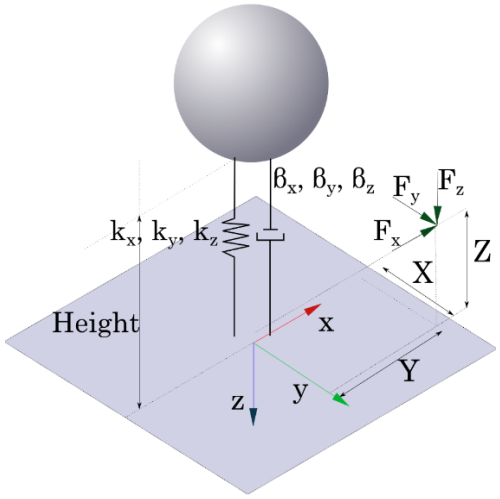


Figure 3-26 Computational representation of the superstructure

A description of the input types is in the table below:

Item	Description	Limit
Weight	Total weight of superstructure	≥ 0
Height	Height of superstructure	≥ 0
$\boldsymbol{\beta_x, \beta_y, \beta_z}$	Damping ratio of the structure in the x, y, and z directions, respectively	$0 \leq \beta_i \leq 1.0$
$\boldsymbol{F_x, F_y, F_z}$	Magnitude of external forces in the x, y, and z directions, respectively	–
$\boldsymbol{M_x, M_y, M_z}$	Magnitude of external moments in the x, y, and z directions, respectively	–
***X*, *Y*, and *Z* Locations**	Location of the forces to be applied in the x , y, and z directions, respectively. If a non-zero location of force is specified, an additional moment acting the structure is computed automatically by Dynapile	–

3.3.7 Ground Motion

The Ground motion tab (Figure 3-27) provides means to enter data ground motion data. When enabled, Dynapile will compute the response time-history response of the pile group in the time domain. Filling the Ground Motion tab is optional.

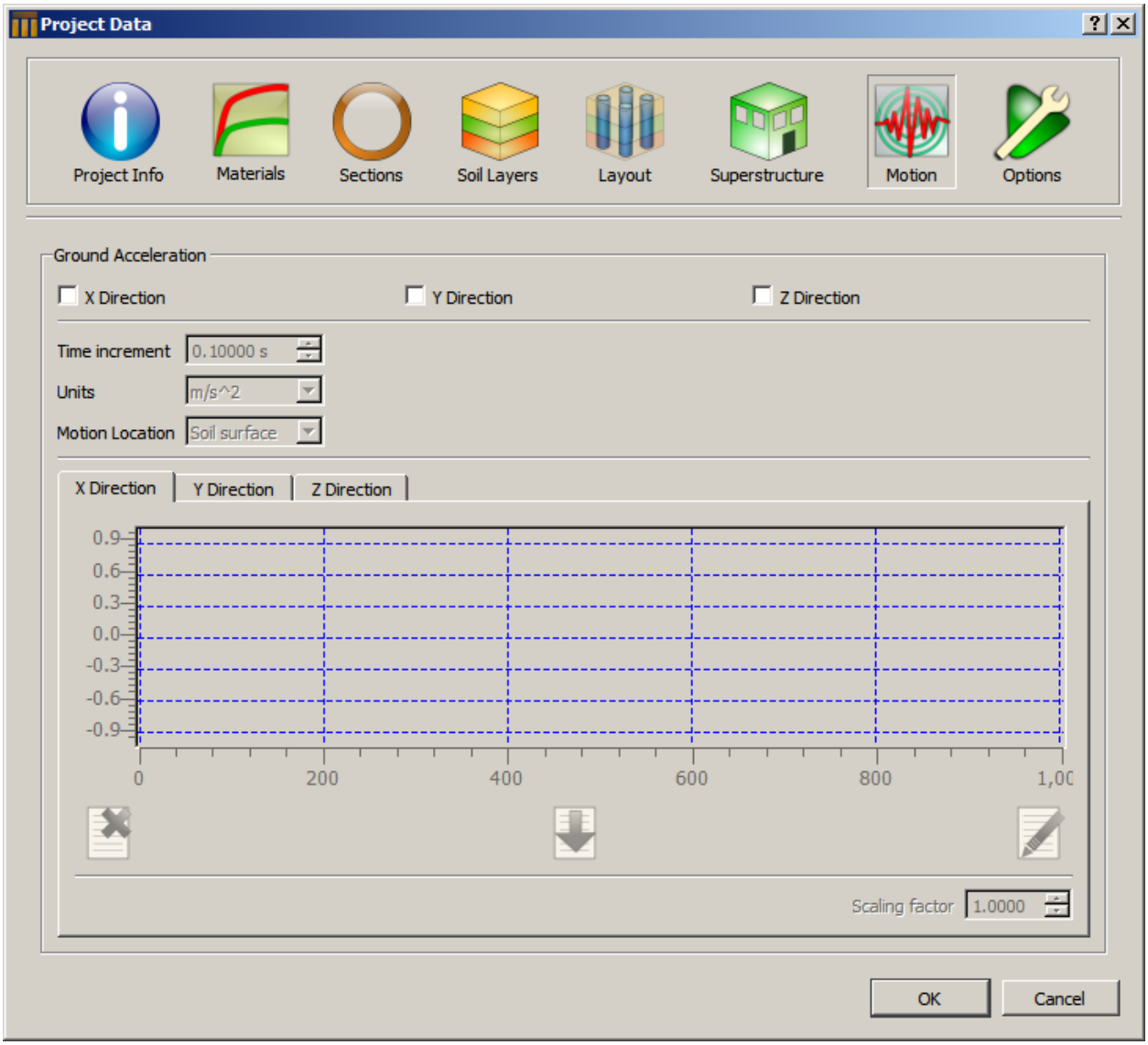


Figure 3-27 Ground motion tab

In addition to the ground motion data, the use is required to specify:

- **Time increment**: Time-increment between the data points specified. Only a fixed time-increment can be specified. This time-increment is used for ground motion in all directions
- **Units**: Units associated with the entered data. Ground motion data will be converted and presented in this specified unit when editing or inserting new data (see below).

- **Ground motion location**: The epicenter of the ground motion, either at the soil surface, or bedrock

The ground acceleration records may be manipulated by the three buttons on the bottom of the tab for each direction independently:

Internally, Dynapile will only use the first 4096 points of the time record, and discard the rest.

Icon	Action
	To edit/insert data points. Upon clicking this button, a window will be prompted open (Figure 3-29) and display the existing data points in the window. The units of the data points will be specified in the toolbar. Data points may be copy-and-pasted into this point in any format. Upon clicking "OK", the data will be processed. Note that during processing, spaces, commas, and new lines will all be ignored and data will be stored in a single array. Figure 3-28 shows inputting the same set of data in three different ways which will be stored in the same format. In addition, any letters specified will be treated as having a numerical value of zero.
	Import data from an existing file on the system. A window will open prompting for name and location of ground acceleration data. Upon selecting the file, the import wizard will be displayed to help in importing the data specified in the file into the project (see Section 3.3.7.1 below).
	Delete any existing ground motion record in the current direction

```
1 2 3
4 5 6 7
8 9 10 11 12 13 14
15
```

```
1 2 3 4 5 6 7 8 9 10 11
12 13 14 15
```

```
1,2,3,4
5;6;7;8
9,10, 11 12
13 14 15
```

Figure 3-28 Different ways of specifying the same set of data

3.3.7.1 Import Ground Motion Dialog

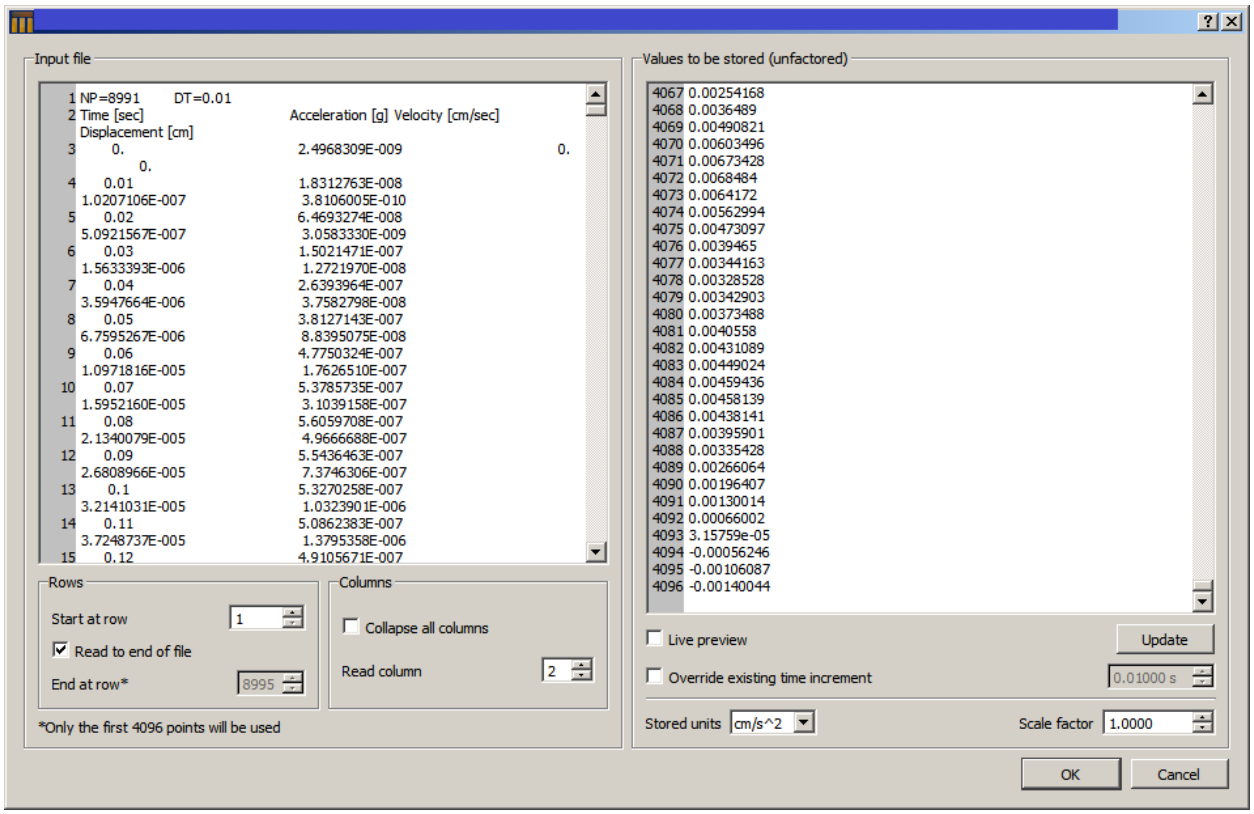


Figure 3-29 Import ground acceleration from file

The import dialog (Figure 3-29) will be prompted open upon selecting an input file in the Ground Motion dialog. In the left pane of the window, the contents of the input file are displayed as they appear in the file. The starting row as well as the manner in which to read the input file can be specified in this window as follows:

- **Start row**: Specify the row at which to start reading values. As a guide, the line numbers of the input file are shown in on the side bar in gray color.
- **End at row**: Stop reading values at the specified line (by default, the input file is read to end of file). If the total rows is more than 4096 points, input data points will be truncated to 4096.
- **Collapse all columns**: If selected, data is read left to right (Figure 3-30). If unchecked, only the specified column in the input file is read.

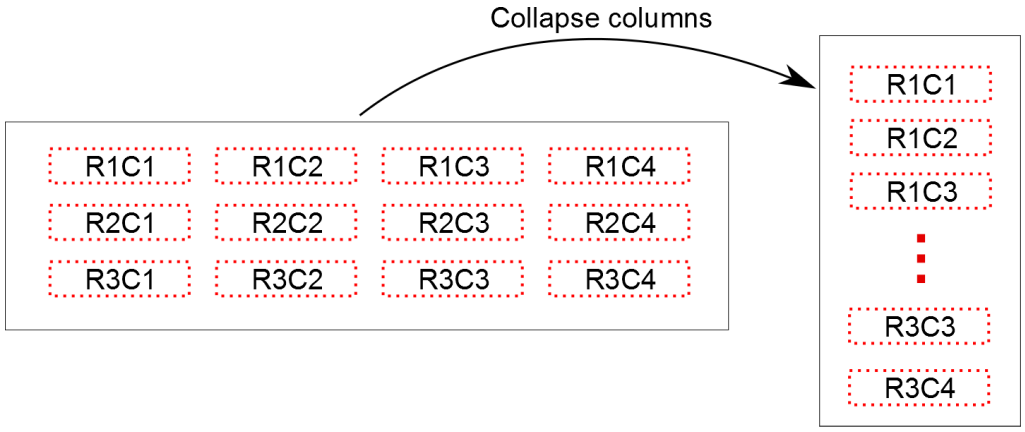


Figure 3-30 Order of read values when collapsing columns

A live update of the raw (unfactored) values to be stored are automatically updated on the right pane of the window. The final stored values can be specified through the appropriate widgets on the right pane as follows:

- **Stored Units**: The acceleration unit to be associated with the imported numbers
- **Scale factor**: Factor by which the numbers are to be multiplied upon saving the data. Consider, for instance, an input file which contains acceleration data points in non-dimensional gravity units "g". Then, the stored data points may be associated, for instance, with Stored Units of $\frac{m}{s^2}$ ("m/s^2" in the drop-down menu), and "Scale Factor" of 9.81.
- **Override existing time-increment**: Override the existing time increment for ground motion with the specified value.

3.3.8 Analysis Options

The dynamic analysis of the pile foundation system is performed in the frequency-domain. The analysis options window (Figure 3-31) allows the user to specify the range of frequencies to consider, as well as specify the interaction factor between piles.

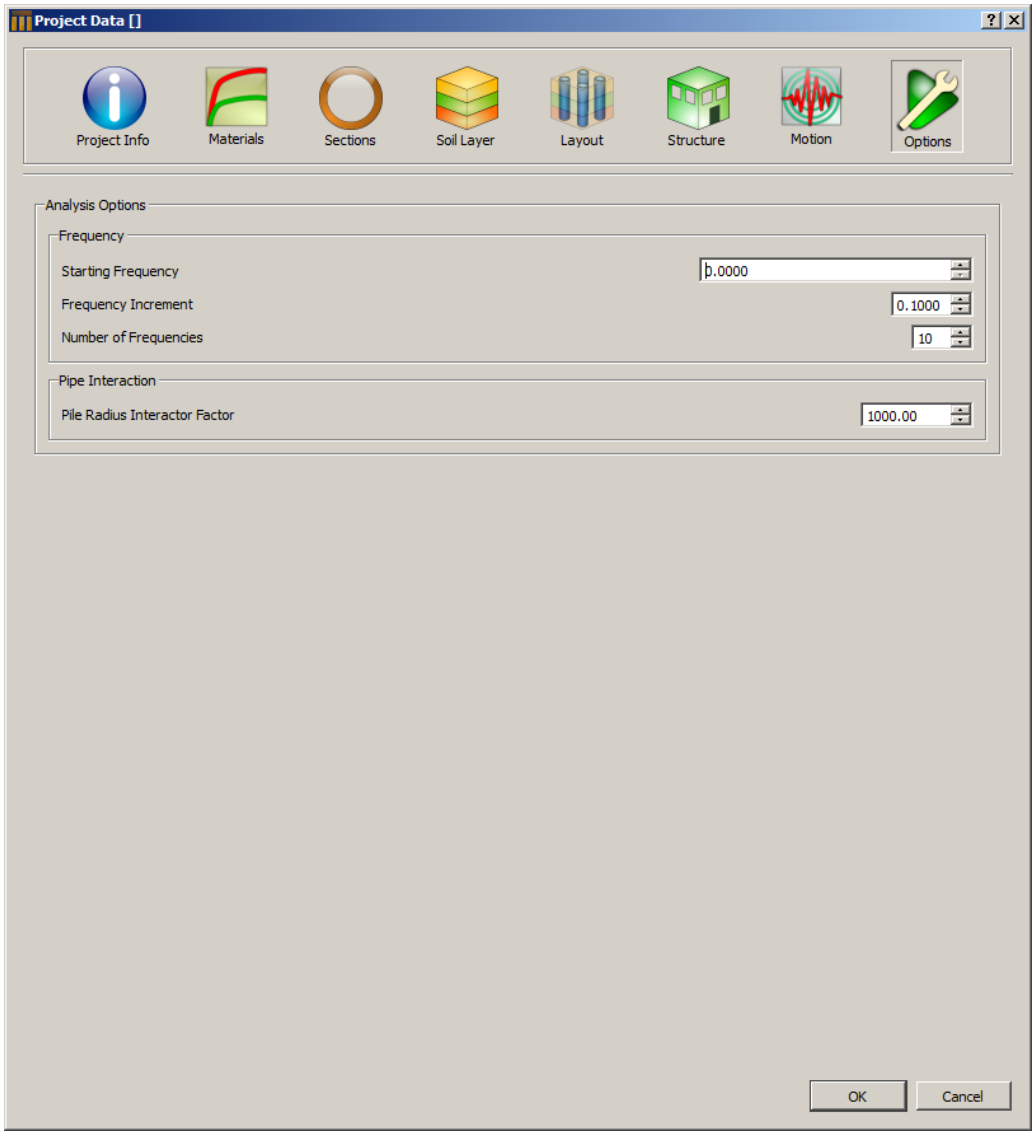


Figure 3-31 Analysis options

The values which may be changed for analysis are as follows:

- **Starting frequency**: starting frequency to begin the analysis
- **Number of frequencies**: number of frequencies to be considered

- **Frequency increment**: increment between the frequencies considered.
- **Pile interaction factor**: factor of pile effective radius beyond which to consider interaction (discussed below)

Let (x_i, y_j) denote the center of pile i with equivalent depth d_i on the soil surface. Then define (Figure 3-32)

$$d_{ij} = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} > 0, i \neq j$$

$$r_{x_i} = (\text{radius interaction factor}) \times \frac{d_i}{2}$$

Dynapile will compute d_{ij} and r_{x_i} for each pile set. If $r_{x_i} < d_{ij}$ between pile i and pile j, then Dynapile will include pile-pile interaction terms while computing the stiffness of the pile foundation. Figure 3-33 shows the pile configurations under different interaction factors.

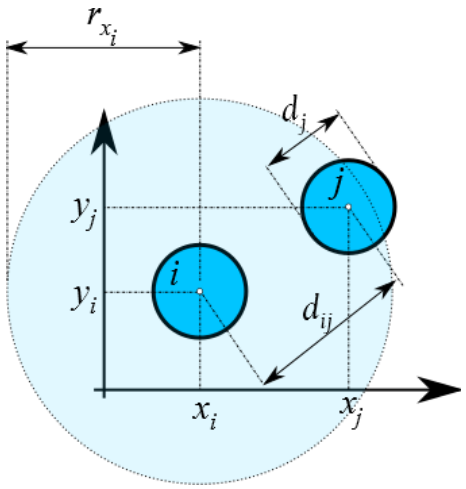


Figure 3-32 Radius interaction factor

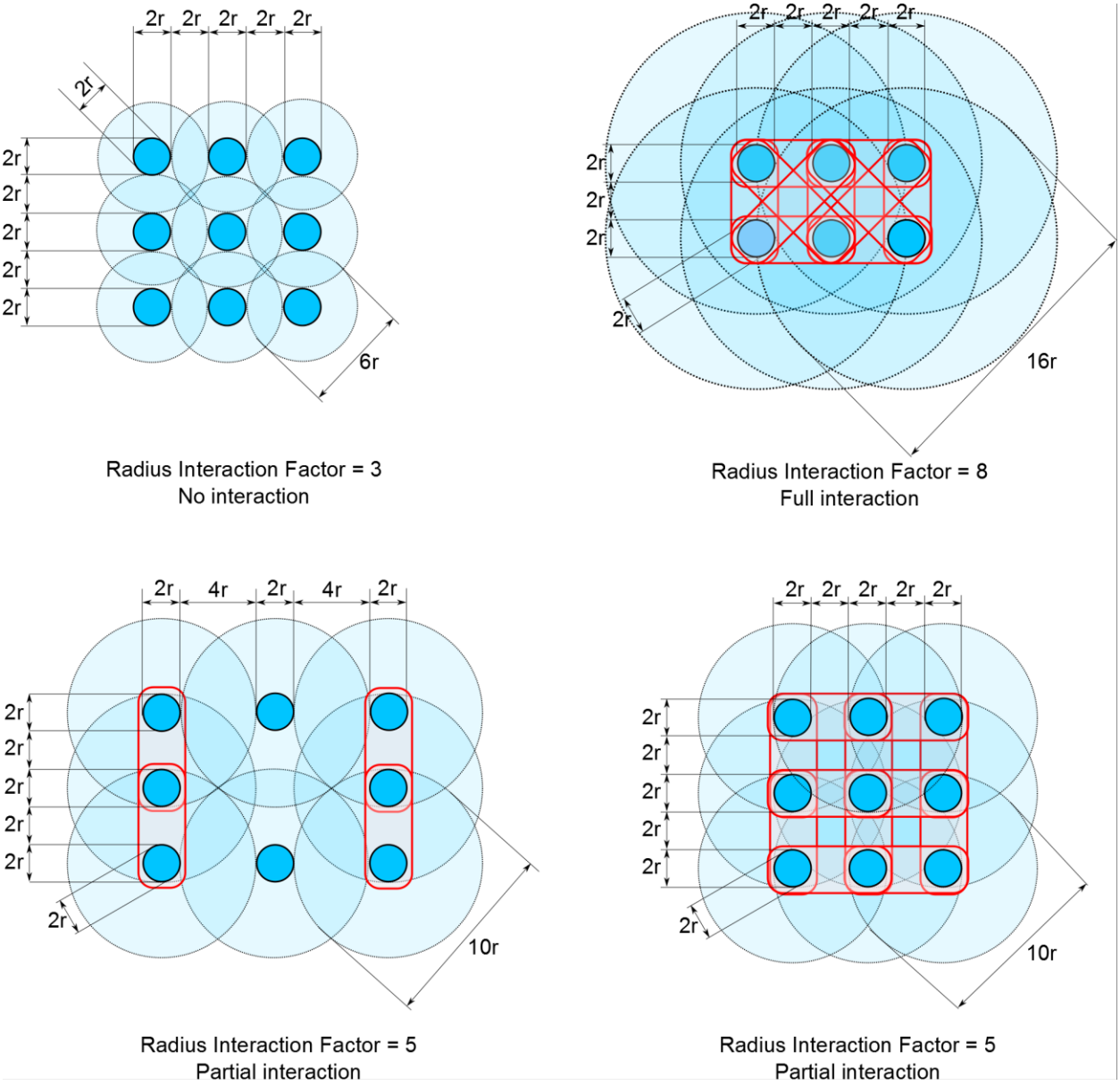


Figure 3-33 Pile configuration and radius interaction factors

3.4 Running Analysis

Once all required data has been entered into data pile (see Section 3.3), the project must be saved prior to starting the computations. Once saved, press the  button either from the Main toolbar (Section 3.2.1), or from the Analysis menu bar (Section 3.1.3).

Once pressed, Dynapile will perform the following actions in order listed:

1. Validate project data. If invalid data was detected, the status dock (Figure 3-1) will be shown, and error messages will be displayed and analyis terminated.
2. If project data was found to be valid, Dynapile will execute the solver. During the analysis, the three sets of files are generated in the directory containing the saved input file with the following extension

Extenison	Containing data
.dy3u	Pile cap and foundation displacement data in raw form. Length units are in meters. Note these values are not labeled, and processed by Dynapile directly.
.dy3p	Solution data in raw format. Length, force, pressure, and mass units associated to these values are meters, kilonewtons, and kilograms, respectively. Note that these values are not labeled, and processed by Dynapile directly
.dy3h	Pile cap time-history displacement in raw format. The length unit associated to these values are in meters. Note that these values are not labeled, and processed by Dynapile directly.
.dy3r	Solver error output

3. Once analysis is completed, Dynapile will prompt open the Plot window (Section 3.5.1) to show the solution results

Please note that while Dynapile is performing computation, the Dynapile window may become unresponsive.

3.4.1 Troubleshooting

When starting an analysis, Dynapile looks for inconsistencies or errors in inputted data as well as program execution. If errors are found, the status dock is prompted open, and the errors are listed in color red. Some of the common errors along with explanations are listed in Table 3-16. In the tables below, *[SAVED_FILENAME]* refers to the name of the project used when saving the file, excluding the extension. For instance, if the project was saved as "project_1.dy3d", *[SAVED_FILENAME]* would be "project_1".

Table 3-16 Run-time error messages

Error	Possible explanation	Suggested fix
Program running in demo mode	USB security device was not found	See CHAPTER 2
	License on security device is expired	See CHAPTER 2
DPILE2016_DLL could not be loaded	DPILE2016_DLL.dll file on the local drive could not be located	Locate DPILE2016_DLL.dll file from local drive and make sure that it is placed in the same directory as dynapile.exe
	DFORRT.DLL file on the local drive could not be located	Locate DFORRT.DLLfile from local drive and make sure it is placed in the same directory as dynapile.exe
Pile [#] has density of 0 kg/m^3	The indicated pile has not been assigned a material	Make sure a material has been assigned to the indicated pile (see Section 3.3.5)
	The material assigned to the indicated pile an abnormally small density	Make sure the density of the material assigned to the pile has a positive density (see Section 3.3.2)
Pile [#] has damping [#] > 1.0	The indicated pile has not been assigned an invalid material	Make sure a valid material has been assigned to the indicated pile (see Section 3.3.5)
	The material assigned to the indicated pile has an higher damping ratio than 1.0	Make sure the damping ratio of the material assigned to the pile is less than or equal to 1.0

Soil layer [#] has density of 0 kg/m^3	The indicated soil layer has not been assigned a material	Make sure a material has been assigned to the indicated pile (see Section 3.3.4)
	The material assigned to the indicated soil layer an abnormally small density	Make sure the density of the material assigned to the pile has a positive density (see Section 3.3.2)
Pile [#] has damping [#] > 1.0	The indicated soil layer has not been assigned an invalid material	Make sure a valid material has been assigned to the indicated soil layer (see Section 3.3.4)
	The material assigned to the indicated soil layer has an higher damping ratio than 1.0	Make sure the damping ratio of the material assigned to the soil layer is less than or equal to 1.0
Total number of specified soil layers (#) exceeds Dynapile's capacity (47)	The total number of sublayers, i.e. summation of the number of sublayers for each soil layer exceeds Dynapile's capacity	Choose sublayer divisions such that the total number of sublayers will be less than or equal to 47

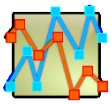
Occasionally, there may be a set of unforeseen specified data sets that can cause numerical errors. In Table 3-17 below, potential known complications are listed.

Table 3-17 Post/During analysis errors

Problem	Possible explanation	Suggested fix
No results are displayed after analysis completes	A numerical error was encountered under the specified set of input data	Recheck the specified project data for errors. Also, consider • manually locating and opening *[SAVED_FILENAME]*.dy3r to view any relevant solver error output • manually locating *[SAVED_FILENAME]*.dy3p to see verify that the results are displayed as "NaN" (not-a-number)
Dynapile has become unresponsive and seems to have frozen	The created model is large and the computation is ongoing.	Wait for analysis to finish. One way to verify if the analysis is still ongoing, is to locate *[SAVED_FILENAME]*.dy3p and checking whether it is being occasionally modified
		Specified input data had errors resulting in unforeseen numerical errors. Close Dynapile, restart the application, and verify that input parameters are consistent

Please also consider technical support (Section 1.8) for additional troubleshooting.

3.5 Viewing Analysis Results



3.5.1 Plot Data

Upon completion of a computation, the solution data are generated in the same directory as the input file with the extension ".dy3p". These plot data are read by the interface and can be visualized directly using the Plot Window organized in tree-view.

The plot window (Figure 3-34) is automatically prompted open following the completion of an analysis, and can be manually opened from the Main Toolbar, or accessed through the menu bar:

Analysis → Plots.

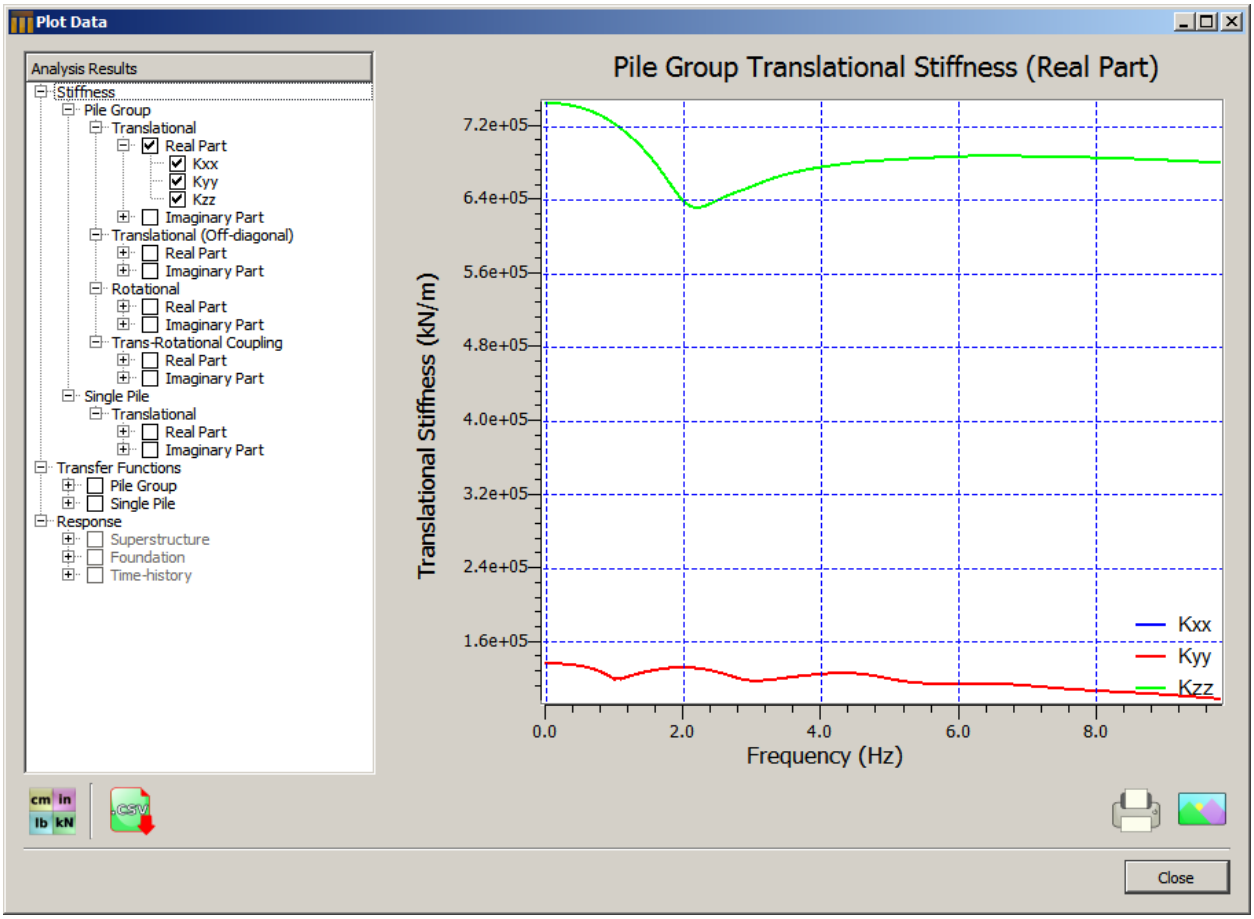


Figure 3-34 Plot window

When prompted open, the window only shows the real part of the translational stiffness terms of the foundation system. In order to view other plot items, click the ☐ box besides the category name. Once checked, other available categories will be automatically collapsed and unchecked. Similarly, the visibility of the plot categories children (individual plots) can be toggled by toggling the checkboxes next to their names.

The notation used throughout the program to refer to the stiffness terms is as follows (Figure 3-35):

- Translational stiffness (also referred to as swaying stiffness) terms are denoted as $K_{\square\blacksquare}$ where ☐ and ■ are either x, y or z. For instance, translational stiffness in the x direction is denoted as K_{xx}, translational stiffness in the x, z direction denoted as K_{xz}, etc
- Rotational stiffness (also referred to as rocking stiffness) terms are denoted as $K_{r\square r\square}$ where ☐ is either x, y or z. Note that only the diagonal terms are available
- Translational-rotational coupling terms (also referred to as cross-sway-rocking stiffness) are denoted as $K_{\square r\blacksquare}$ where ☐ and ■ are either x, y or z.

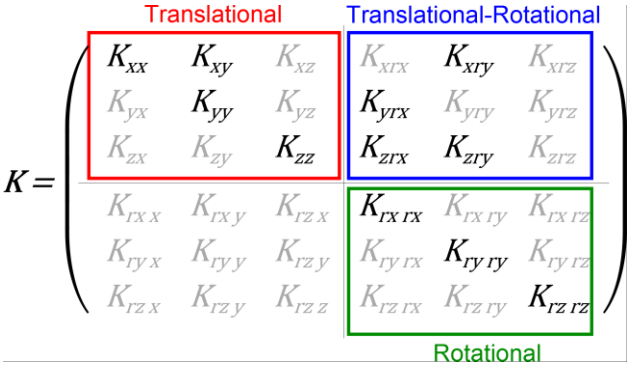


Figure 3-35 Stiffness nomenclature

The organization of the plot data in the tree view is as follows (Figure 3-34):

- **Stiffness**: stiffness values as a function of frequency
  - **Pile Group**
    - **Translational Stiffness**: real and imaginary components of the diagonal stiffness terms of the stiffness matrix of pile group, namely K_{xx}, K_{yy}, K_{zz}.
    - **Translational (Off-diagonal) Stiffness**: real and imaginary parts of the diagonal stiffness terms of the stiffness matrix of pile group, namely K_{xy}
    - **Rotational Stiffness**: Real and imaginary parts of the diagonal rotational stiffness matrix $K_{rxrx}, K_{ryry}, K_{rzrz}$
    - **Trans-rotational coupling stiffness**: Real and imaginary parts of the coupling terms between the translational and rotational stiffness terms $K_{xry}, K_{yrx}, K_{zrx}, K_{zry}$
  - **Single Pile**

        - **Translational stiffness**: real and imaginary components of the diagonal stiffness terms of the stiffness matrix of pile group. Since the piles are assumed to be doubly symmetric about the x, y plane, only K_{xx}, K_{zz} are displayed.
- **Transfer Functions**
    - **Pile Group**:
        - **Pile Head/Pile Tip X**: Ratio of the pile head displacement at the pile cap to pile tip displacement in the x direction (U_P/U_G in Figure 3-36b)
        - **Pile Head/Pile Tip Y**: Ratio of the pile head displacement at the pile cap to pile tip displacement in the y direction (U_P/U_G in Figure 3-36b)
        - **Pile Head/Free-field X**: Ratio of the pile head displacement at the pile cap to free-field displacement in the x direction
        - **Pile Head/Free-field Y**: Ratio of the pile head displacement at the pile cap to free-field displacement in the y direction
    - **Single Pile**:
        - **Pile Head/Free-field**: Ratio of the pile head displacement at the pile head to free-field displacement
        - **Pile Head/Pile Tip**: Ratio of the pile head displacement at the pile head to pile tip displacement in the (U_P/U_G in Figure 3-36a)
        - **Free-field/Pile Head**: Ratio of the free-field to pile head displacement
- Response
    - **Foundation**: Response of foundation at pile group head in the x, y, and z directions
    - **Superstructure**: Response of superstructure at the x, y, and z directions
    - **Time-history**: Response of the foundation in the time domain under inputted ground motion

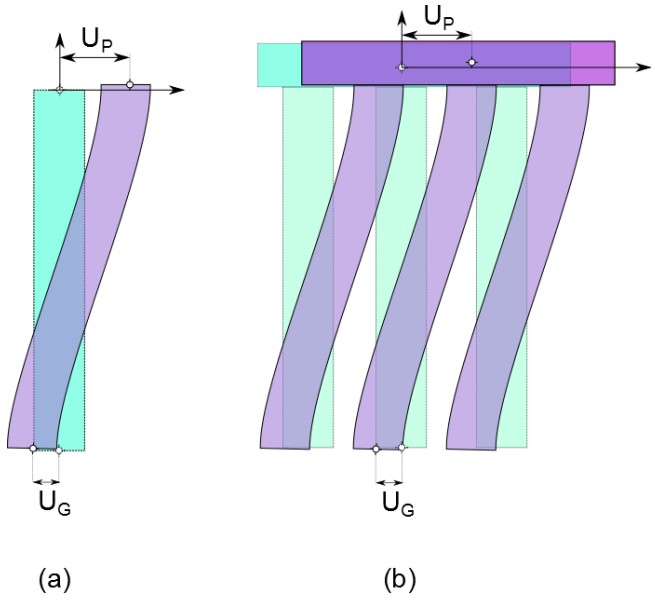


Figure 3-36 Transfer function definition (a) single pile (b) pile group

At the bottom of the window, four button exist for exporting results, as well as manipulating the units as described in the bellow:

Icon	Action
	Change the display units of the plots. This change in units will be temporary for the current instance of the window
	Export the entirety of the data in Comma Separated Values format (.csv). The exported values can then be imported into spreadsheet software such as OpenOffice, LibreOffice, Microsoft Office, etc.
	Send current plot to a printer
	Save current plot as an image file to disk

3.5.2 Solution Data

Following the completion of the analysis, the solution results may be viewed in form of a report through the Report button, available on the Main Toolbar, and accessible also through the menu bar:

Analysis → Report

The information available in the report window are categories as Input Data, and Output Data. A brief summary of the available items in each category is presented in the below:

1. Input Data
    - Soil layer properties
    - Superstructure properties
    - Pile coordinate layout (table)
    - Pile properties
    - Ground acceleration (figure)
2. Output Data
    - Pile group stiffness terms (real and imaginary)
    - Pile group transfer functions
    - Single pile stiffness terms
    - Single pile transfer functions
    - Foundation response
    - Superstructure response
    - Time-domain response

The nomenclature used for the data is consistent with the ones used in the Plot Window (Section 3.5.1). In the input file, E, G, C_s, and ν correspond to the elastic modulus, shear modulus, shear wave velocity, and Poisson's ratio of a material. Additionally, L/D corresponds to the ratio of the pile length to its diameter.

The displayed data can be copy and pasted into word processors such as LibreOffice, OpenOffice, or Microsoft Office, as well as spreadsheet applications such as Microsoft Excel while preserving the formatting as follows:

1. Select the portion of results to copy (alternatively, press CTRL + A to select the entire window)
2. Press CTRL + C to copy the data (alternatively, right click on the window and select copy).
3. Open a word processor
4. Press CTRL + V to paste the data

The displayed data can be manipulated using the buttons on the bottom of the window as follows:

Icon	Action
	Change the display units. This change in units will be temporary for the current instance of the window
	Prompt open the data options window (Figure 3-37) and choose which data to show on the screen
	Export the plot in view as a Portable Document File (PDF)
	Send the report to a printer

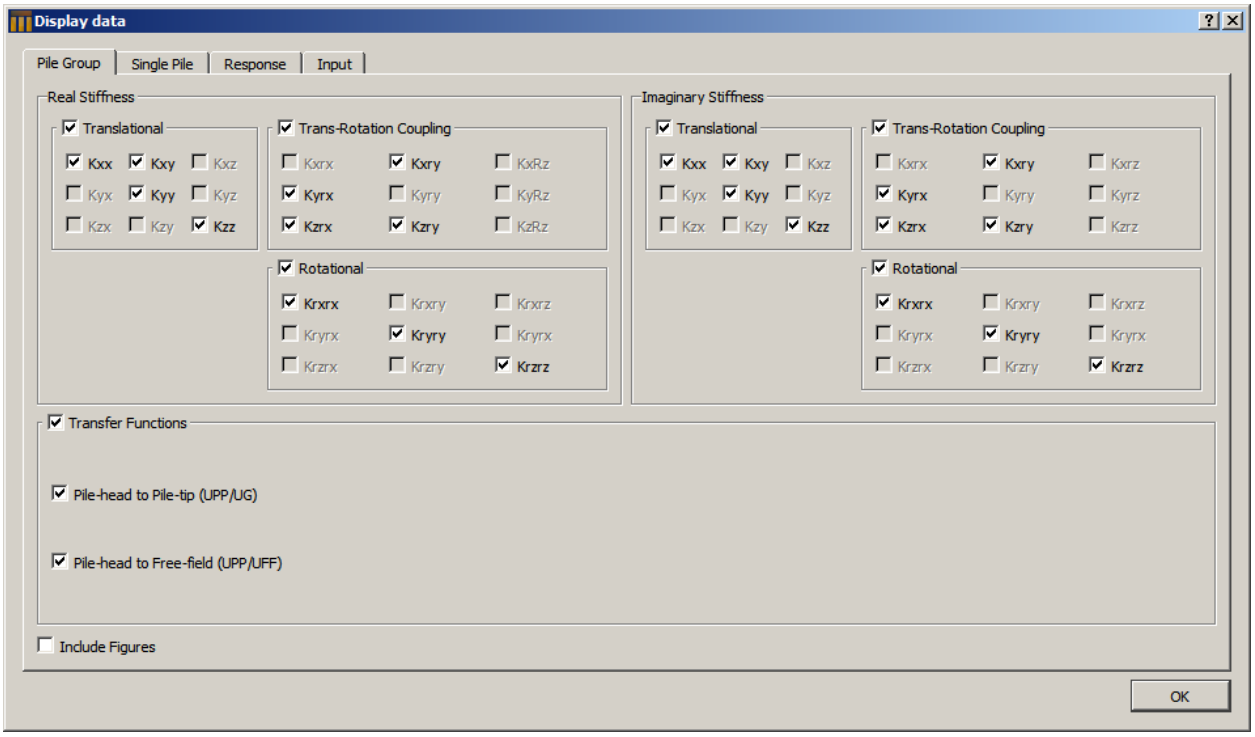


Figure 3-37 Available solution data for displaying

CHAPTER 4. Examples

Two examples involving the dynamic analysis of pile foundations are considered in this chapter. Each example is organized as follows. A brief description of the problem is presented. A step by step approach for creating the model in Dynapile is then highlighted. Finally, the generated results are presented and compared with other published results in the literature.

4.1 Example 1

Consider 4 piles arranged in a square layout with a center-to-center spacing of 1.5 meters (Figure 4-1). The piles are 20 meters in length, and have hollow circular cross-section with outer and inner radii of 0.300 and 0.291 m, respectively.

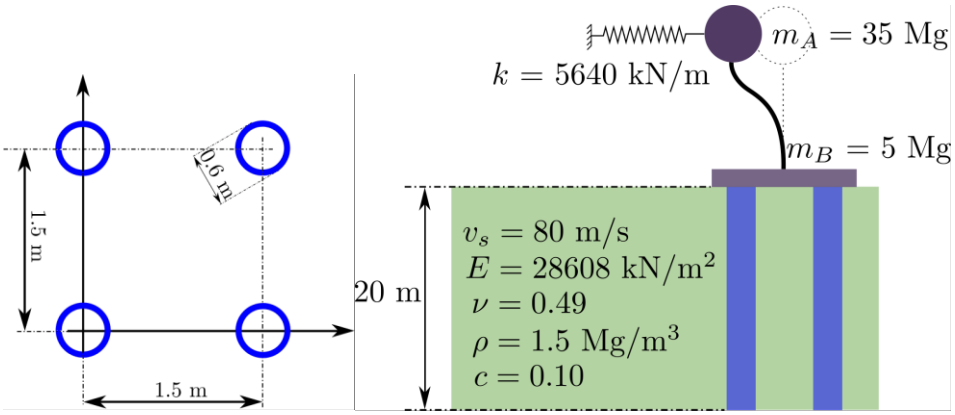


Figure 4-1 Pile configuration in Example 1

The material properties of soil and pile are tabulated in Table 4-1.

Table 4-1 Material properties of soil and pile in Example 1

	Elastic Modulus (kPa)	Shear Wave velocity (m/s)	Mass Density (kg/m^3)	Poisson's Ratio	Damping (%)
Soil	28608	80.00	1500.00	0.49	1.0
Piles	2.1e8	3207.66	7850.00	0.30	0.0

The pile group support a structure with a mass of 35,000 kg and a basement mass of 5,000 kg, with a horizontal stiffness of 5,640 kN/m.

4.1.1 Creating the Model in Dynapile

1. Start Dynapile
2. Start entering project data by clicking the Project Data icon ( ) from the main toolbar
    a. Project Information
        i. Change Project Label to “Example 1” and leave units as default
    b. Navigate to the Materials tab ( )
        i. Click the icon to add a new material for soil layers
            1. In the Material Properties, enter the following:
                a. **Label**: soilMaterial
                b. **Density**: 1500 kg/m^3 (Note: you may also right-click on the units, change input units to Mg/m^3, and enter 1.50 as the value)
                c. **Poisson’s Ratio**: 0.49
                d. **Damping**: 0.10
                e. **Shear Wave Velocity**: 80 m/s
        ii. Click the icon to add a new material for piles
            1. In the Material Properties, enter the following:
                a. **Label**: steel
                b. **Density**: 7850 kg/m^3
                c. **Poisson’s Ratio**: 0.30
                d. **Damping**: 0.00
                e. **Elastic Modulus**: 2.1e8 (kPa)
    c. Navigate to the Section tab ( )
        i. Click icon to add a new cross-section for piles
            1. Select circular tube ( ) in the Add Section window
                a. Enter the following in the Circular Tube Section window:
                    i. **Label**: pileSection
                    ii. **Outer Radius**: 0.300 m
                    iii. **Inner Radius**: 0.291 m
                b. Press “OK” to accept and close the window
    d. Navigate to the Soil Layer tab ( )
        i. Click the button to insert a new row in the table
            1. Double click the cell under “Label” and enter “Layer1”
            2. Double click the cell under “Material”, and select “soilMaterial” from the drop-down menu
            3. Double click the cell under “Thickness” header, and enter “20”
            4. Double click the cell under “Number of Sublayers” and enter 36
    e. Navigate to the Pile Layout tab ( )
        i. Click the button to insert a blank line
            1. Double-click the “Label” cell and enter Pile1

2. Double-click the “Material” cell and select “steel” file the drop-down menu
3. Double-click the “Geometry” cell and select “pileSection” from the drop-down menu
4. Double-click the “Length” cell and enter 20 m as its value

ii. Click the  **three** times to duplicate Pile1 three times.

iii. Make the following adjustments to the new table (double click the cells to alter values):

1. Row 2:
   a. Rename “Pile1” to “Pile2”
   b. Set x coordinate of pile center to 1.5 m
2. Row 3:
   a. Rename “Pile1” to “Pile 3”
   b. Change y coordinate of pile center to 1.5 m
3. Row 4:
   a. Rename “Pile1” to “Pile 4”
   b. Change x and y coordinates of pile center to 1.5 m and 1.5 m, respectively

f. Navigate to the Options tab ()

i. Enter the following:

1. Frequency Increment: 0.1
2. Number of Frequencies: 99
3. Pile Radius Interaction Factor: 1000

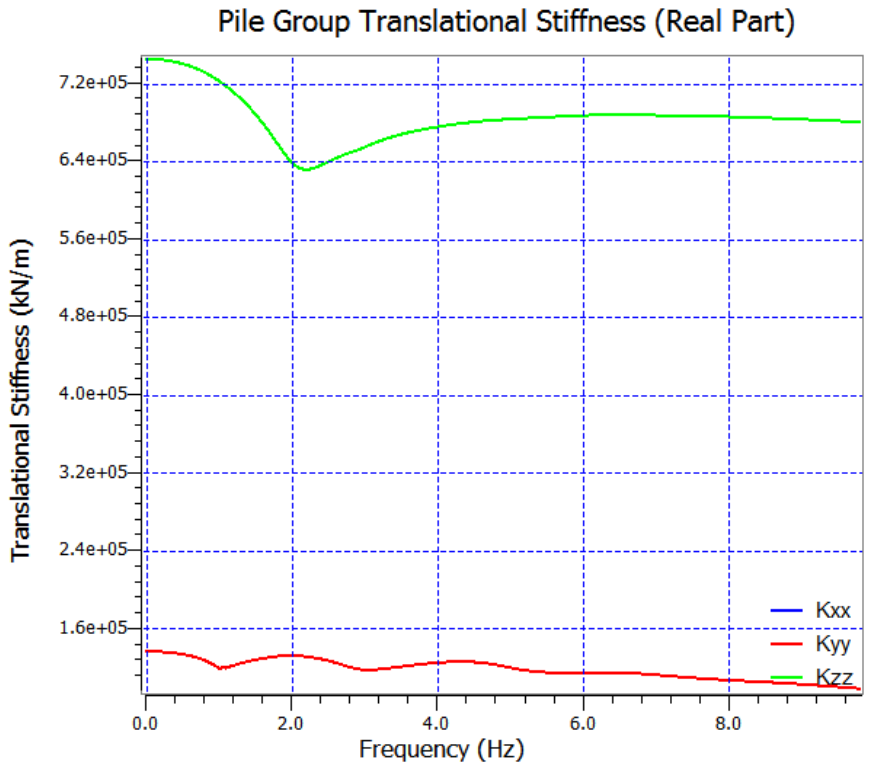
g. Click “OK” to close Project Data window. The layout shown in Figure 4-2 should appear in the 3D view area

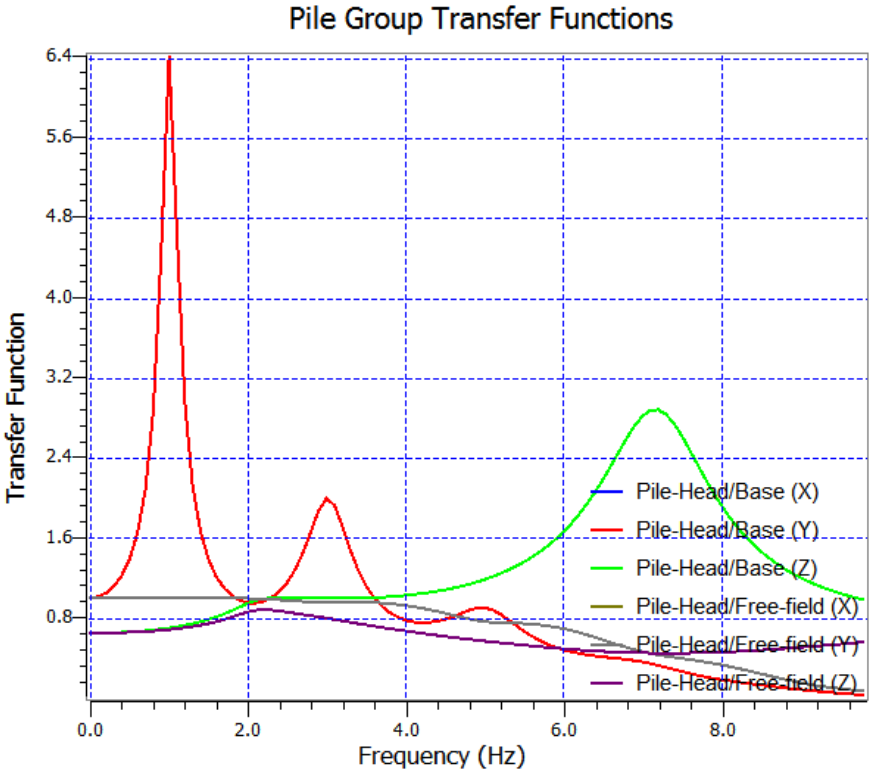
3. Save the project by clicking  button on the main toolbar
   a. Locate a desired folder and specify filename to save the file to local drive
4. Click the  button on the main toolbar to start the analysis

Figure 4-2 Isometric view of Example 1

4.1.2 Results

Upon completion of the results, a window showing the plot window is displayed on the window (Section 3.5.1). The solution data, presented in the below, can be viewed through the Report window (Section 3.5.2).


Pile Group Translational Stiffness (Real Part)
Translational Stiffness (kN/m)
7.2e+05
6.4e+05
5.6e+05
4.8e+05
4.0e+05
3.2e+05
2.4e+05
1.6e+05
0.0
2.0
4.0
6.0
8.0
Frequency (Hz)
Kxx
Kyy
Kzz


Pile Group Transfer Functions
Transfer Function
6.4
5.6
4.8
4.0
3.2
2.4
1.6
0.8
0.0
2.0
4.0
6.0
8.0
Frequency (Hz)
Pile-Head/Base (X)
Pile-Head/Base (Y)
Pile-Head/Base (Z)
Pile-Head/Free-field (X)
Pile-Head/Free-field (Y)
Pile-Head/Free-field (Z)

4.1.3 Comparison

Dynapile outputs for transfer functions are compared against results of (Gazetas, et al., 1992) in Figure 4-3 through Figure 4-7 below.

Figure 4-3 Single pile transfer function (Pile-head to pile-tip, x-direction)

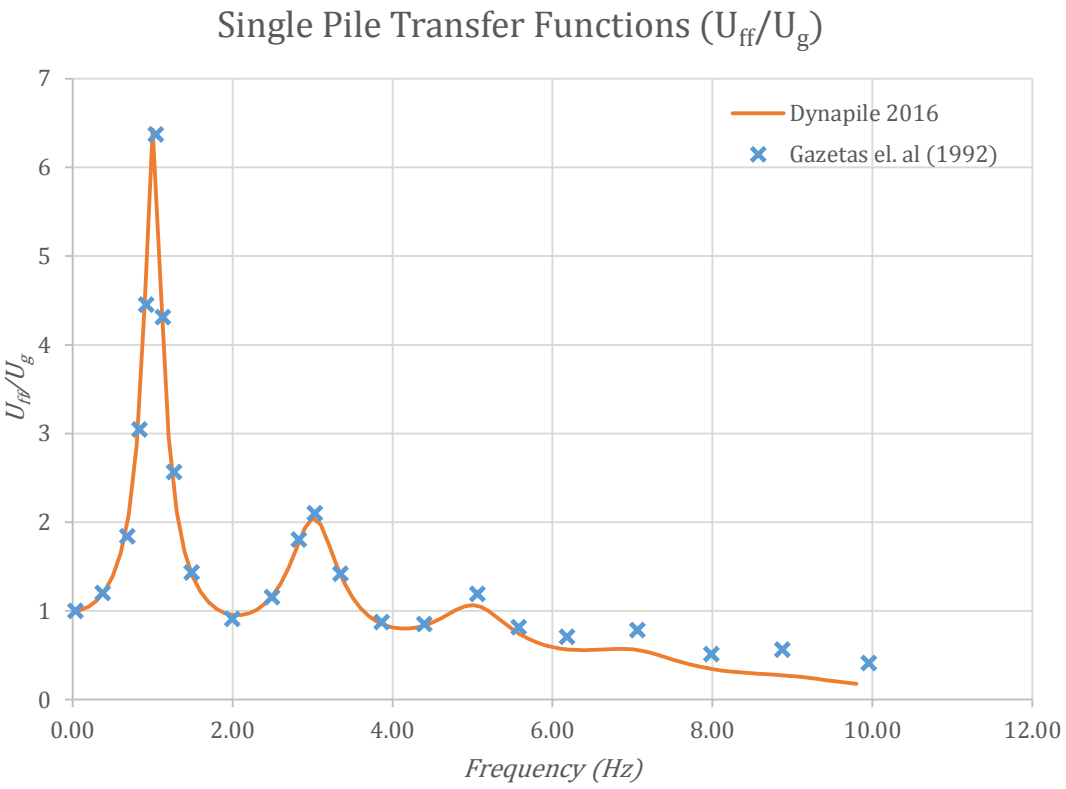


Figure 4-4 Single pile transfer function (Free-field to pile-tip, x-direction)

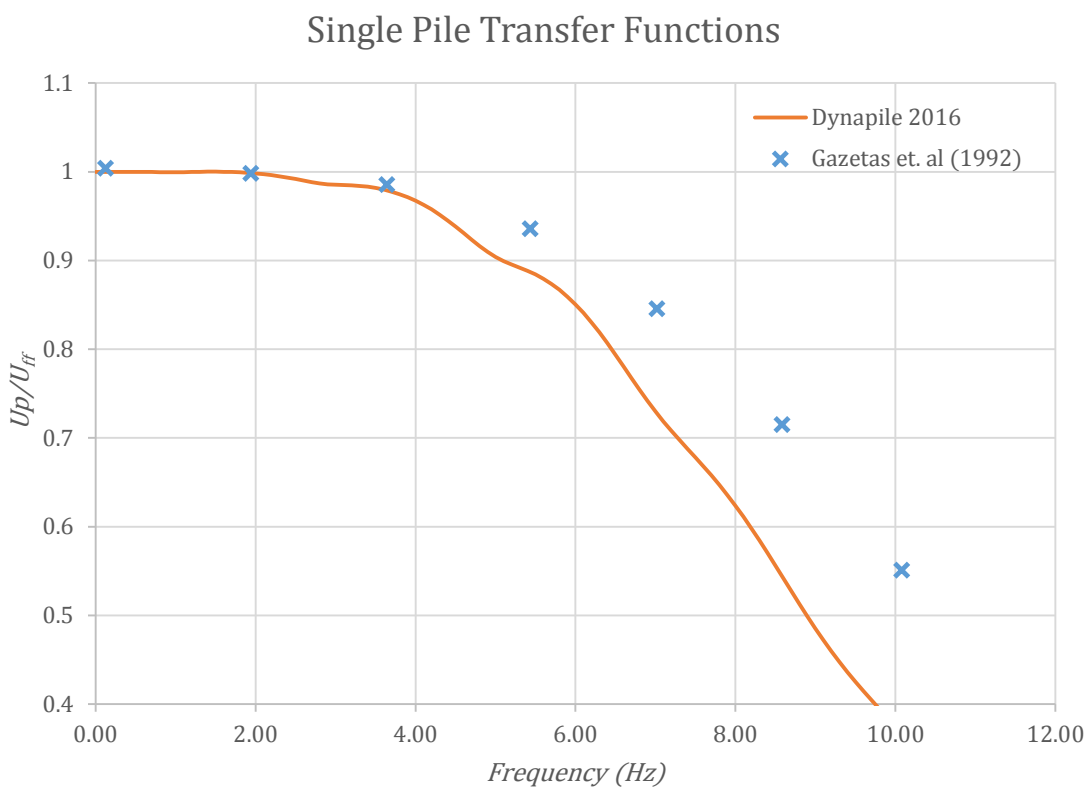


Figure 4-5 Single pile transfer function (pile-head to free-field)

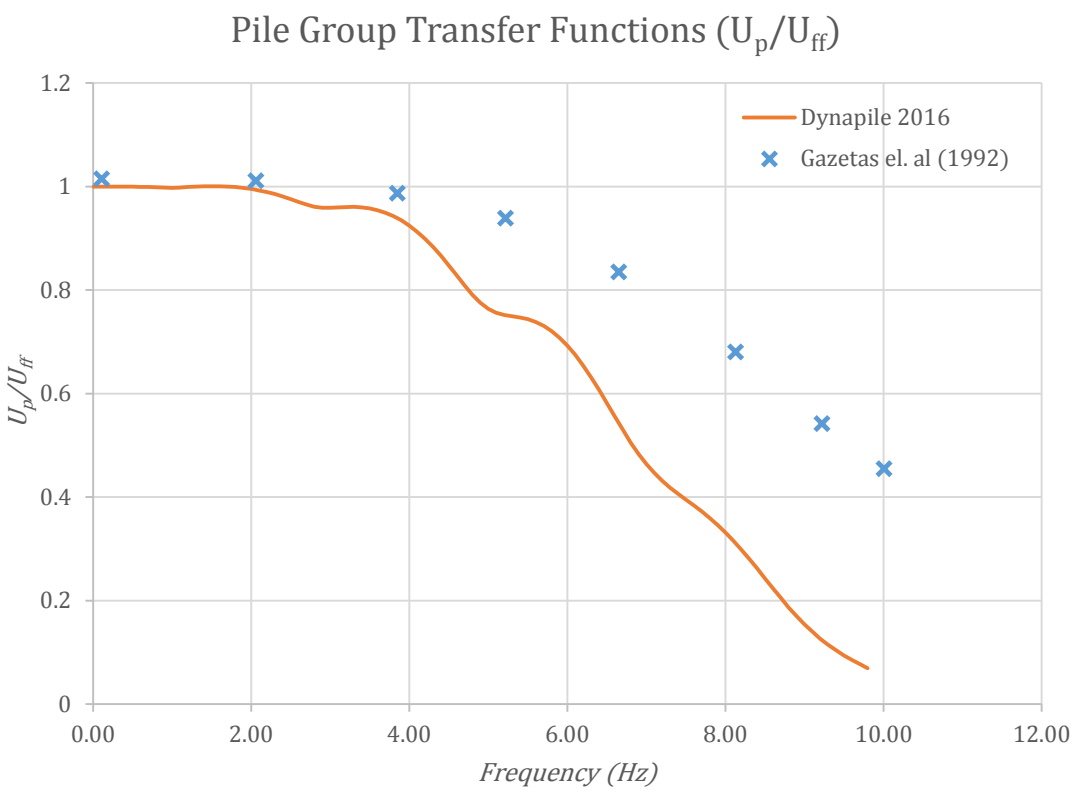


Figure 4-6 Pile group transfer function (pile-head to free-field, x-direction)

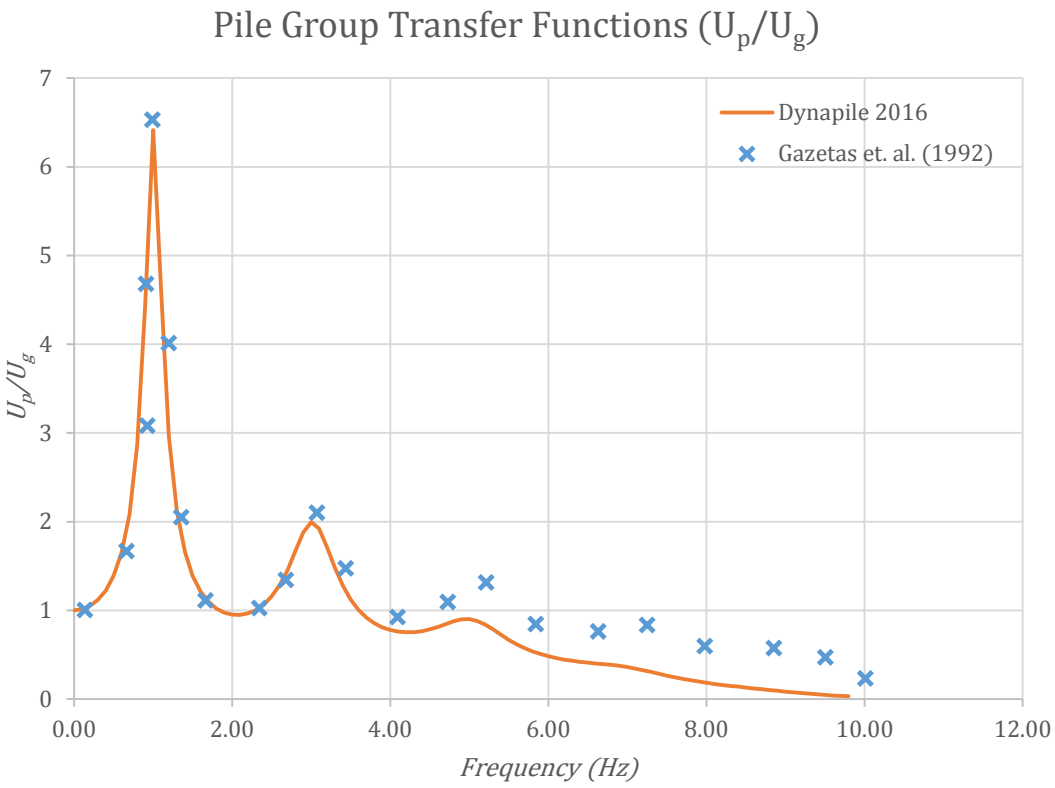


Figure 4-7 Pile group transfer function (pile-head to pile-tip, x-direction)

4.2 Example 2

Consider the 36 piles arranged in a square layout with a center-to-center spacing of 3.0 meters (Figure 4-8). The piles are 20 meters in length, and have hollow circular cross-section with outer and inner radii of 0.300 and 0.291 m, respectively.

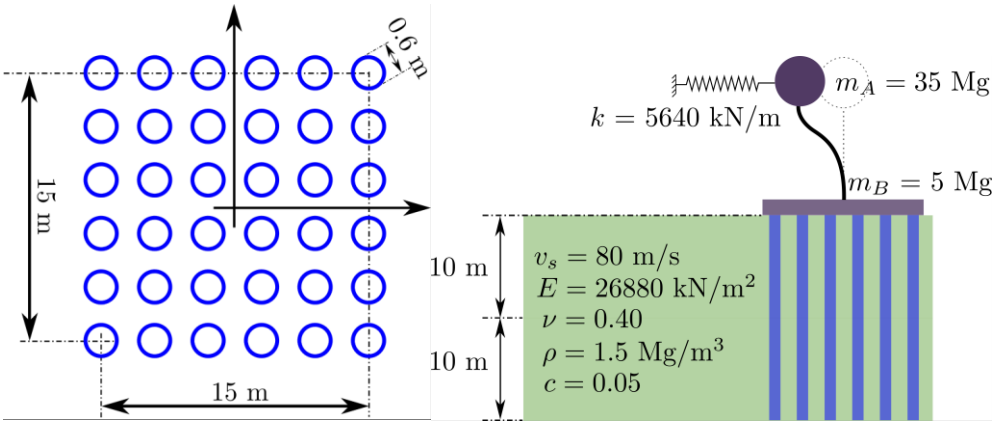


Figure 4-8 Example 2 configuration

The material properties of soil and pile are tabulated in Table 4-2.

Table 4-2 Material properties of soil and pile in Example 2

	Elastic Modulus (kPa)	Shear Wave velocity (m/s)	Mass Density (kg/m^3)	Poisson's Ratio	Damping (%)
Soil	26880	80.00	1500.00	0.49	5.0
Piles	3.0e7	2362.5	2150.00	0.25	0.5

4.2.1 Creating Dynapile Model

1. Start Dynapile
2. Start entering project data by clicking the Project Data icon ( ) from the main toolbar
    a. Project Information
        i. Change Project Label to "Example 2" and leave units as default
    b. Navigate to the Materials tab ( )
        i. Click the icon to add a new material for soil layers
            1. In the Material Properties, enter the following:
                a. **Label**: soilMaterial
                b. **Density**: 1500 kg/m^3 (Note: you may also right-click on the units, change input units to Mg/m^3, and enter 1.5 as the value)
                c. **Poisson's Ratio**: 0.49
                d. **Damping**: 0.05
                e. **Shear Wave Velocity**: 80 m/s
        ii. Click the icon to add a new material for piles
            1. In the Material Properties, enter the following:
                a. **Label**: concrete
                b. **Density**: 2150 kg/m^3
                c. **Poisson's Ratio**: 0.25
                d. **Damping**: 0.005
                e. **Elastic Modulus**: 3.0e7 kPa
    c. Navigate to the Section tab ( )
        i. Click icon to add a new cross-section for piles
            1. Select circular tube in the Add Section window
                a. Enter the following in the Circular Tube Section window:
                    i. **Label**: pileSection
                    ii. **Outer Radius**: 0.300
                    iii. **Inner Radius**: 0.291
                b. Press "OK" to accept and close the window
    d. Navigate to the Soil Layer tab ( )
        i. Click the button to insert a new row in the table
            1. Double click the cell under "Label" and enter "Layer1"
            2. Double click the cell under "Material", and select "soilMaterial" from the drop-down menu
            3. Double click the cell under "Thickness" header, and enter "10"
            4. Double click the cell under "Number of Sublayers" and enter 20
        ii. Click the button to duplicate Layer1
            1. Double click the "Label" item and change the label to "Layer2"
            2. Double click the "Number of Sublayers" and change the value to 10

e. Navigate to the Pile Layout tab ()
    i. Click the  button to create pile layout from template
        1. In the new window, enter the following:
            a. **(Horizontal) Quantity**: 6
            b. **(Horizontal) Spacing**: 3.0 (m)
            c. **(Vertical) Quantity**: 6
            d. **(Vertical) Spacing**: 3.0 (m)
            e. **Material**: concrete
            f. **Section**: pileSection
            g. **Length**: 20 (m)
        2. Click "OK" to create pile layout
        3. Double-click the "Material" cell and select "steel" file the drop-down menu
        4. Double-click the "Geometry" cell and select "steel" from the drop-down menu
        5. Double-click the "Length" cell and enter 20 as its value
f. Navigate to the Structure tab ()
    i. Enable Superstructure input by checking the checkbox
    ii. Enter the following:
        1. **Mass**: 35,000 kg
        2. $\boldsymbol{K_x}$: 5,640 kN/m
        3. Leave other fields with zero values
g. Click "OK" to close Project Data window. The layout shown in Figure 4-9 should appear in the 3D view area

3. Save the project by clicking  button on the main toolbar
    a. Locate a desired folder and specify filename to save the file to local drive
4. Click the  button on the main toolbar to start the analysis

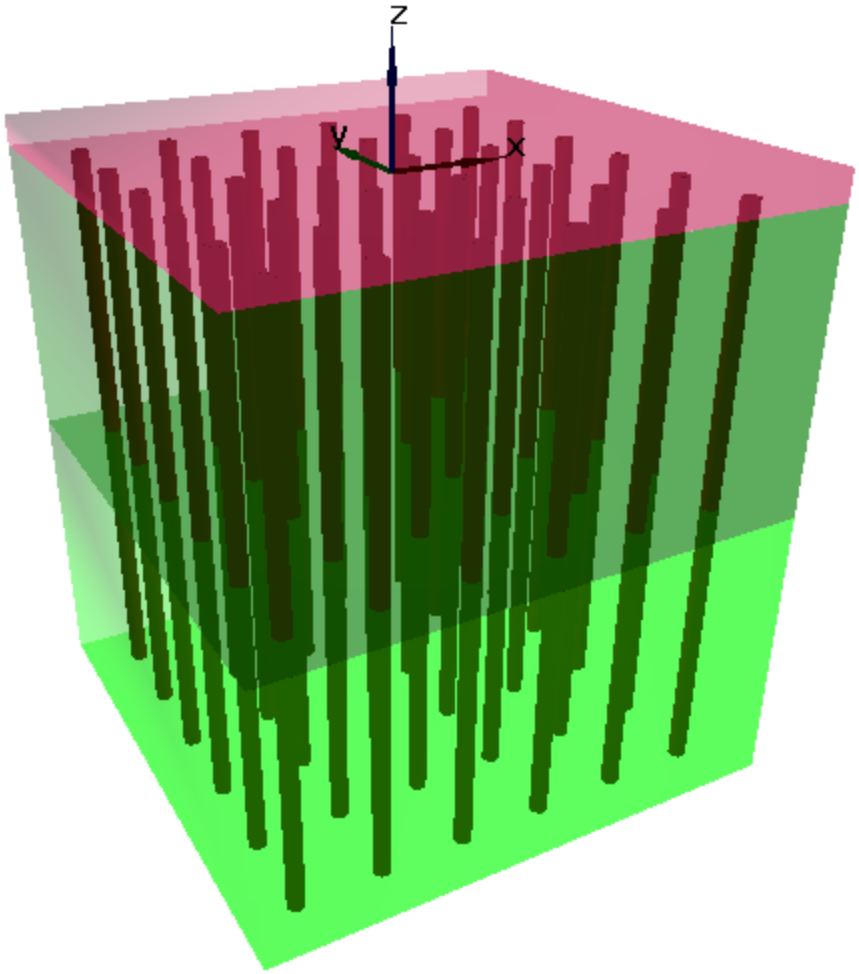
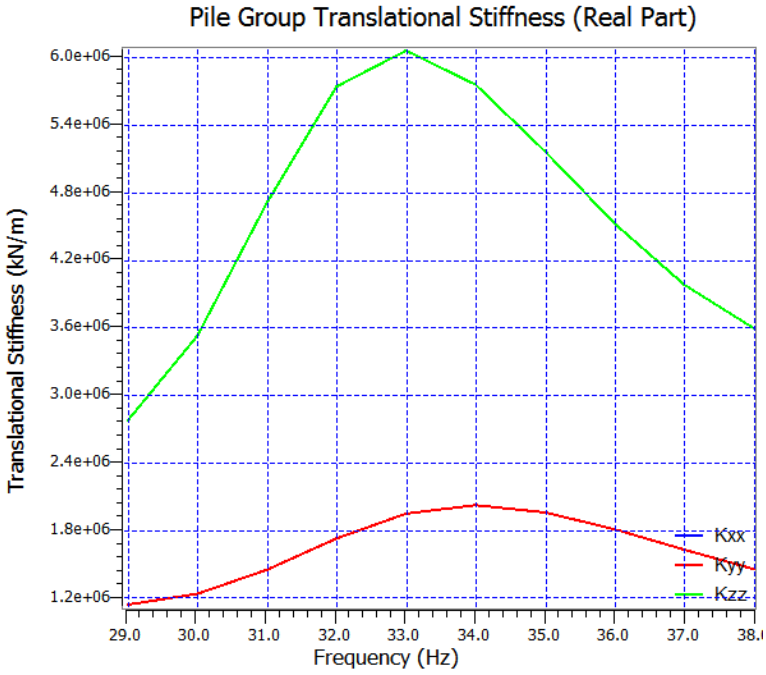
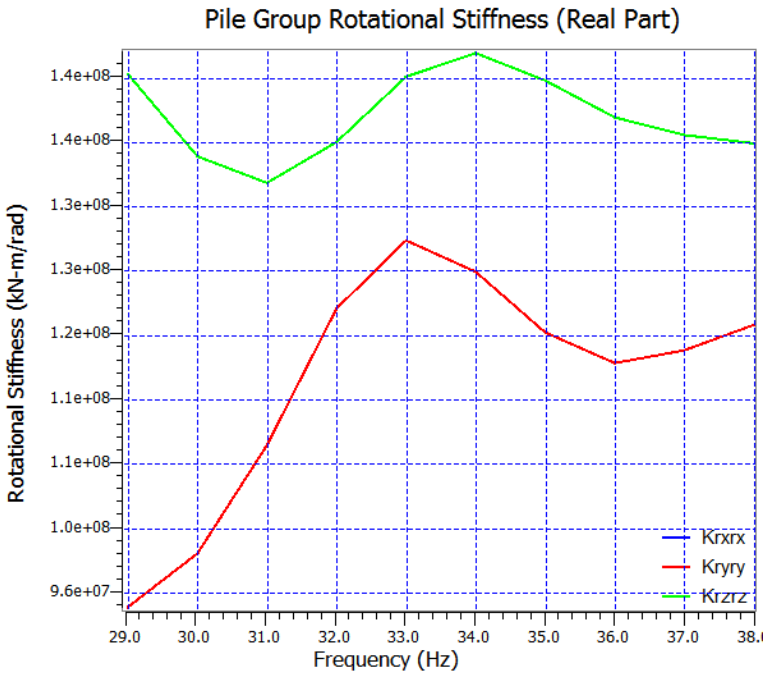
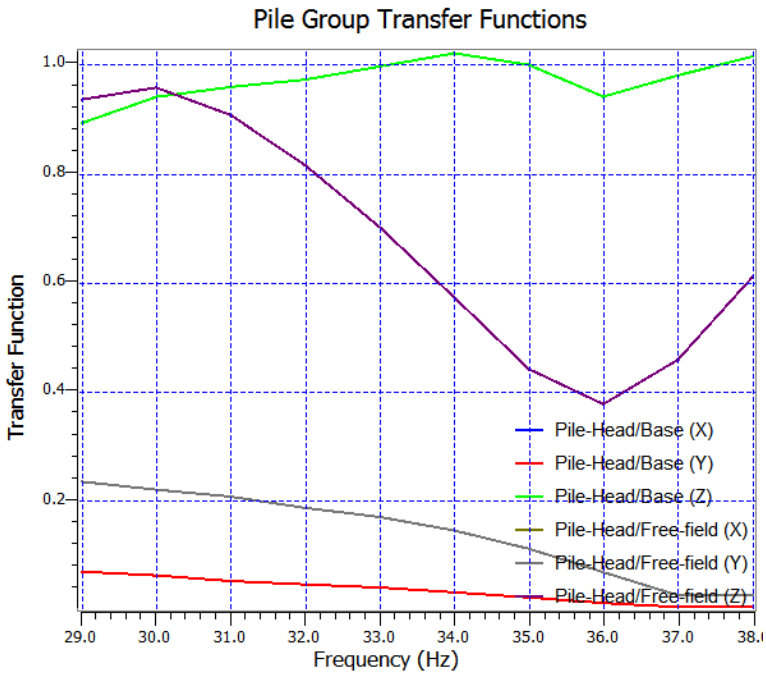


Figure 4-9 Isometric view of Example 2

4.2.2 Results


Pile Group Translational Stiffness (Real Part)
Translational Stiffness (kN/m)
6.0e+06
5.4e+06
4.8e+06
4.2e+06
3.6e+06
3.0e+06
2.4e+06
1.8e+06
1.2e+06
29.0
30.0
31.0
32.0
33.0
34.0
35.0
36.0
37.0
Frequency (Hz)
Kxx
Kyy
Kzz


Pile Group Rotational Stiffness (Real Part)
Rotational Stiffness (kN-m/rad)
1.4e+08
1.4e+08
1.3e+08
1.3e+08
1.2e+08
1.1e+08
1.1e+08
1.0e+08
9.6e+07
29.0
30.0
31.0
32.0
33.0
34.0
35.0
36.0
37.0
Frequency (Hz)
Krxrx
Kryry
Krzrz


Pile Group Transfer Functions
Transfer Function
1.0
0.8
0.6
0.4
0.2
29.0
30.0
31.0
32.0
33.0
34.0
35.0
36.0
37.0
Frequency (Hz)
Pile-Head/Base (X)
Pile-Head/Base (Y)
Pile-Head/Base (Z)
Pile-Head/Free-field (X)
Pile-Head/Free-field (Y)
Pile-Head/Free-field (Z)

4.3 Example 3

We consider a single circular pile of length 20m embedded in a homogeneous soil layer. The material properties of soil and pile are tabulated in Table 4-3.

Table 4-3 Material properties of soil and pile in Example 3

	Elastic Modulus (kPa)	Shear Wave velocity (m/s)	Mass Density (kg/m^3)	Poisson's Ratio	Damping (%)
Soil	1	18.898	1.00	0.4	5.0
Pile	1000	501.507	1.42	0.4	5.0

4.3.1 Creating Dynapile Model

1. Start Dynapile
2. Start entering project data by clicking the Project Data icon ( ) from the main toolbar
    a. Project Information
        i. Change Project Label to “Example 3” and leave units as default
    b. Navigate to the Materials tab ( )
        i. Click the icon to add a new material for soil layers
            1. In the Material Properties, enter the following:
                a. **Label**: soilMat
                b. **Density**: 1 kg/m^3
                c. **Poisson’s Ratio**: 0.4
                d. **Damping**: 0.05
                e. **Elastic Modulus**: 1 kPa
        ii. Click the icon to add a new material for piles
            1. In the Material Properties, enter the following:
                a. **Label**: pileMat
                b. **Density**: 1.42 kg/m^3
                c. **Poisson’s Ratio**: 0.40
                d. **Damping**: 0.05
                e. **Elastic Modulus**: 1000 kPa
    c. Navigate to the Section tab ( )
        i. Click icon to add a new cross-section for piles
            1. Select circular tube ( ) in the Add Section window
                a. Enter the following in the Circular Section window:
                    i. **Label**: pileSection
                    ii. **Radius**: 0.5 m
                b. Press “OK” to accept and close the window
    d. Navigate to the Soil Layer tab ( )
        i. Click the button to insert a new row in the table
            1. Double click the cell under “Label” and enter “soil”
            2. Double click the cell under “Material”, and select “soilMat” from the drop-down menu
            3. Double click the cell under “Thickness” header, and enter “20”
            4. Double click the cell under “Number of Sublayers” and enter 46
    e. Navigate to the Pile Layout tab ( )
        i. Click the button to insert a blank line
            1. Double-click the “Label” cell and enter Pile1
            2. Double-click the “Material” cell and select “pileMat” file the drop-down menu

3. Double-click the “Geometry” cell and select “pileSection” from the drop-down menu
4. Double-click the “Length” cell and enter 20 as its value

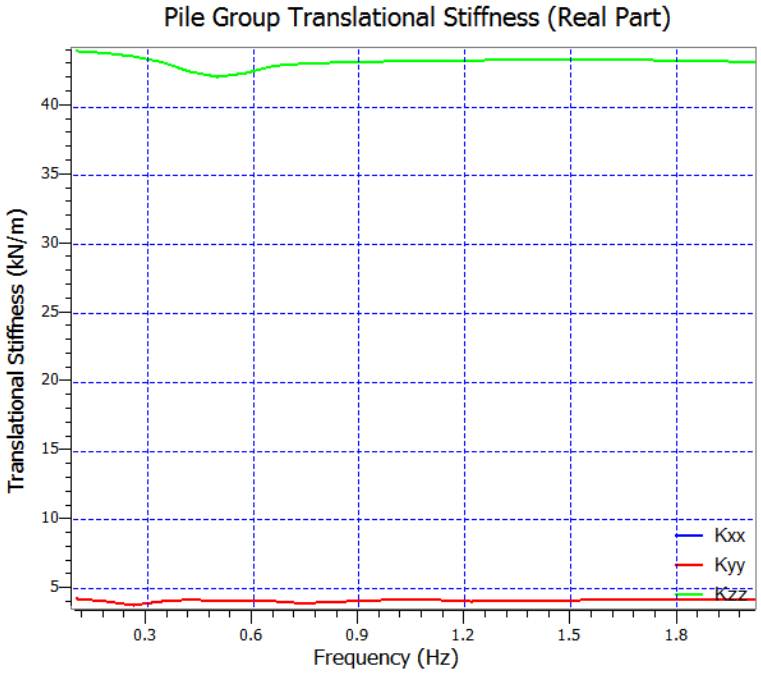
f. Navigate to the Options tab ( )
   i. Enter the following:
      1. Frequency Increment: 0.08
      2. Number of Frequencies: 20

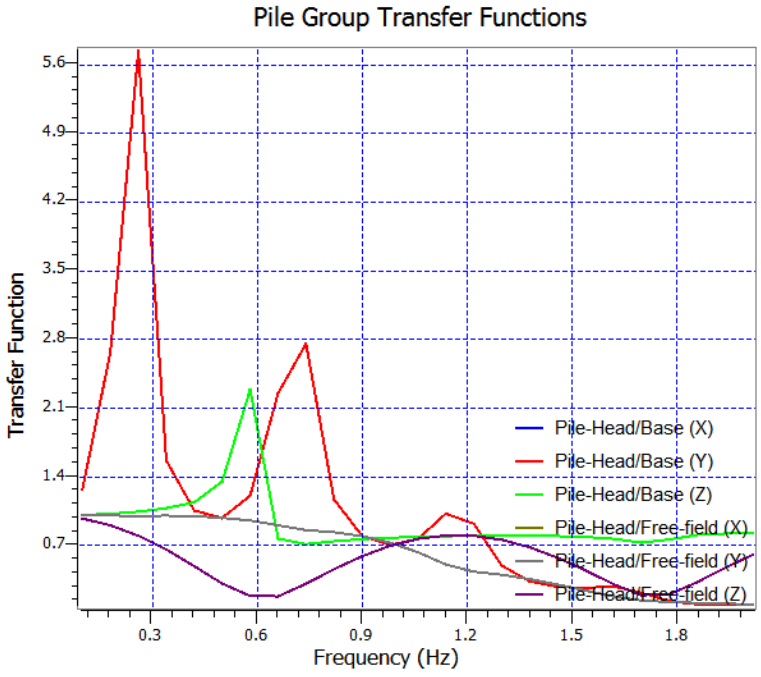
g. Click “OK” to close Project Data window. The layout shown in Figure 4-10 should appear in the 3D view area

3. Save the project by clicking button on the main toolbar
   a. Locate a desired folder and specify filename to save the file to local drive
4. Click the button on the main toolbar to start the analysis

Figure 4-10 Isometric view of Example 3

4.3.2 Results


Pile Group Translational Stiffness (Real Part)
Translational Stiffness (kN/m)
40
35
30
25
20
15
10
5
0.3
0.6
0.9
1.2
1.5
1.8
Frequency (Hz)
Kxx
Kyy
Kzz


Pile Group Transfer Functions
Transfer Function
5.6
4.9
4.2
3.5
2.8
2.1
1.4
0.7
0.3
0.6
0.9
1.2
1.5
1.8
Frequency (Hz)
Pile-Head/Base (X)
Pile-Head/Base (Y)
Pile-Head/Base (Z)
Pile-Head/Free-field (X)
Pile-Head/Free-field (Y)
Pile-Head/Free-field (Z)

4.3.3 Comparison

Single pile transfer function is compared against results of (Fan, Gazetas, Kaynia, Kausel, & Ahmad, 1991) in Figure 4-11. The results are then repeated for $\frac{E_p}{E_s} = 10{,}000$ by changing pile's elastic modulus to 10,000 (See Step 2.b.ii.1.e in Section 4.3.1). The results of single pile transfer function are shown in Figure 4-12.

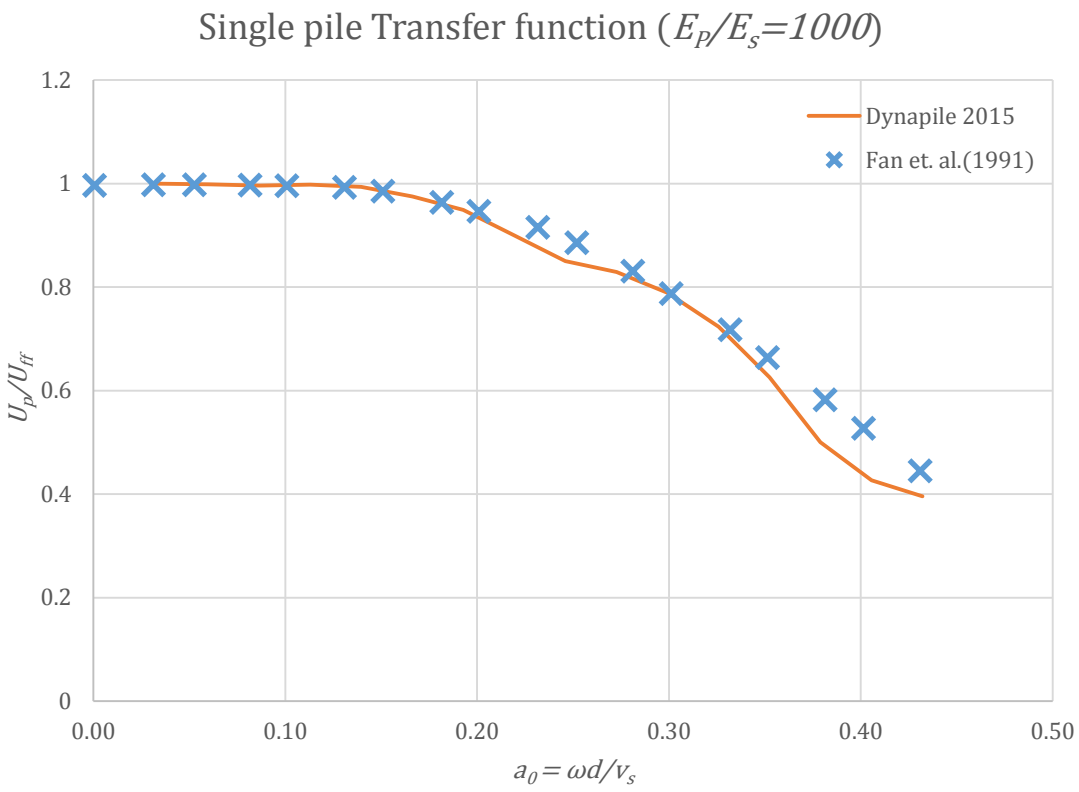


Figure 4-11 Single pile transfer function (Pile-head to free-field in the x-direction, $\frac{E_p}{E_s} = 1000$)

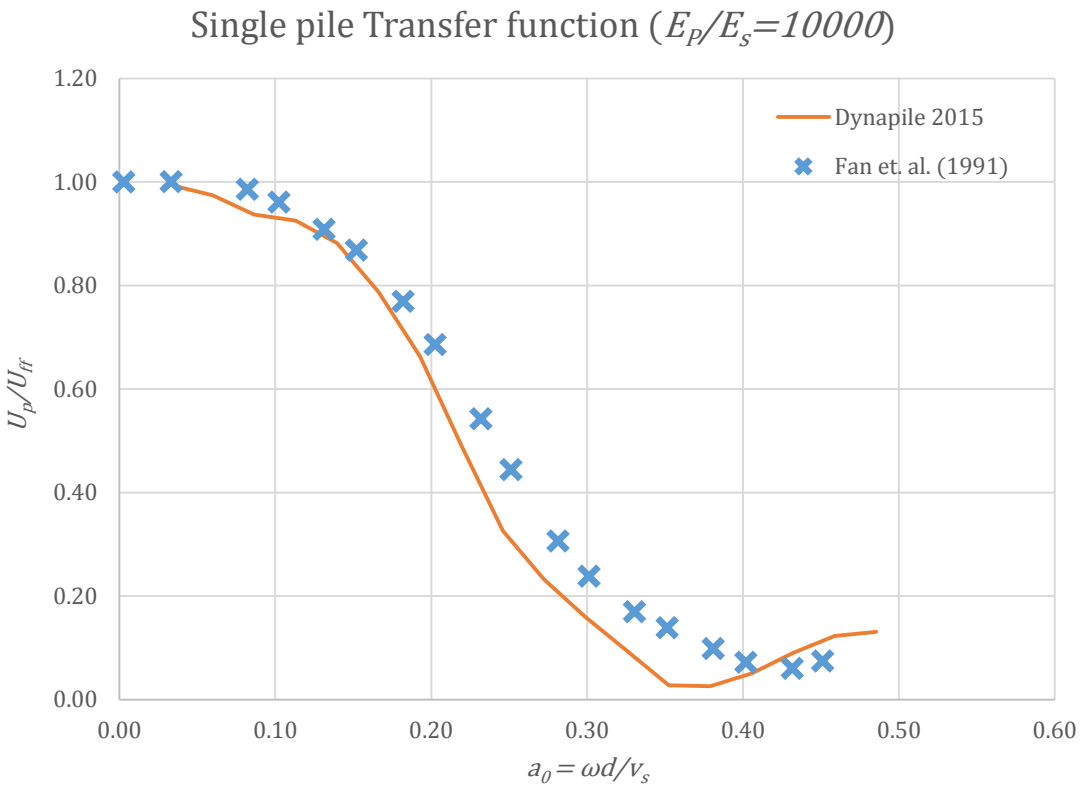


Figure 4-12 Single pile transfer function (Pile Head to Free-field in x-direction, $\frac{E_p}{E_s} = 10000$)

4.4 Example 4

We consider a 2x2 pile group centered around (0,0) with length of 37.5m. The soil and pile properties are chosen such that

$$\frac{L}{d} = 37.5, \qquad \frac{H}{d} = 75.0$$

$$\frac{s}{d} = 5.0, \qquad \frac{L}{d} = 37.5$$

$$\frac{\pi G_s L^2}{E_p A} = 1.0$$

where, L is the pile lengths, H is the total depth of soil, d is the diameter of the piles, A is the cross-sectional area of the piles, s is the center-to-center spacing of piles, G_s is the shear modulus of the soil, and E_p is the pile elastic modulus.

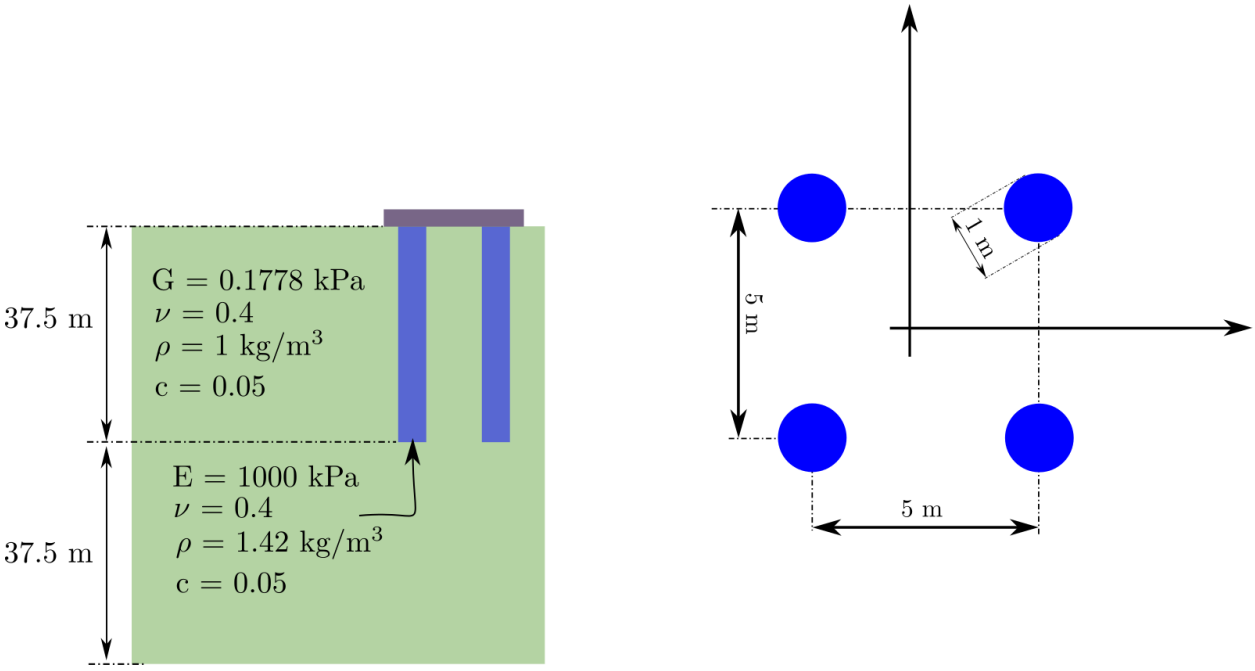


Figure 4-13 Example 4 configuration

4.4.1 Creating Dynapile Model

5. Start Dynapile
6. Start entering project data by clicking the Project Data icon ( ) from the main toolbar
    a. Project Information
        i. Change Project Label to "Example 4" and leave units as default
    b. Navigate to the Materials tab ( )
        i. Click the icon to add a new material for soil layers
            1. In the Material Properties, enter the following:
                a. **Label**: soilMat
                b. **Density**: 1 kg/m^3
                c. **Poisson's Ratio**: 0.4
                d. **Damping**: 0.05
                e. **Shear Modulus**: 0.1778 kPa
        ii. Click the icon to add a new material for piles
            1. In the Material Properties, enter the following:
                a. **Label**: pileMat
                b. **Density**: 1.42 kg/m^3
                c. **Poisson's Ratio**: 0.40
                d. **Damping**: 0.05
                e. **Elastic Modulus**: 1000 kPa
    c. Navigate to the Section tab ( )
        i. Click icon to add a new cross-section for piles
            1. Select circular tube ( ) in the Add Section window
                a. Enter the following in the Circular Section window:
                    i. **Label**: pileSection
                    ii. **Radius**: 0.5 m
                b. Press "OK" to accept and close the window
    d. Navigate to the Soil Layer tab ( )
        i. Click the button to insert a new row in the table
            1. Double click the cell under "Label" and enter "layer1"
            2. Double click the cell under "Material", and select "soilMat" from the drop-down menu
            3. Double click the cell under "Thickness" header, and enter "37.5" (m)
            4. Double click the cell under "Number of Sublayers" and enter 40
        ii. Click the button to duplicate Layer1, and make the following changes to the new layer:
            1. Label: layer2
            2. Number of Sublayers: 5
    e. Navigate to the Pile Layout tab ( )

i. Click the button to create pile layout from template
    1. In the new window, enter the following:
        a. **(Horizontal) Quantity**: 2
        b. **(Horizontal) Spacing**: 5.0 (m)
        c. **(Vertical) Quantity**: 2
        d. **(Vertical) Spacing**: 5.0 (m)
        e. **Material**: pileMat
        f. **Section**: pileSection
        g. **Length**: 37.5 (m)
    2. Click "OK" to create pile layout

f. Navigate to the Options tab ( )
    i. Enter the following:
        1. Frequency Increment: 0.07
        2. Number of Frequencies: 40
        3. Pile Radius Interaction Factor: 1000

g. Click "OK" to close Project Data window. The layout shown in Figure 4-14 should appear in the 3D view area

7. Save the project by clicking button on the main toolbar
    a. Locate a desired folder and specify filename to save the file to local drive
8. Click the button on the main toolbar to start the analysis

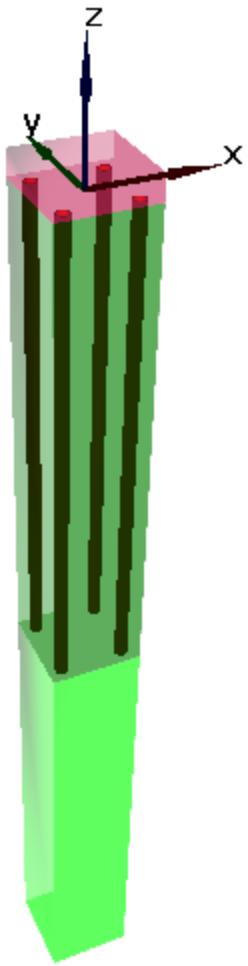
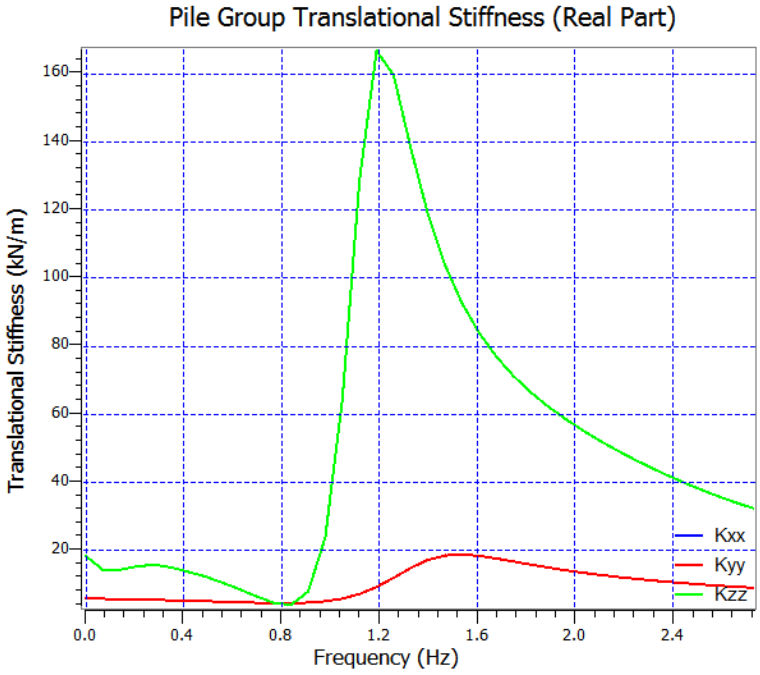
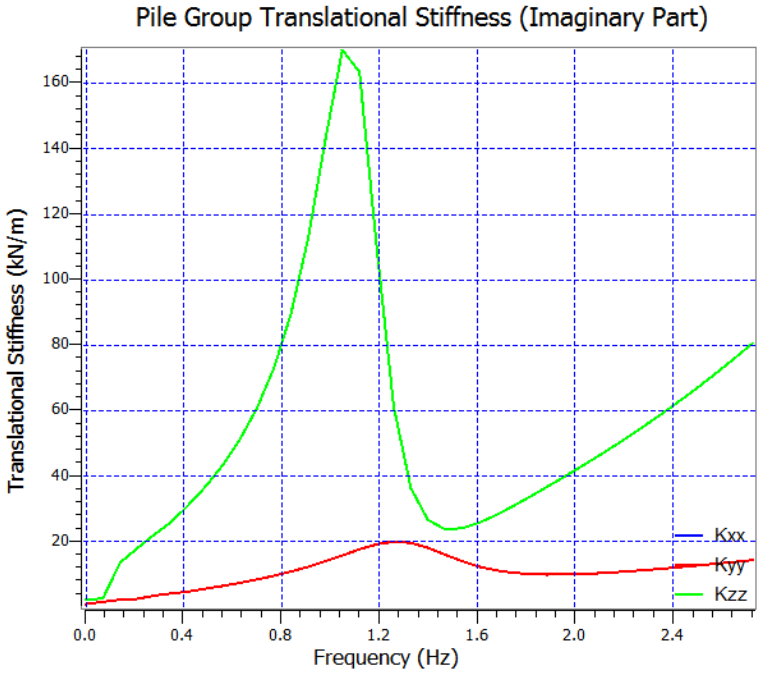
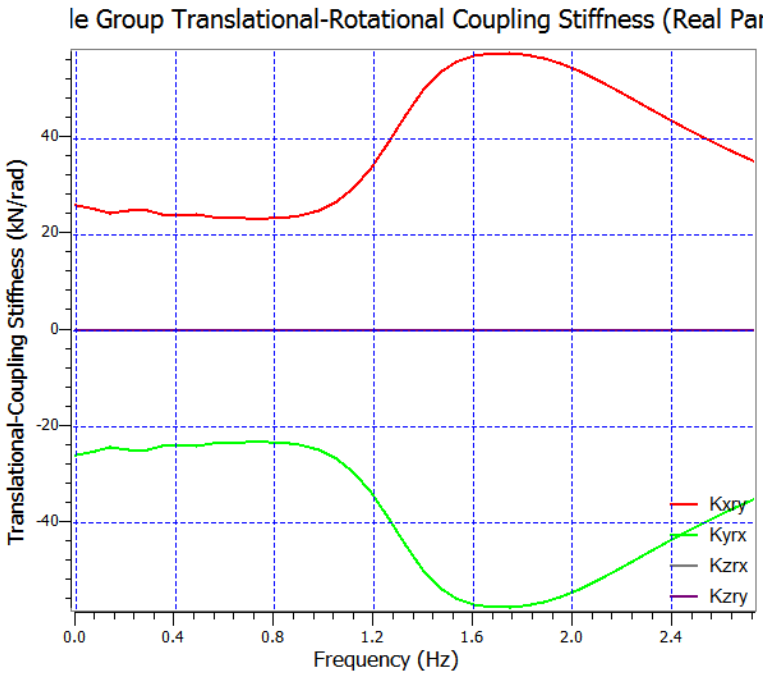


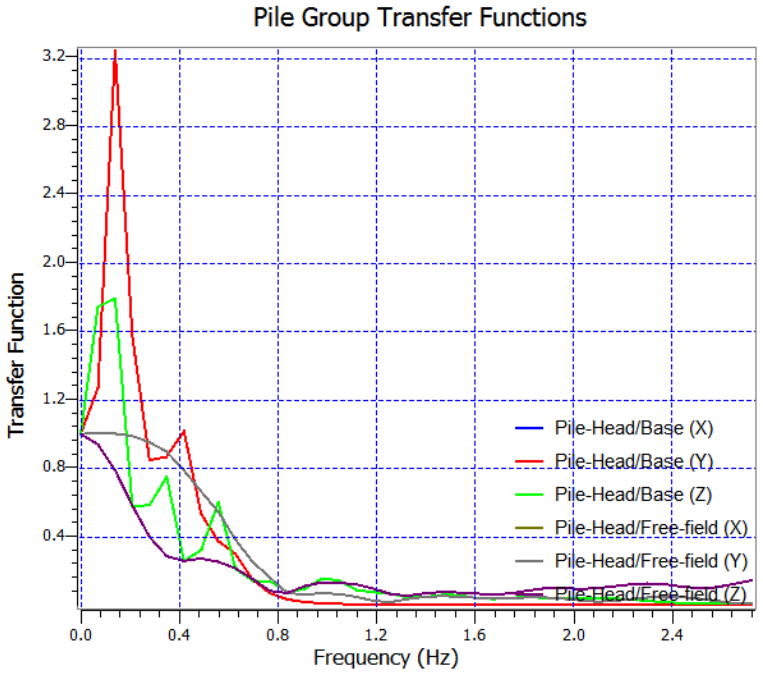
Figure 4-14 Isometric view of Example 4

4.4.2 Results


Pile Group Translational Stiffness (Real Part)
Translational Stiffness (kN/m)
160
140
120
100
80
60
40
20
0.0
0.4
0.8
1.2
1.6
2.0
2.4
Frequency (Hz)
Kxx
Kyy
Kzz


Pile Group Translational Stiffness (Imaginary Part)
Translational Stiffness (kN/m)
160
140
120
100
80
60
40
20
0.0
0.4
0.8
1.2
1.6
2.0
2.4
Frequency (Hz)
Kxx
Kyy
Kzz





4.4.3 Comparison

In this section we compare the vertical stiffness and damping with the results of (Kaynia & Kausel, 1982).

The vertical stiffness of pile group is normalized as

$$\hat{K}_{zz} = \frac{Re(K_{zz})}{Re(K_{zz}(a_0 = 0))}$$

and the vertical damping of pile group is normalized as

$$\hat{C}_{zz} = \frac{C_{zz}}{4 \cdot Re(K_{zz}^{s}(a_0 = 0))}$$

In the above, K_{zz} is the vertical stiffness of the pile group, K_{zz}^{s} is the vertical stiffness of a single pile, $a_0 = \frac{\omega d}{C_s}$ is the normalized frequency, d is the pile diameter, C_s is the shear-wave velocity of the soil, and $K_{zz}(a_0 = 0)$ is the vertical stiffness of the pile group at normalized frequency of 0. The normalized stiffness and damping are shown in Figure 4-15 and Figure 4-16, respectively.

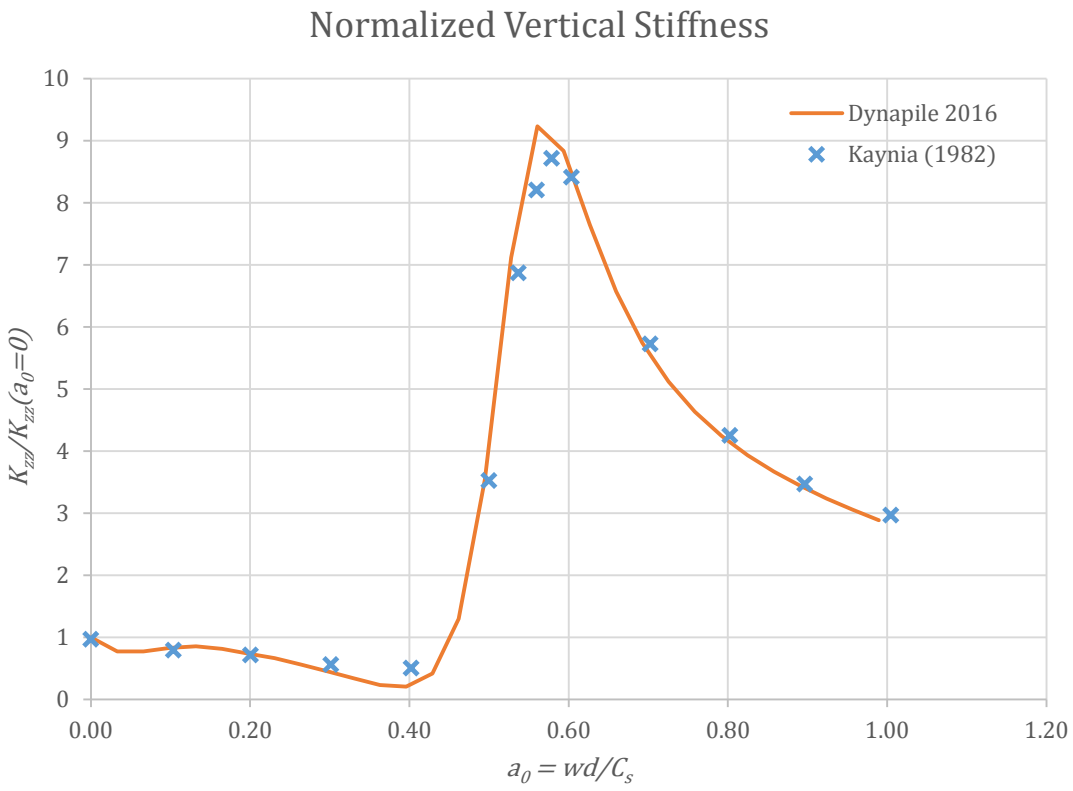


Figure 4-15 Normalized real part of vertical translation stiffness

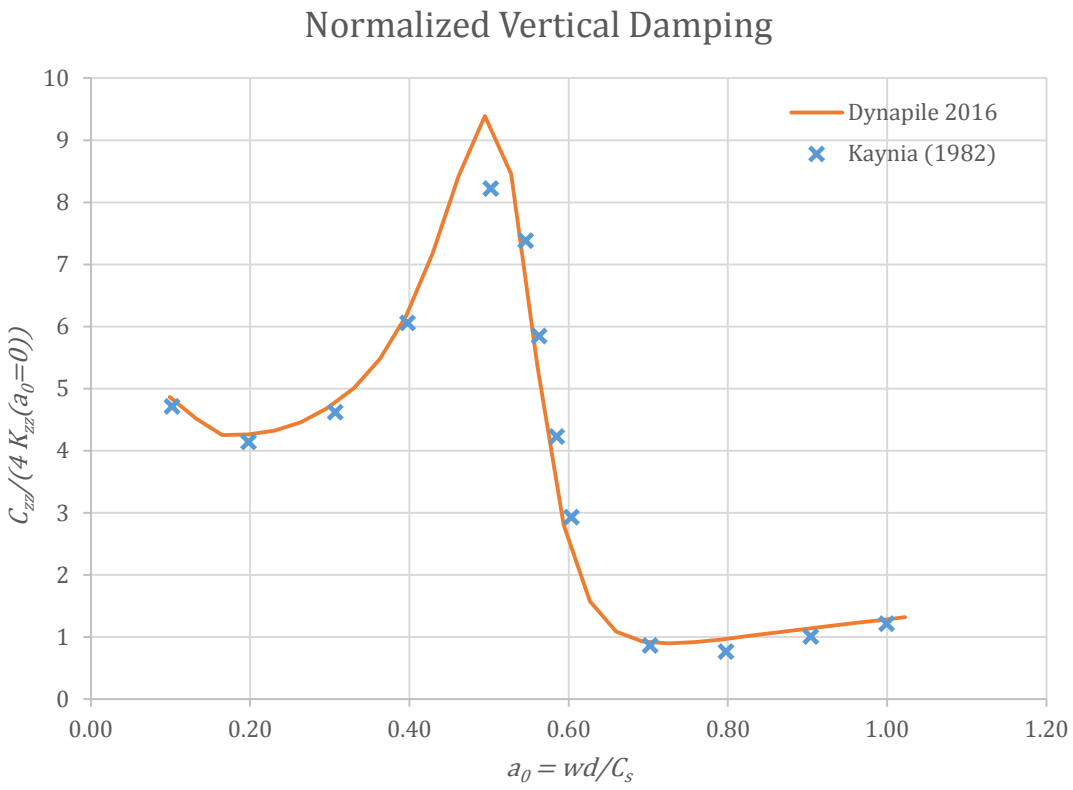


Figure 4-16 Normalized vertical damping of pile group

4.5 Example 5

In this example, we wish to investigate the response of a superstructure supported by a pile group in the frequency domain. We consider a superstructure with a mass of 35 Mg, and a horizontal stiffness of 5640 kN/m supported on a 5×5 pile group. Piles have an elastic modulus of $E = 2.048 \times 10^8$ kPa, density $\rho = 7850$ kg/m^3, poisons ratio of $\nu = 0.3$, moment of inertia of $I = 1.086 \times 10^{-4}$ m^4, and a cross-sectional area of $A = 1.38 \times 10^{-2}$ m^2.

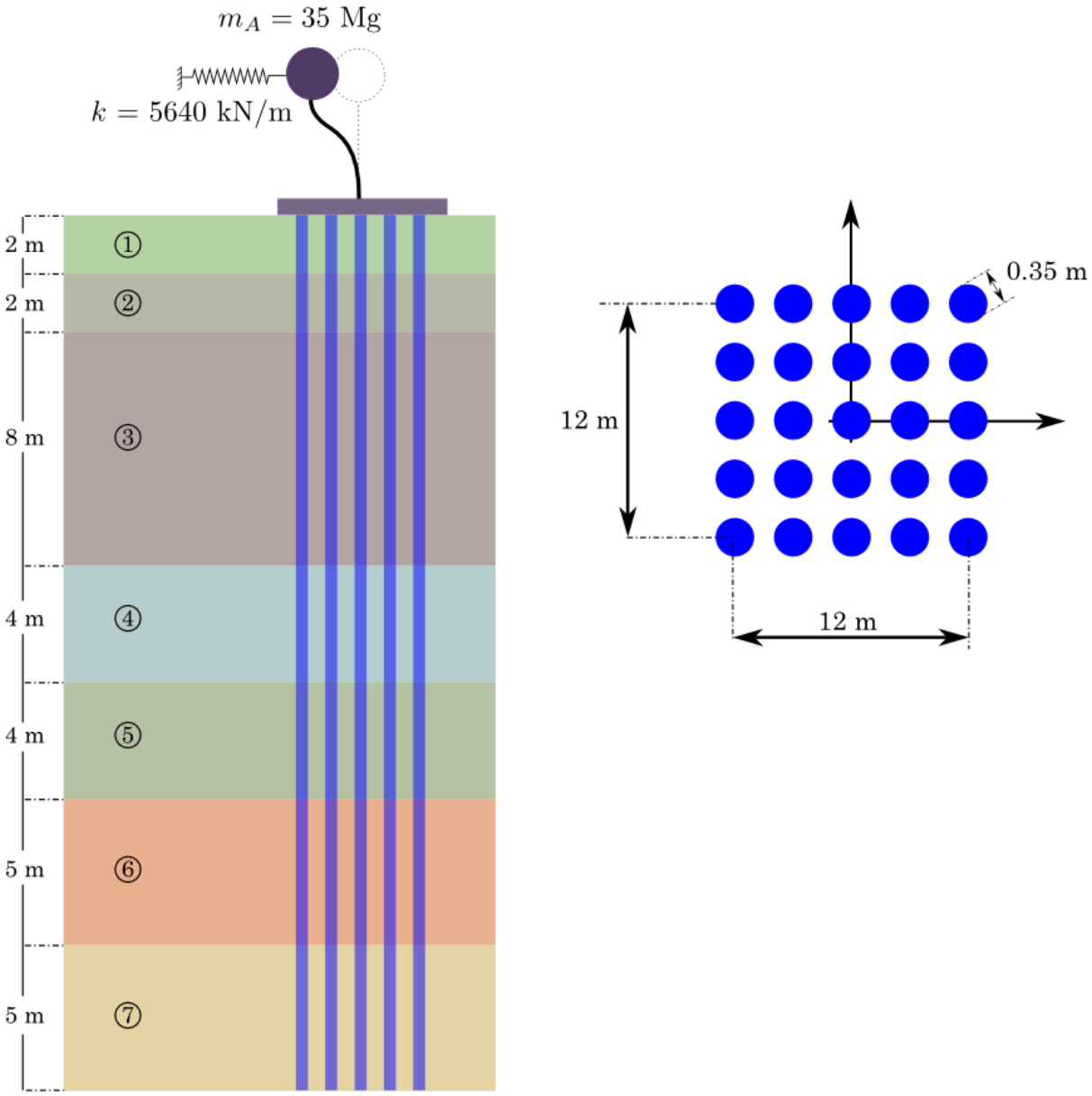


Figure 4-17 Example 5 configuration

Table 4-4 Soil layer properties in Example 5

Layer Index	Label	Shear Wave Velocity (m/s)	Density (kg/m^3)	Poisson's Ratio	Damping Ratio	Depth (m)	Sublayers
1	Soft clay	130	1830	0.25	0	2	2
2	Fine sand	140	1830	0.25	0	2	2
3	Stiff clay	300	2039	0.25	0	8	8
4	Silty sand	240	1940	0.25	0	4	4
5	Silty clay	300	1830	0.25	0	4	4
6	Weathered shale	200	2040	0.25	0	5	5
7	Dense sand	300	2040	0.25	0	5	5

4.5.1 Creating Dynapile Model

9. Start Dynapile
10. Start entering project data by clicking the Project Data icon ( ) from the main toolbar
    a. Project Information
        i. Change Project Label to "Example 5" and leave units as default
    b. Navigate to the Materials tab ( )
        i. Click the icon to add a new material for soil layers
            1. In the Material Properties, enter the following:
                a. **Label**: steel
                b. **Density**: 7850 kg/m^3
                c. **Poisson's Ratio**: 0.3
                d. **Damping**: 0.00
                e. **Elastic Modulus**: 2.048 kPa
        ii. Click the button and add the soil layers listed in Table 4-4
    c. Navigate to the Section tab ( )
        i. Click icon to add a new cross-section for piles
            1. Select general section in the Add Section window
                a. Enter the following in the Circular Section window:
                    i. **Label**: pileSection
                    ii. **Moment of inertia**: 0.0001086 m^4
                    iii. **Area**: 0.0138 m^2
                    iv. **Effective Diameter**: 0.346 m
                b. Press "OK" to accept and close the window
    d. Navigate to the Soil Layer tab ( )
        i. Create the layer configuration tabulated in Table 4-4
    e. Navigate to the Pile Layout tab ( )
        i. Click the button to create pile layout from template
            1. In the new window, enter the following:
                a. **(Horizontal) Quantity**: 5
                b. **(Horizontal) Spacing**: 3.0 (m)
                c. **(Vertical) Quantity**: 5
                d. **(Vertical) Spacing**: 3.0 (m)
                e. **Material**: steel
                f. **Section**: pileSection
                g. **Length**: 30.0 (m)
            2. Click "OK" to create pile layout
    f. Navigate to the Superstructure tab and enable the Superstructure option.
        i. Enter the following entries
            1. **K_x**: 5640 kN/m

2. **Mass**: 35 Mg
3. **Height**: 1 m
4. **F_x**: 100 kN
5. **F_z**: 100 kN

g. Navigate to the Options tab ( )
   i. Enter the following:
      1. Frequency Increment: 0.0
      2. Number of Frequencies: 30
      3. Pile Radius Interaction Factor: 1000

h. Click "OK" to close Project Data window. The layout shown in Figure 4-18 should appear in the 3D view area

11. Save the project by clicking button on the main toolbar
    a. Locate a desired folder and specify filename to save the file to local drive
12. Click the button on the main toolbar to start the analysis

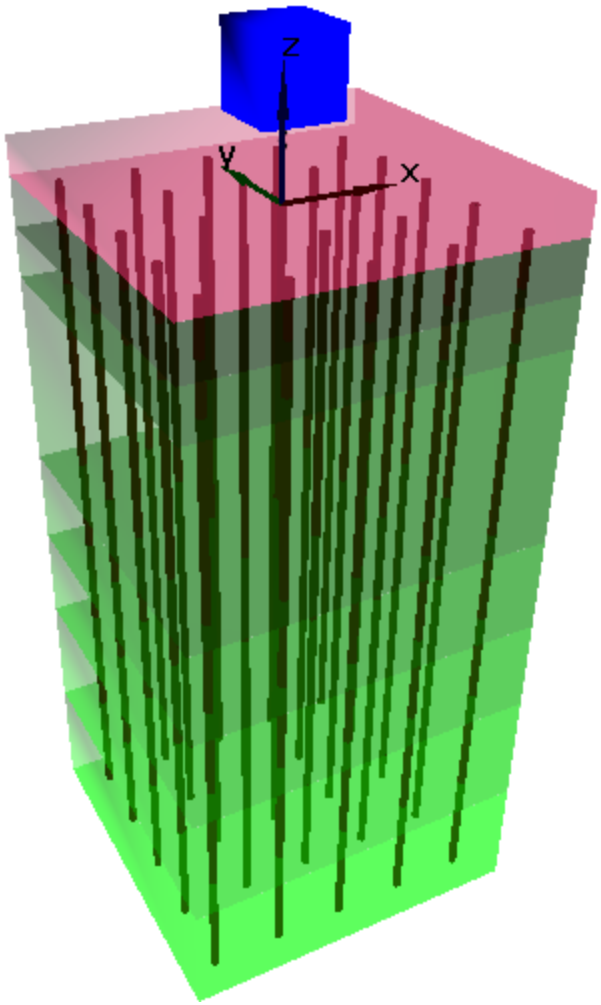
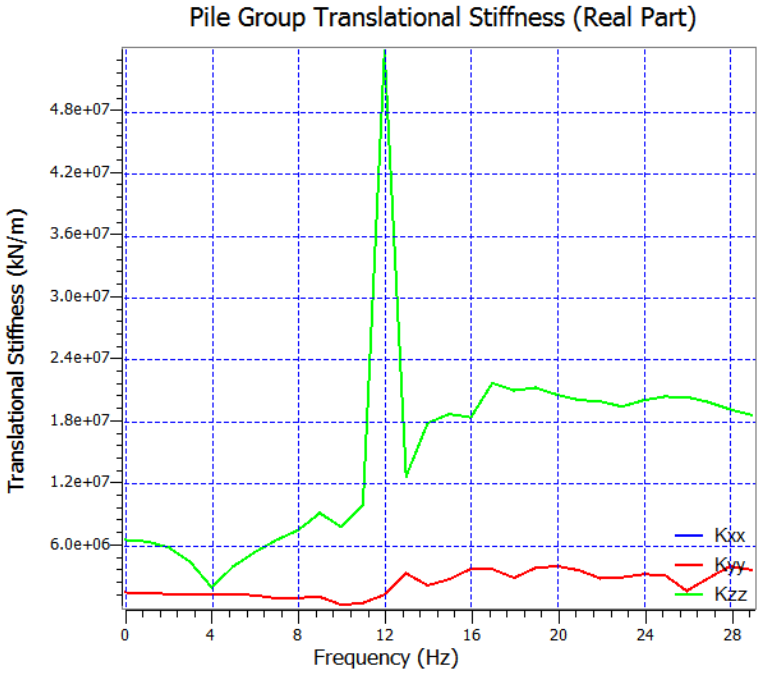
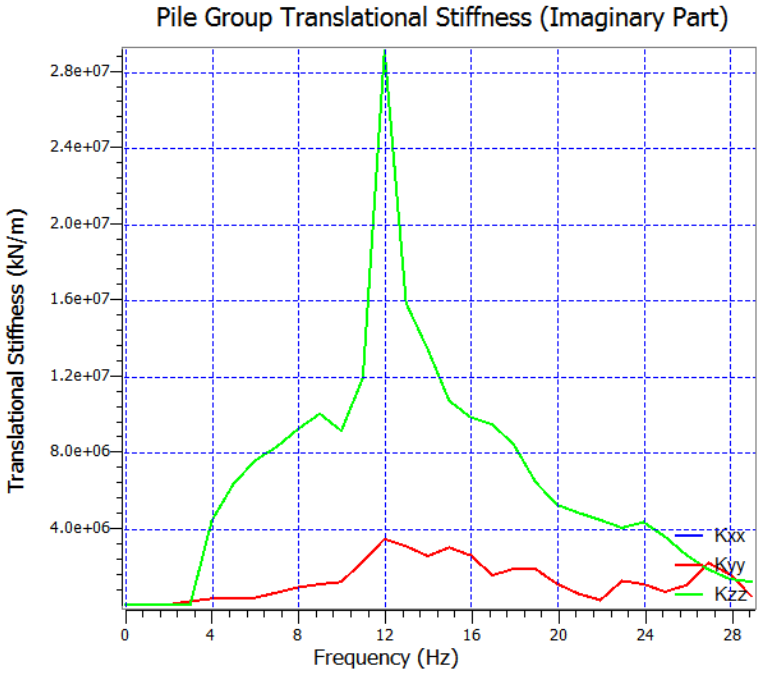
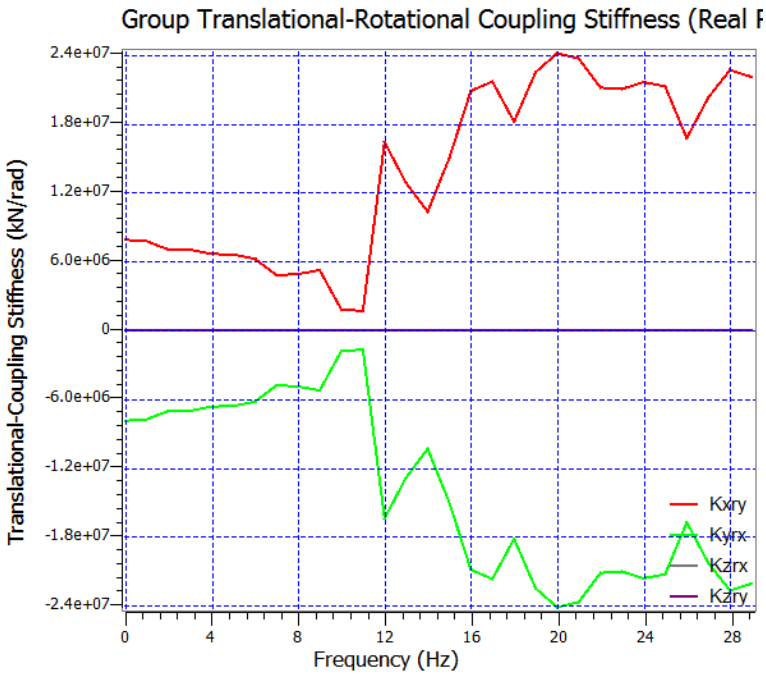


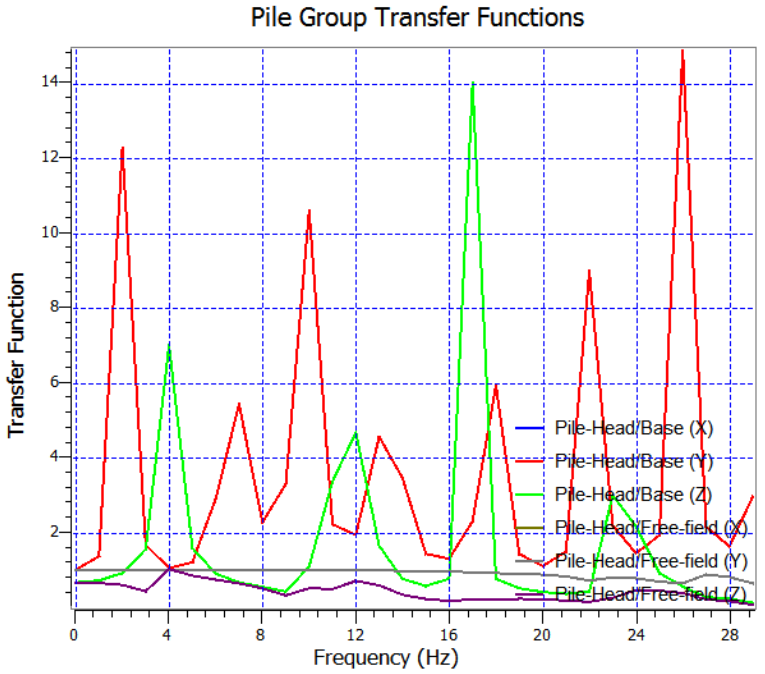
Figure 4-18 Isometric view of Example 5

4.5.2 Results


Pile Group Translational Stiffness (Real Part)
Translational Stiffness (kN/m)
4.8e+07
4.2e+07
3.6e+07
3.0e+07
2.4e+07
1.8e+07
1.2e+07
6.0e+06
0
4
8
12
16
20
24
28
Frequency (Hz)
Kxx
Kyy
Kzz


Pile Group Translational Stiffness (Imaginary Part)
Translational Stiffness (kN/m)
2.8e+07
2.4e+07
2.0e+07
1.6e+07
1.2e+07
8.0e+06
4.0e+06
0
4
8
12
16
20
24
28
Frequency (Hz)
Kxx
Kyy
Kzz


Group Translational-Rotational Coupling Stiffness (Real F
Translational-Coupling Stiffness (kN/rad)
2.4e+07
1.8e+07
1.2e+07
6.0e+06
0
-6.0e+06
-1.2e+07
-1.8e+07
-2.4e+07
0
4
8
12
16
20
24
28
Frequency (Hz)
Kxry
Kyrx
Kzrx
Kzry


Pile Group Transfer Functions
Transfer Function
14
12
10
8
6
4
2
0
4
8
12
16
20
24
28
Frequency (Hz)
Pile-Head/Base (X)
Pile-Head/Base (Y)
Pile-Head/Base (Z)
Pile-Head/Free-field (X)
Pile-Head/Free-field (Y)
Pile-Head/Free-field (Z)

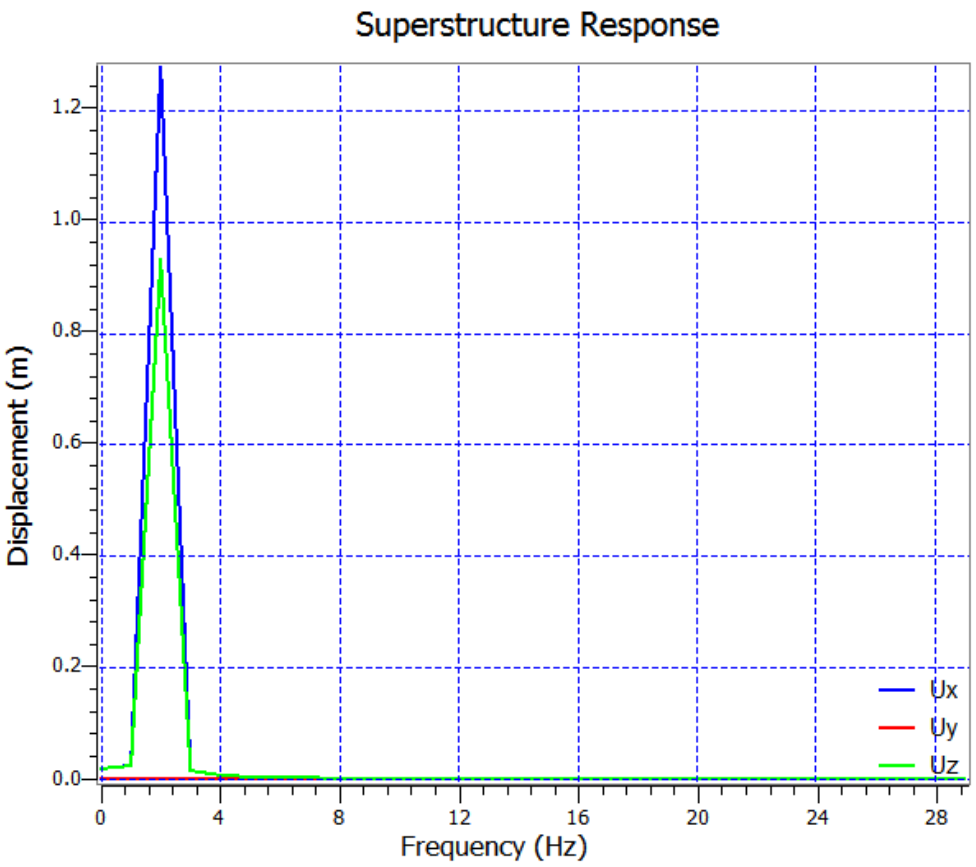


Figure 4-19 Superstructure response in Example 5

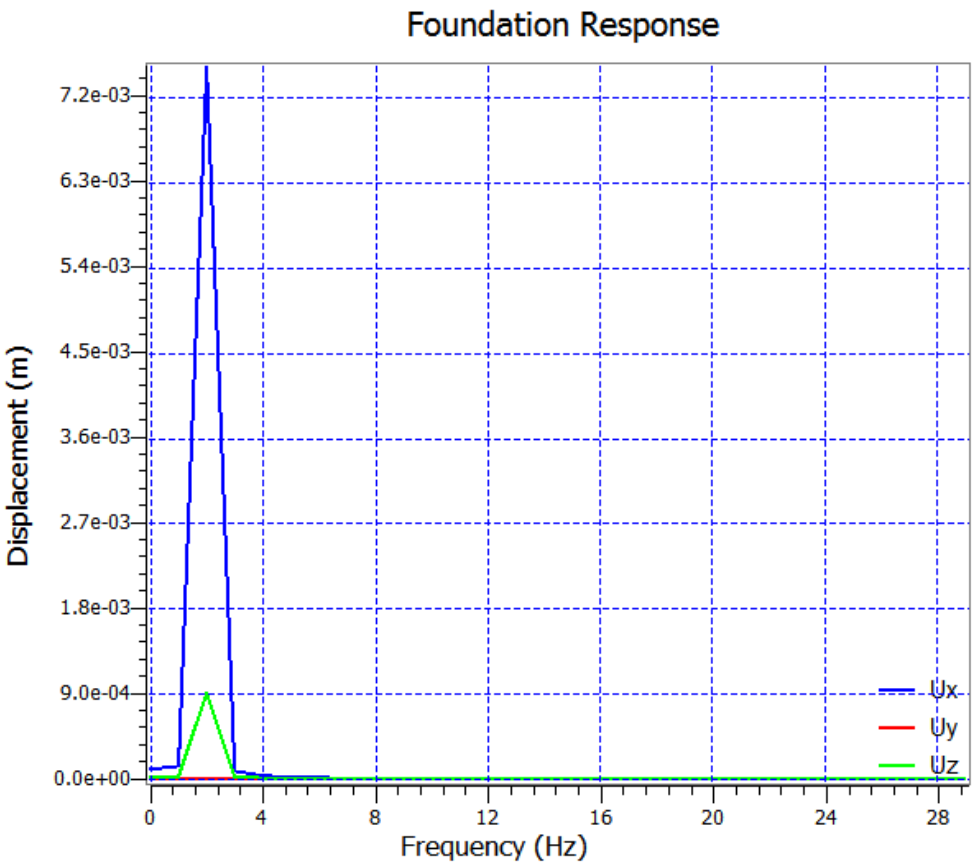


Figure 4-20 Foudnation response in Example 5

4.6 Example 6

We reconsider Example 5 in Section 4.5, but this time we wish to consider the response of the superstructure due to specified ground motion at the bed-rock.

4.6.1 Creating Dynapile Model

1. Start Dynapile
2. Open Example 5
3. Start entering project data by clicking the Project Data icon () from the main toolbar and make the following changes
    a. Project Information
        i. Change Project Label to "Example 6" and leave units as default
    b. Navigate to the Superstructure tab and make the following changes:
        i. F_x: 0 kN
        ii. F_z: 0 kN
    c. Navigate to the Motion tab
        i. Enable ground acceleration in the X-direction
        ii. Select Bedrock for 'Motion Location'
        iii. Click 'Import from File' button and select a ground motion time-record. For this example, we will use the `OLE_CHICHI_CHY029E.dat` file that is available in the `Examples/example6` directory. Specify the following options in the import dialog window (Figure 4-21)
            1. Enter '3' under 'Start at row' option
            2. Unselect 'Read to end of file' and enter '4099' under 'End at row'
            3. Unselect 'Collapse all columns' and enter '2' under 'Read column'
            4. Select 'Overwrite existing time increment' and select '0.01 s' as the time-increment
            5. Select 'cm/s^2' as the imported units

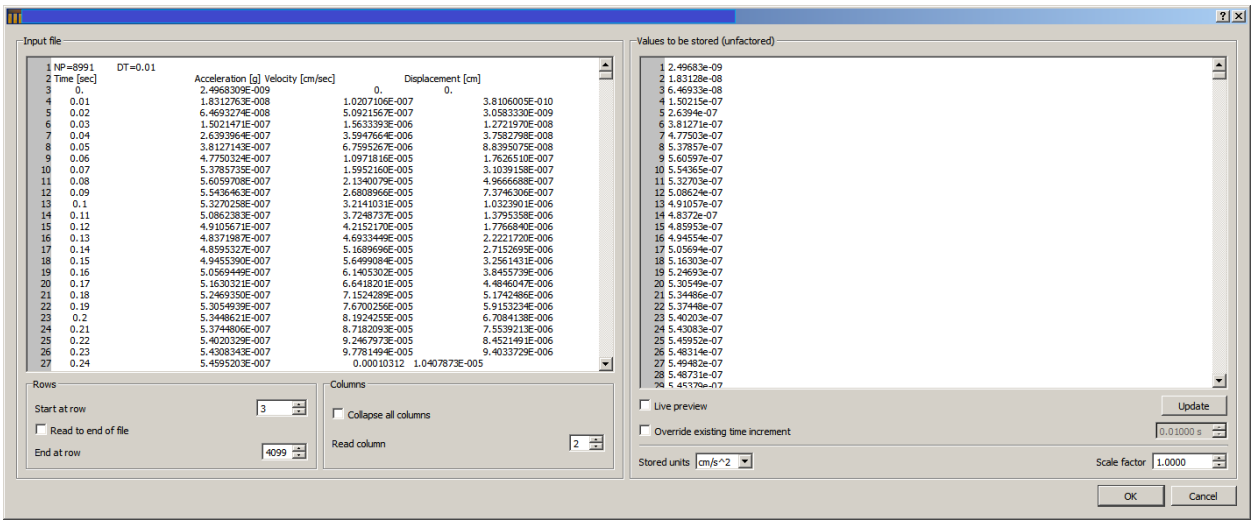


Figure 4-21 Selected options for importing acceleration data

6. Click 'OK' to import the ground acceleration data to project (Figure 4-22

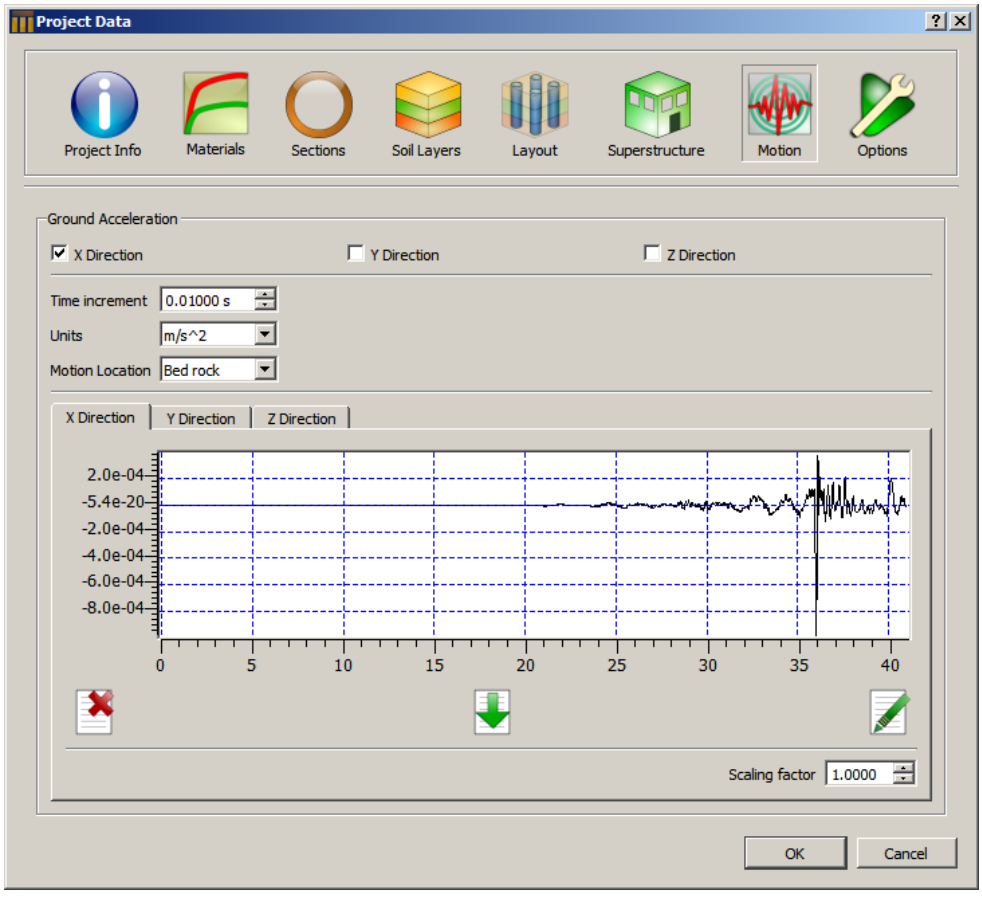
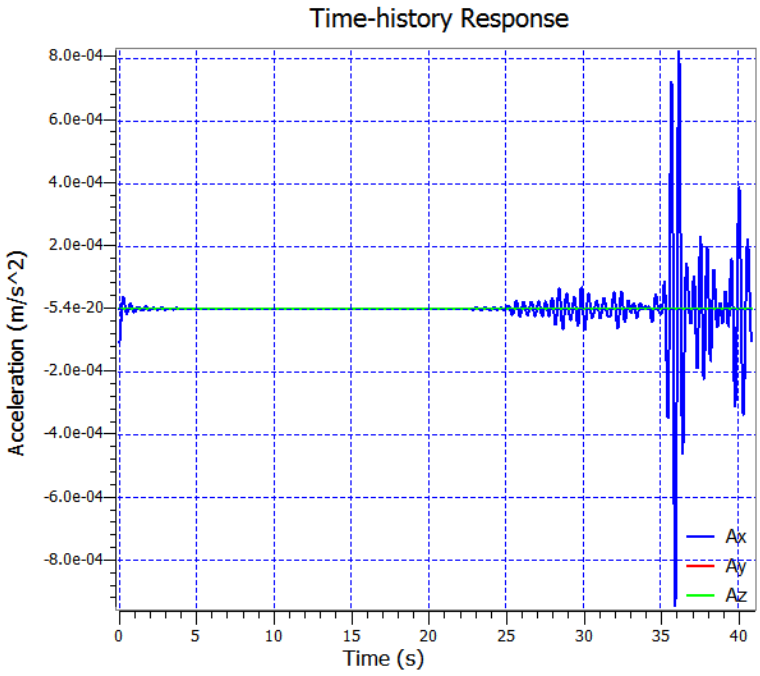


Figure 4-22 Imported ground acceleration data

d. Click OK to close the Project Data dialog

4. Click ‘Save As’ and save the project as ‘example6’
5. Click run to start the analysis

4.6.2 Results



CHAPTER 5. References

Fan, K., Gazetas, G., Kaynia, A., Kausel, E., & Ahmad, S. (1991). Kinematic seismic response of single piles and pile groups. *J. geotech. eng., 117*(12).

Gazetas, G., Fan, K., Tazoh, T., Shimizu, K., Kavvadas, M., & Makris, N. (1992). Seismic pile-group -- structure interaction. In G. Gazetas, K. Fan, T. Tazoh, K. Shimizu, M. Kavvadas, N. Makris, & S. Prakash (Ed.), *Piles under dynamic loads* (pp. 56-93). New York, New York: American Society of Civil Engineers.

Kaynia, A. M., & Kausel, E. (1982). *Dynamic stiffness and seismic response of pile groups.* Massachusetts: Massachusetts Institute of Technology Cambridge.

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