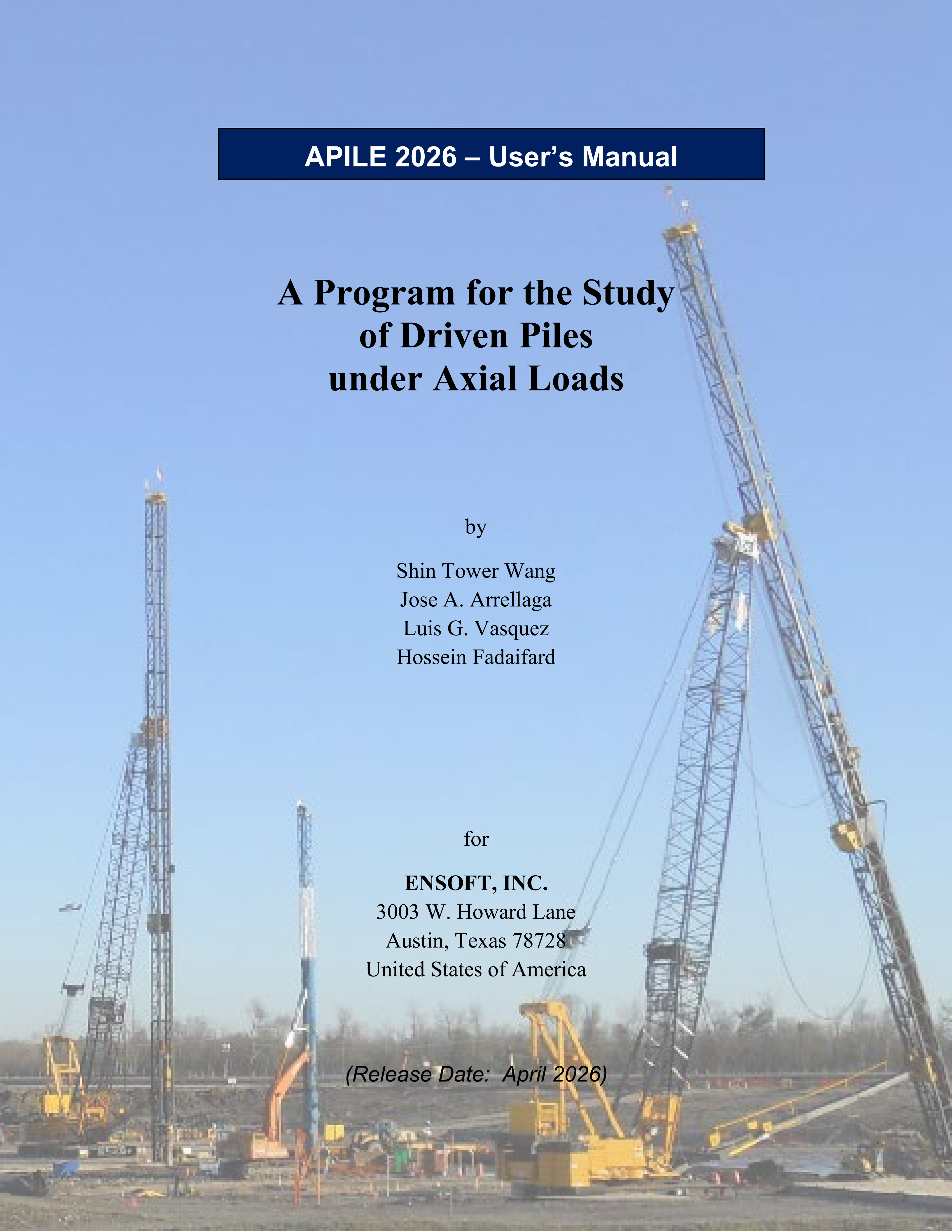


APILE 2026 – User's Manual

A Program for the Study of Driven Piles under Axial Loads

by

Shin Tower Wang
Jose A. Arrellaga
Luis G. Vasquez
Hossein Fadaifard

for

ENSOFT, INC.
3003 W. Howard Lane
Austin, Texas 78728
United States of America

(Release Date: April 2026)

SOFTWARE LICENSE AGREEMENT & DISCLAIMER

IMPORTANT NOTICE: *Please carefully read the terms of the license agreement and disclaimer at the end of this book. Usage of this software signifies acceptance with those terms.*

COPYRIGHT, WARRANTY & DISCLAIMER

Although the program has been used with apparent success in many analyses, new information is being developed and new or updated versions may be written from time to time. All users are requested to inform ENSOFT, INC. immediately of any possible errors that are found in the coding of our software. As modifications, updates, or new versions are produced, notices will be sent to subscribed users that keep their address current on ENSOFT, INC.'s files.

No warranty, expressed or implied, is offered as to the accuracy of results from ENSOFT, INC.'s software products. The software products should not be used for design unless caution is exercised in interpreting the results and independent calculations are available to verify the general correctness of the results. Users are assumed to be knowledgeable of the information in the printed documentation that are distributed with the digital media. Users are assumed to recognize that the input parameters, eg., soil and rock properties, shaft length, diameter of rock socket, and many others, can have a significant effect on the solution and must be chosen carefully. Users should have a thorough understanding of the relevant theoretical criteria (appropriate references are suggested in the software documentation).

Table of Contents

List of Figures

List of Tables

CHAPTER 1. Introduction

1.1 General Description

The interaction among the piles and the surrounding soil are complex. Pile driving generally alters the character of the soil and intense strains are set up locally near the piles. The load transfer mechanics (side friction and tip resistance from soils) vary with many factors such as the types of soils, the installation method, the pile material, the pile geometry and others. Because of the inherent complexities of pile behavior, it is necessary to use practical semi-empirical methods of design, and to focus attention on significant factors rather than minor or peripheral details. APILE utilizes two related codes to provide the user with information on the behavior of driven piles under axial loading.

The first of these codes makes use of four different sets of established empirical methods for computing the axial capacity of piles as a function of depth. Those methods include: API method (established by American Petroleum Institute), USACE method (published by U.S. Army Corps of Engineers), FHWA method (published by U.S. Federal Highway Administration), and Lambda method (with the effective-stress contribution). Most of the semi-empirical design methods for prediction of axial capacity of piles require internal friction angles (ϕ) for calculating the side friction in sand layers, and the undrained cohesive strength for calculating the side friction in clay layers. The design engineers should gather all the necessary soil parameters based on the geotechnical investigation report prepared for the application site. The subsurface can be divided into sub-layers based on the soil properties (cohesive or non-cohesive) with the associated layer depth and soil parameters.

Recently, the cone penetration test (CPT) has been widely used in subsurface explorations worldwide. Four empirical methods for prediction of the axial capacity of driven piles based on CPT data have been recommended by the offshore industry and are included in APILE Offshore Version. Those four coned-based empirical methods include: NGI-99 method (published by Norwegian Geotechnical Institute), ICP/MTD method (published by Richard Jardine et al from Imperial College in London in 2005), Fugro method (published by Fugro in 2005), and UWA method (published by the University of Western Australia in 2005).

The second of the two codes employ *t-z* curves to compute the load versus settlement of the pile at the greatest length that is specified in the input. If these results fail to satisfy the requirements of a particular application, the user may refer to the results of load versus depth and select a revised length. Each of these codes is described in detail in the following sections and example computations are also presented.

APILE is a special-purpose program based on rational procedures for analyzing a driven pile under axial loading. The program computes settlement of the top and base of the driven pile as a function of axial loading, along with the distribution of axial load along the length of the pile.

1.2 Features of the Program

Program APILE has the following features that are designed to enhance the ability of the engineer to obtain usable results.

1. Unit load transfer in side resistance (skin friction) and end bearing are computed, along with the capacity of a pile to sustain axial loading.
2. Results from four different analytical methods are provided in the basic version for comparison and/or code compliance. Additional results from four cone-based analytical methods are available in the special Offshore version of APILE.

3. The APILE program makes internal computations of the development of a plug in an open-ended pile as it is driven into the ground.
4. At the user's discretion, the values of unit load transfer computed by the program or those provided by the user (externally from APILE) can be used to estimate load versus settlement.
5. Graphical output of load-distribution curves, load-settlement curves, and bearing capacity as a function of depth are provided.
6. APILE has options for computation of pile capacity under tension (uplift loads) with considerations for buoyancy effects where necessary.
7. Option for applying reduction factors for each soil layer, such as strength reduction during pile driving, pile-group reduction factor, or LRFD strength reduction factor.
8. The cone penetration test (CPT) has been widely used in subsurface explorations worldwide. The latest APILE has an option to read a CPT data via an external file, and then convert the CPT data to equivalent SPT-N values and equivalent cohesive strength internally for the user.

1.3 History of Development

1.3.1 APILE1 (1987)

With the advent of wide-spread availability of personal computers, the founder of ENSOFT, Inc., had a vision to improve the engineering capability for analysis and design of deep foundations by providing useful software tools. The development of APILE1 was completed under the direction of Dr. Lymon C. Reese and was first commercially distributed in 1987. While based on an earlier mainframe program, APILE1 was developed to use an interactive input method.

1.3.2 APILE Plus v1 (1989)

APILE Plus was released in 1989. This version incorporated the program APILE2 (Portion of TZPILE), which was developed as a subroutine for computing the load-vs-settlement at the pile head based on the *t-z* curve method. Therefore, Program APILE Plus is a complete program for analyzing the behavior of driven piles under axial loading. It not only calculates the ultimate skin friction and tip resistance at each depth, but also computes the load-vs.-settlement relationship at the pile head. In addition, a menu-based DOS interface was introduced.

1.3.3 APILE Plus v2 (1995)

The success of Windows 3.1 from Microsoft, Inc., as the dominant platform for personal computers pushed software development to adopt a standard, graphical-user interface. This version of APILE Plus utilized Windows-based pre- and post-processors, while retaining the original computing engine from Version 1.

1.3.4 APILE Plus v3 (1998)

This version of APILE Plus was a complete recoding of both the pre-and post-processing programs running under Windows 95/NT and the computing engine. The graphical-user interface was recoded to provide a more intuitive process for data input and to enhance the graphical capabilities.

In addition, in the technical side, Version3 includes two new methods for computing the axial capacity of driven piles. One is the FHWA method recommended by the Federal Highway and Works Administration (FHWA). The other one is the USACE method recommended by the US Army Corps of Engineers (USACE).

The program presents the computed results for all four different methods and the user can make a selection based on the site condition and the application.

1.3.5 APILE Plus v4 (2004)

This version of APILE Plus is upgraded for the requirement under Windows 2000/XP and the later system. The most recent files of the input data will be listed under File Menu for users to load or retrieve quickly and conveniently.

APILE Plus Version 4 now has an option to generate compatible data file used by GRLWEAP for pile driving analyses. The program also provides the user with an option to generate *t-z* curves at depths specified by the user. Furthermore, the program prints and plots the unit side friction and accumulated side friction as a function of depth for comparison.

1.3.6 APILE Plus v5 (2007)

APILE Plus Version 5 added an option for computation of pile capacity under tension (uplift loads). Another new feature in Version 5 is to allow the user entering the variation of cross-sectional area as a function of depth. This feature is particularly useful for tapered piles or long pipe piles with sections using different inside diameters (ID). Recently the cone penetration test (CPT) has been widely used in subsurface explorations worldwide. APILE Plus Version 5 now has an option to read the CPT data via an external file, and then convert the CPT data to equivalent SPT-N values and equivalent cohesive strength internally for the user.

Two empirical methods for prediction of the axial capacity of driven piles based on the CPT data have been evaluated by API. The first one is NGI-99 method published by Norwegian Geotechnical Institute and the other one is MTD method published by Richard Jardine et al (2005) from Imperial College in London. Several uncommon soil parameters particularly are required for MTD method, which may not be of interest to driven piles installed onshore. APILE Plus provides the user with the basic version and an offshore version. The difference between these two versions is that the offshore version includes the predicted pile capacity based on NGI-99 and MTD methods for offshore applications.

1.3.7 APILE 2014 (v6)

Program APILE uses the year number as the version sequence starting in 2014, while keeping the second number of the release equal to the input data format (input data format 6). The major improvements in v2014.6 were a complete rewrite for a more intuitive interface and to provide options for specifying the reduction factors on side friction and tip resistance for each soil/rock layer if the user selects the LRFD method.

The new release also introduces the ability to compute elastic shortening for pile portions above ground level (either in air or water), which is useful for many offshore applications.

Two more cone-based empirical methods, including Fugro method (published by Fugro in 2005), and UWA method (published by the University of Western Australia in 2005), were added into the APILE 2014 Offshore version.

The new program allows the user to change the line width and font sizes in the generated plots. In addition, v2014 introduces compatibility to Windows 8 and 8.1. The program text book was updated and released in separate User's and Technical Manuals, both improved plus released electronically in protected PDF format.

1.3.8 APILE 2015 (v7)

Improvements in v2015 (data format 7) included an extended set of user-selectable parameters for the FHWA criteria (users can now select a desired adhesion factor in each CLAY layer), introduced a SILT criteria for USACE computations, improved computational options for SAND criteria, added a new feature for export of any output plot into a new Microsoft Excel spreadsheet (created by APILE) to help users in presentation graphics for reports and also added new sets of speed buttons.

1.3.9 APILE 2018 (v8)

This new full version introduces data format 8 with four new main features: i) the ability to analyze batter piles (installed at an angle from vertical), ii) new 3D graphics for display of the pile, soils and load transfers, iii) ability to specify the use of long-pile factors for USACE method, and iv) introduction of the FHWA 2016 method of neutral plane method for estimations of downdrag forces. All new features are described in more details in associated sections of the new User's and Technical Manuals.

1.3.10 APILE 2019 (v9)

The main new feature in v2019 is the ability for users to modify certain shapes of the internal *t-z* curves produced by the program. This new feature ensures compliance with guidelines set since the API 2A-WSD from November 2014. New features are described in more details in associated sections of the new User's and Technical Manuals.

1.3.11 APILE 2023 (v10)

The most important improvements implemented in APILE v2023 (equivalent to APILE v10 when using the old release numbering) are included in the list below.

1. Introducing a new feature to import and analyze files from any cone penetrometer (CPT) to create soil layering and properties for inputting into APILE for capacity estimations:
   - Users can interactively import any CPT data in any format and in any units.
   - Users can select Sand or Clay layers quickly based on interpreted Cohesion and Friction Angles.
   - CPT can be quickly evaluated and interactive plot helps users for the selection of desired mechanical parameters for top and bottom of each layer.
   - Interpreted data can be exported to APILE and later edited using CPT screen and/or using the standard APILE dialog boxes.
2. Background programming has been improved for the data entry process.
3. Users can now enter data for soil layers and pile length in Elevations or in Depths (distance from grade) and can switch between them as needed for any part of the data-entry process.
4. Output graphics will display program results in the selected Elevations or Depths.

5. A new feature allows users to specify the depths above/below pile tip that should be used to average the computations of end bearing.
6. Users can specify *t-z* multipliers for any depth along the pile.
7. Users can specify *Q-w* multipliers for the pile tip.
8. APILE v2023 has a feature for exporting a data file with definition of soil transfers for drivability analyses with the separate GRLWeap 14 software.
9. There is a new viewer of output plots where users can quickly observe results in graphical form and/or produce/export of basic plots (more detailed formatting of output plots are recommended with Exporting to Excel spreadsheet).
10. Users are able to open the new v2023 Technical Manual in standard PDF file format.
11. A new reporting tool introduces a pre-formatted Microsoft Word file that contains input data of the model along with a selection of output tables and charts.

1.3.12 APILE 2025 (v11)

New features and enhancements in APILE v2025 are as follows:

1. Added the Tomlinson (1979) Table D for computations of α (Adhesion Factor) in clays when using the FHWA Method for Axial Pile Capacity. This new feature expands the selections of FHWA Adhesion Factors with the addition of softer clays than the ones included with the previous APILE.
2. For the APILE Offshore Version, added two new CPT-based methods for Axial Pile Capacity: (i) the Unified CPT-Based (UCPT) Method and (ii) the Alm & Hamre (A&H) Method.
3. The new Alm & Hamre (A&H) Method for APILE Offshore Version, allows users to specify any initial pile side friction (fsi factor) that should be used for the Top and Bottom of any Clay Layer.
4. Added several noticeable improvements:
    - Improved the 'Data > Soil Layers' dialog:
      - Rows can be re-arranged with 'click-and-drag' mouse functionality
      - Any of the cells can be 'copy' and 'pasted' to Clipboard (for 'pasting' into other applications or other cells/soil layers
    - Removed soil layer exit confirmation when layers are not modified.
    - Improved error handling when APILE cannot successfully run a model and terminates without any generated plot data.
    - Replaced the legacy File > Save dialog with a more modern interface.
    - Replaced the Windows Notepad default viewer of output text files with a custom output content viewing application.
    - Added a display of the new custom output content viewing application after successful computation run of all APILE models. The new interface provides quick access to output text data and applicable output graphs.

- Added a speed button for Export Graphs to MS Excel when accessing any plot under the Graphics menu and to the Graphs tab in the new custom output content viewing application.
- Considerably reduced the delay in accessing any of the plots under the Graphics menu.

5. New image in the background canvas of the APILE interface displays features of the working model. Users are now able to double click some of the displayed features to access the corresponding data entries. This new functionality allows for quick and easy access to main data entry screens (such as Soil Layers and Pile Details).
6. A new request for 'username' entry is provided when the program first starts after a fresh software installation. This 'username' can be edited at any time in the 'Help > User Information' menu. The user can enter any line of information to personalize the individual installation of the APILE software, thus identifying the person that ran the analyses.
7. Introduction and management of optional Cloud Subscription Licensing.
8. Released new Technical and User's Manuals.

1.3.13 APILE 2026 (v12)

New features and enhancements in APILE v2026 are as follows:

1. Added a command line interface for running modifying APILE input files and running analyses allowing integration with Microsoft Excel or other scripting languages application.
2. Added a dialog window for running parametric analyses by varying one or more parameters of a soil layer or pile properties.
3. Revamped and improved soil and pile properties dialog windows:
   - Consolidated all soil layer properties in a single window.
   - Explicitly mark optional and auto-computable properties.
4. Improved behavior under tension where buoyancy effect causes negative tip load:
   - Negative effect is applied to all the displacements used for estimation of load settlement curve.
   - Improved interpolation for t-z curves when negative load is applied at the tip.
5. Improved importing CPT data:
   - Propose initial layering when importing CPT data into a blank project.
   - Display interpreted 'sensitivity' from imported CPT data.
6. Improved report generating functionality.
7. Improved tools for generating reports and or processing data:
   - Significantly improved speed for generating Microsoft Word report documents.
   - Added context menu to copy graphs as images or copy underlying data to clipboard.
8. APILE is now built for x64 systems.
9. Added a new utility with the entire selection of HP piles from AISC 16 and from CISD 12 to automate their dimensions and computed values of area and perimeter.
10. Expanded most CPT-based capacity methods with user-specified values of soil sensitivity.

1.4 Organization of APILE Manuals

The documentation provided with the computer program APILE 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 Technical Manual provides information about: the theory of pile behavior under axial loading, the semi-empirical equations for pile-capacity computation, the concept of load-transfer, and load-vs.-settlement of piles in different types of soil strata. The Technical Manual includes other helpful references related to concepts utilized in program APILE.

ENSOFT holds a copyright of both manuals. The manuals are distributed in protected Adobe© PDF file format to licensed users of the APILE program. The content of these files/manuals cannot be copied and/or distributed to others unless specific written approval by ENSOFT.

Both Manuals are installed with the APILE program and accessible via any one of the following three methods: i) from the Windows Start Menu, ii) from the Ensoft tile in Windows 11, 10, 8.1 and 8, or iii) from the Help menu within the APILE 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"; "Ctr+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.sf12d*
- Internet and electronic mail addresses are underlined:
  Send email to support@ensoftinc.com

1.6 Contents of the APILE Package

The standard single-user or local network license sent with APILE consists of the following items:

- One USB Key, similar to Figure 1.1. This is a gray (new version) or black (old version) colored USB-based hardware security key (dongle), with a plastic tag indicating its unique serial number, licensed site (office name and location) and name of licensed software. Each USB Key is programmed with the purchased Ensoft Software. The USB Key for a single-user license can be used on any computer when plugged directly into a working USB port of the computer in use (it cannot be shared over a network). The USB Key for a local network license is plugged on a License Server.

- One USB Memory Stick, similar to Figure 1.2. This is a standard memory stick with either silver (new version) or white (old version) flip casing. This memory stick contains installation programs for all Ensoft Software that were available at the time of shipment. Manuals are installed with each software in electronic form using protected PDF files. The USB Memory Sticks may be discarded or reformatted for other uses. Latest updates of all Ensoft Software are always available at www.ensoftinc.com/downloads

a. New Gray Metal Casing b. Old Black Plastic Casing

Figure 1.1 Sample USB Key for Ensoft Software.

Figure 1.2 Sample USB Memory Stick.

In the optional Cloud Subscription Licensing of APILE v2026 there is no longer any need for a shipment of USB Key or USB Memory Stick since users can download the software and are assigned with the proper authorization that is checked when with access to the internet.

1.7 Default Installation Directories

The directories for installation of program files and for example files are selected by the user during program installation. Default values are provided by the installer and confirmed or changed by the user.

1.7.1 Directory for Main Program Files

Program files are installed by default in the following directory:

Root Drive:\Program Files\Ensoft\Apile2026

In most cases the *Root Drive* is the *c:* drive so the default is:

c:\Program Files\Ensoft\Apile2026

Main program files are the following:

Apile2026.exe is the main Windows-program module (executable/application),

Apile2026.dll is the program engine for direct computations,

User's and Technical Manuals are also included in the main installation directory.

1.7.2 Directory for Example Files

Several modeling examples with input files (files with name/extension of the type *filename.ap12d*) are installed on a separate folder that defaults to:

Root Drive:\Ensoft\Apile2026-Examples

In most cases the *Root Drive* is the *c:* drive so the default is:

c:\Ensoft\Apile2026-Examples

1.8 Hardware Requirements

To use this software, the user needs the following minimum hardware configuration:

- Minimum 256MB of storage space.
- 64-bit Windows 7 or newer operating system (Windows 10 or newer for Cloud Licenses).
- Minimum 128MB of memory.
- USB port, v2 or newer (not necessary for Cloud Licenses).
- Graphics card with OpenGL.
- A mouse or similar pointing device.
- Optional: Any windows-compatible printer.

1.9 Technical Support

Although computer program APILE was designed to be distinguished by its ease of use and by the accompanying User's and Technical Manuals, some users may still have questions. The technical staff at ENSOFT strongly supports all licensed users with questions related to the installation or use of APILE. For instance, we evaluate and troubleshoot when a specific model (input data file) provides some errors or when users have a specific question regarding an apparent discrepancy of results when comparing two different models/scenarios. However, our free services of technical support do not include free training or technical interpretations that would require engineering judgment.

New software purchases include free maintenance service for the first year (included in purchase price). After the first year the user is encouraged to purchase/renew the services for yearly maintenance. The yearly maintenance services include free download of the latest version and free technical support (as explained earlier).

1.9.1 Preferred Methods of Software Support

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

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

Users are strongly encouraged to utilize electronic means of support via email. In all technical support requests via email, please include the following information:

- full software version/release/update (obtained from the Help > About dialog),
- a description of the user's problem or concern,
- attach a copy of the input-data file that is associated with the issue/concern (files with name/extension of the type *filename.ap12d*), and
- name and telephone number of the contact person and of the licensed user (or name and office location of the licensed company site and/or serial number of the USB Key).

Although immediate answers are offered on most technical support requests, please allow up to two business days for a resolution in case of difficulties or schedule conflicts.

Technical help by means of direct calls to our local telephone number, (512) 244-6464, is available, but is limited to the business hours of 9 a.m. to 5 p.m. (US central time zone, UTC −6:00). The current policy of Ensoft is that all telephone calls for software support will be answered free of charge if the user has a valid maintenance contract.

1.9.2 Upgrade Verification and Internet Site

Starting from APILE v2018 the software provides options for the user to check the most recent maintenance release through an internet connection by selecting Help > Check for Updates from within the software. 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 expired, the user can download the latest version from our web server directly (https://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.

1.9.3 Renewal of Program Maintenance

The cost to renew program maintenance will depend on the length of time for which the program maintenance has been expired. There are small price increases with time after expiration. The pricing policy for renewing a program maintenance that has not expired can be found on the Ensoft website at https://www.ensoftinc.com/order_form

1.9.4 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 and Getting Started

2.1 Installation Procedures

Program APILE is distributed with an associated USB Key (hardware key or dongle, see Figure 1.1). The USB 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 License Manager/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.

Users with standard single-user licenses can check the following link to a PDF with Installation Notes:
https://www.ensoftinc.com/doc/Ensoft_Single-User_License_Installation_Booklet.pdf

Users with local network licenses can check the following link to a PDF with Network Installation Notes:
https://www.ensoftinc.com/doc/Ensoft_Network_License_Installation_Booklet.pdf

2.1.1 Installation of Single-User Version

This version of APILE has been tested to be compatible with the following versions of the Microsoft Windows® operating systems: Windows 10 and 11 in 64-bit releases.

The following guidelines are recommended during the installation process of APILE for single-user licenses.

1. Plug the supplied USB Key (Figure 1.1) into one of the available and working USB ports in your computer. The USB Key is plug-and-play compatible so the operating system will recognize the USB Key automatically and a small but solid green light should appear at the end of the USB Key (a flickering green light or no light may indicate a faulty port, or 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. You will notice a screen similar to the one in Figure 2.1.
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 Apile 2026 icon and then click on the Install Standard button to start the installation of APILE.
5. The user should read the license agreement shown in Figure 2.2. Users can review the License Agreement online in the following link:

   https://www.ensoftinc.com/doc/Ensoft%20License%20and%20Disclaimer.pdf

   The installer will place the same file (*Ensoft License and Disclaimer.pdf)* in the installation directory. Please click Yes if you agree and would like to proceed.
6. The installer also asks the user to select the type of APILE license that was purchased (see Figure 2.3). Most users will select the default APILE Standard Version. Please change to APILE

Offshore Version if your company purchased the APILE version with additional features (CPT-based methods, commonly used in marine/offshore structures).

7. Select Single-User License in Figure 2.4 then click Next. For network installations please contact Ensoft support (support@ensoftinc.com).

8. The user will be provided with an option to select a drive and directory for the installation of example files (see Figure 2.5). Default installation directory is the following:

   (Root Drive):\Ensoft\Apile2026-Examples

9. The user will also be asked to select a drive and directory for the program installation (see Figure 2.6). Default installation directory is the following:

   (Root Drive):\Program Files\Ensoft\Apile2026

   If the desired directory does not exist, the installation program will automatically create a new directory in the chosen hard drive.

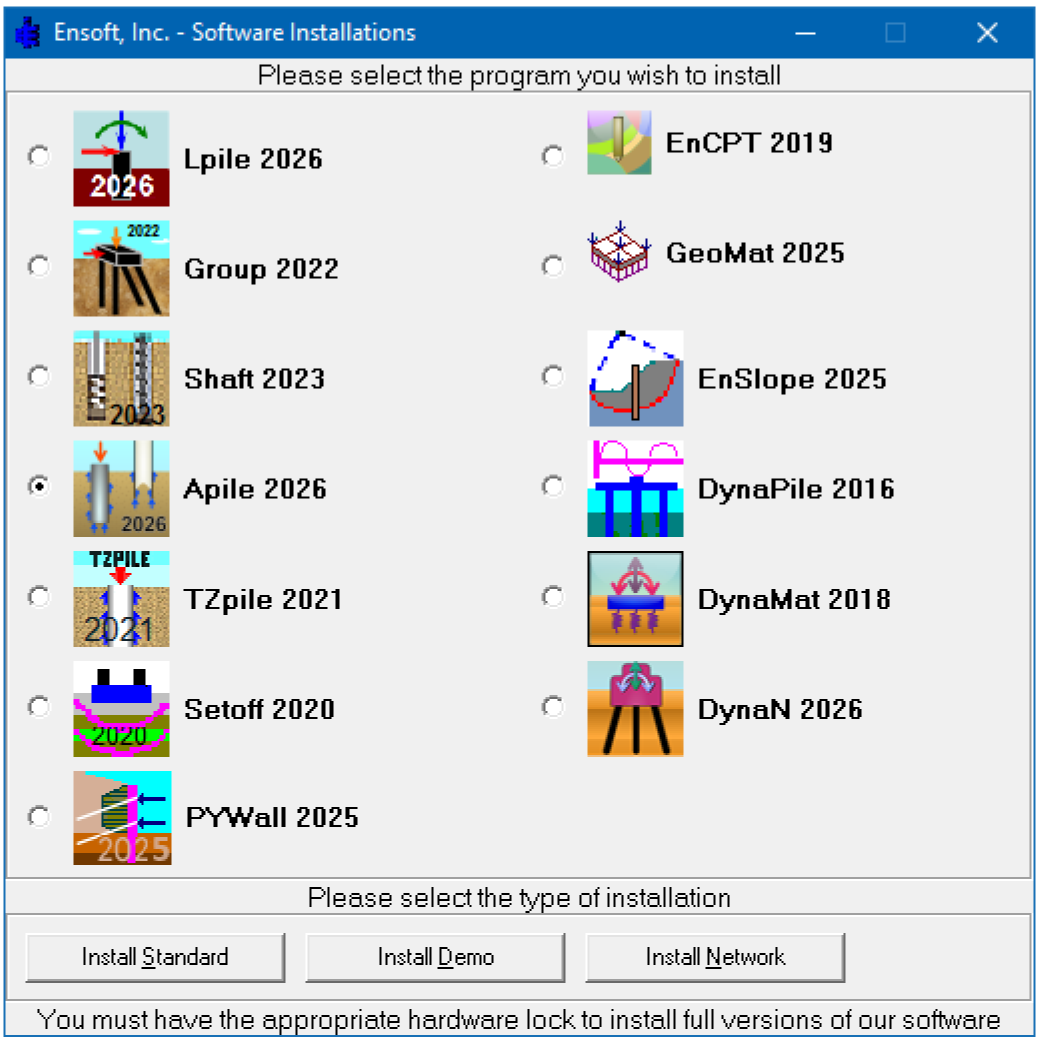


Figure 2.1 Main Installation Screen for ENSOFT Software (may change with time)

10. During the installation the user will be asked to set the file extension association for opening APILE v2026 input data files (see Figure 2.7). If the user agrees (leaves the default check mark) then

double clicking (or running) any input data file with extensions of the type *filename.ap12d* will start the installed APILE v2026 software.

11. The user will be prompted to confirm the shortcut directory name that will be created in the Windows Start Menu (See Figure 2.8). The default is *Start Menu/Programs/Ensoft/Apile2026*. Windows 11, 10 and 8 will automatically create an Ensoft tile with the same shortcuts.

After the installation is finished, it is usually not necessary to reboot Windows for the program to run. The user may run the program by selecting APILE v2026 from the standard links installed in the Microsoft Windows® Start Menu: Start Menu > All Programs > Ensoft > Apile2026

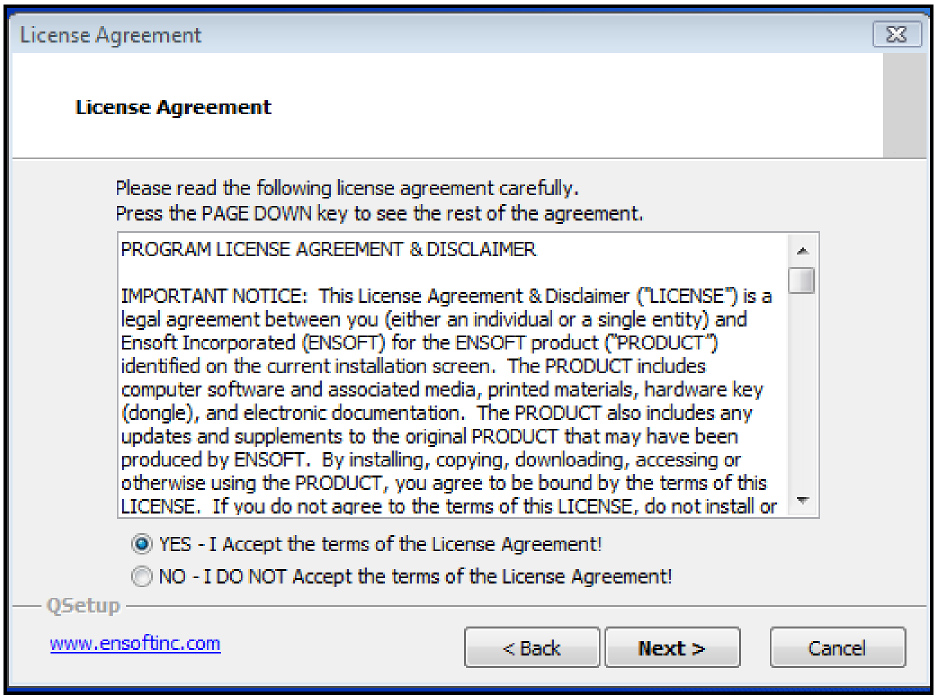


Figure 2.2 Installation screen with License Agreement (may change with time)

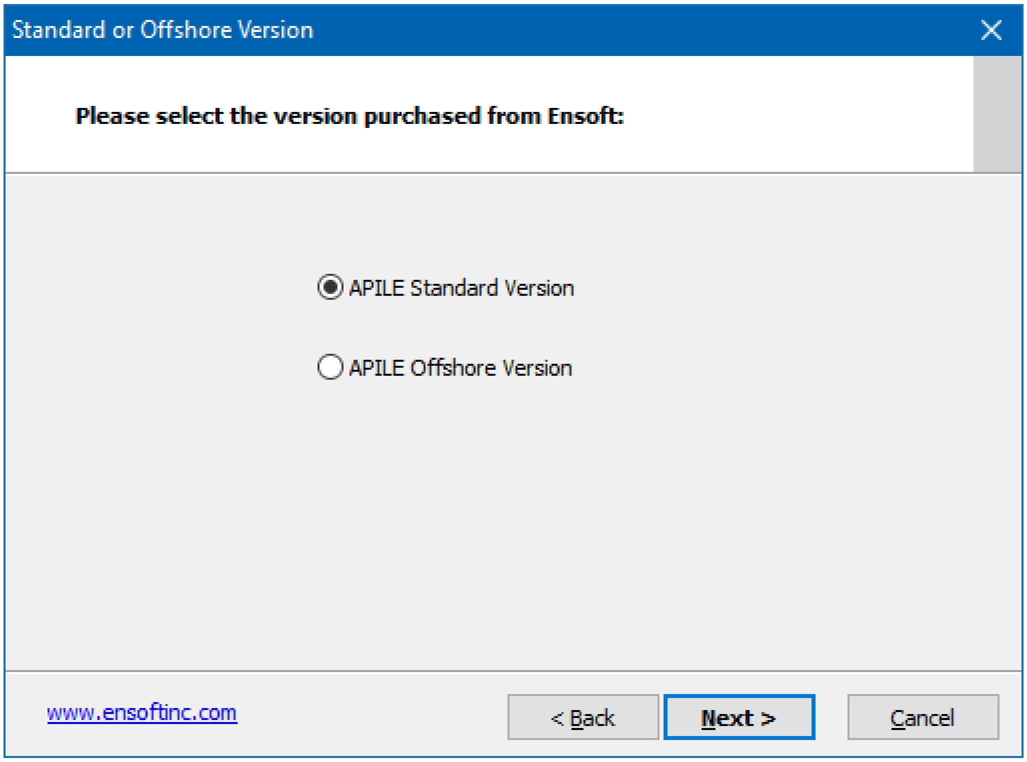


Figure 2.3 Selection of APILE Standard (default) or Offshore Version.

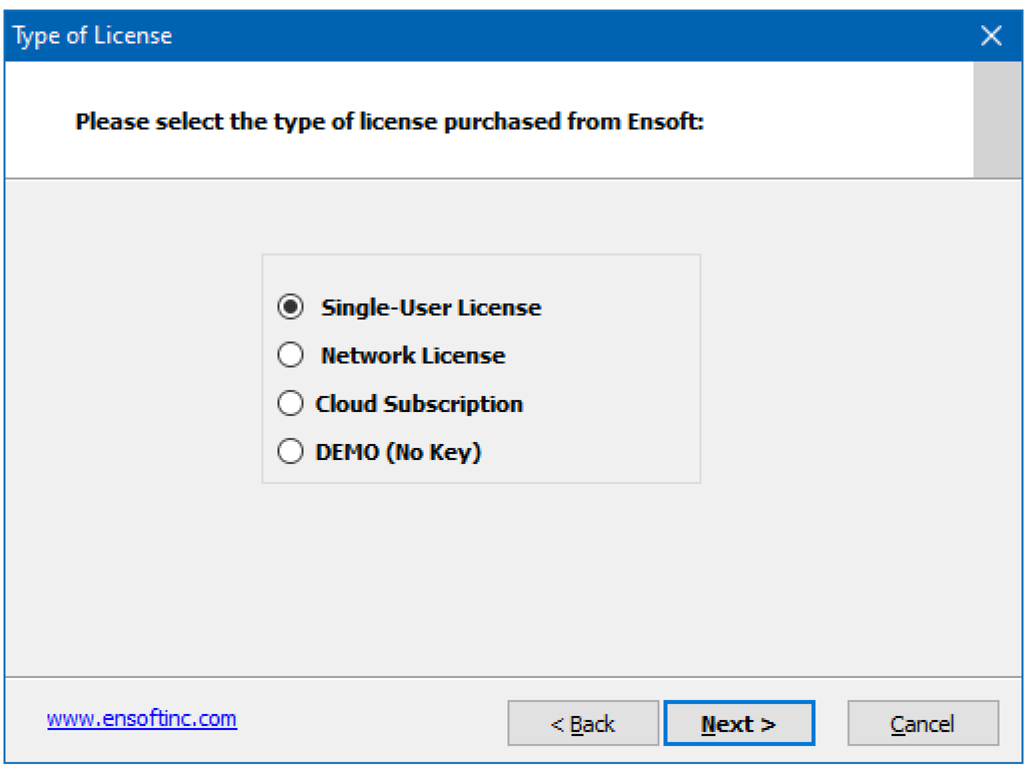


Figure 2.4 Selection of Single-User License (may change with time)

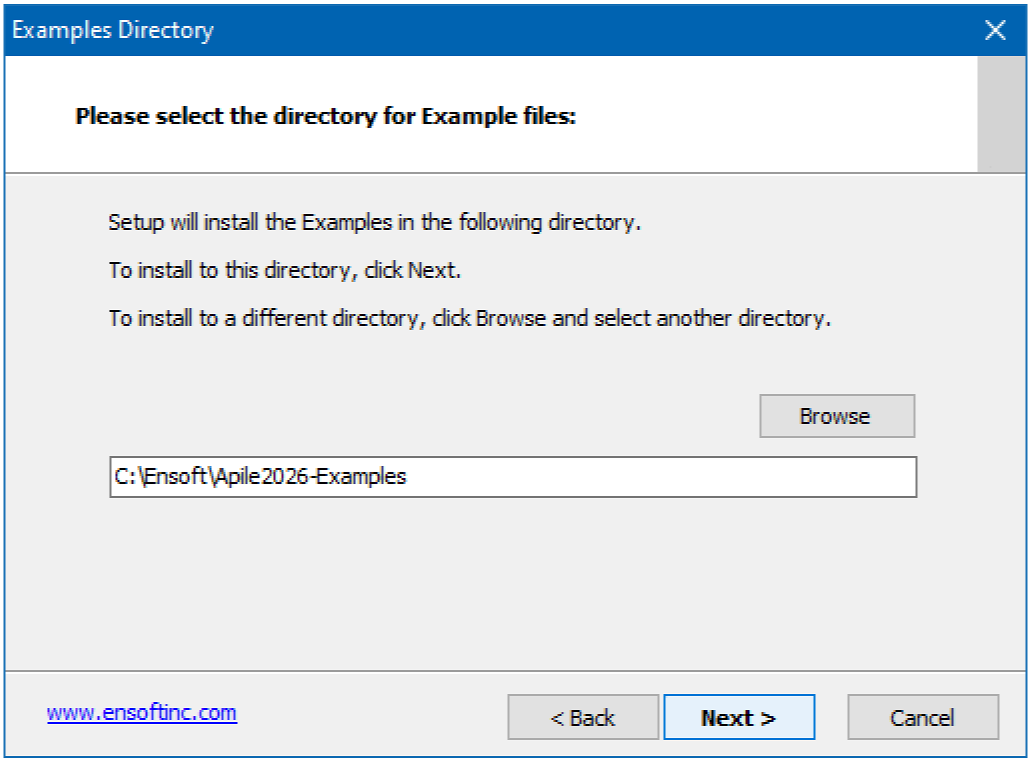


Figure 2.5 Default Installation Directory for Example Files (may change with time)

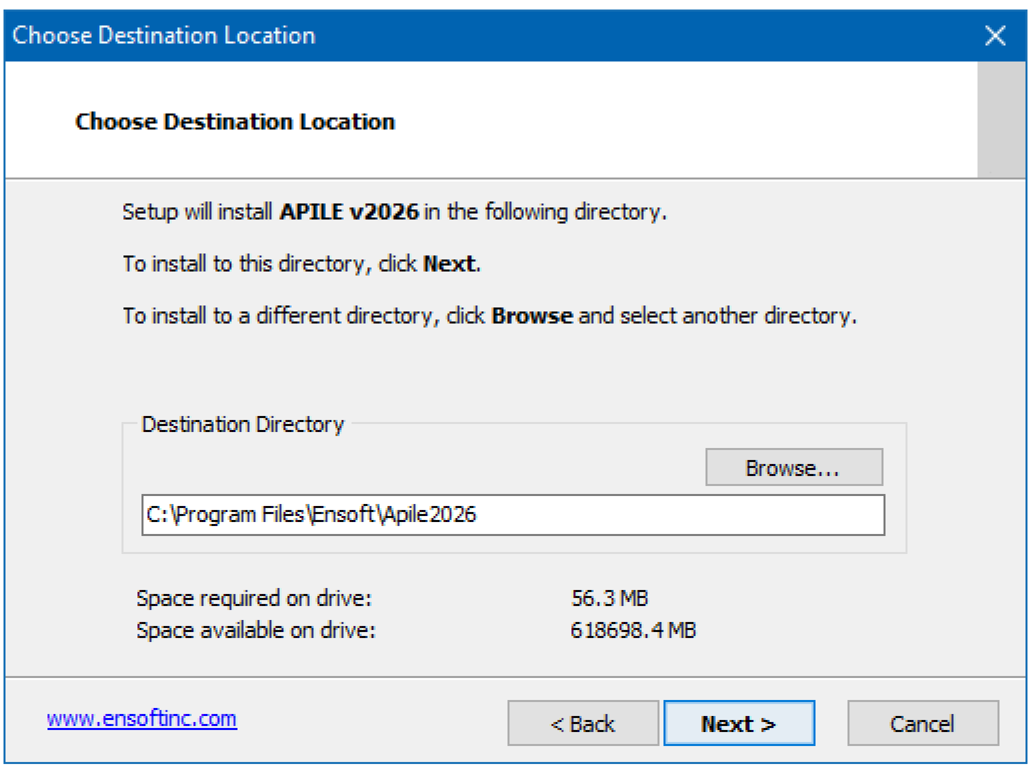


Figure 2.6 Default Installation Directory for Program Files (may change with time)

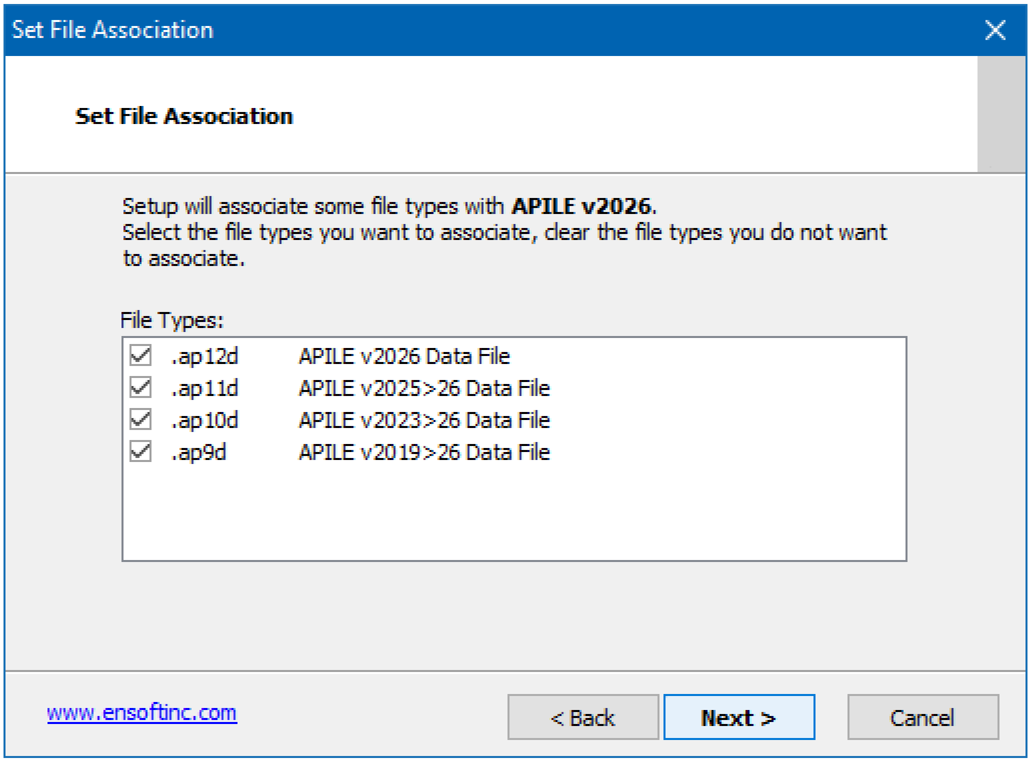


Figure 2.7 File Extension Association for APILE 2025 Data Files (may change with time)

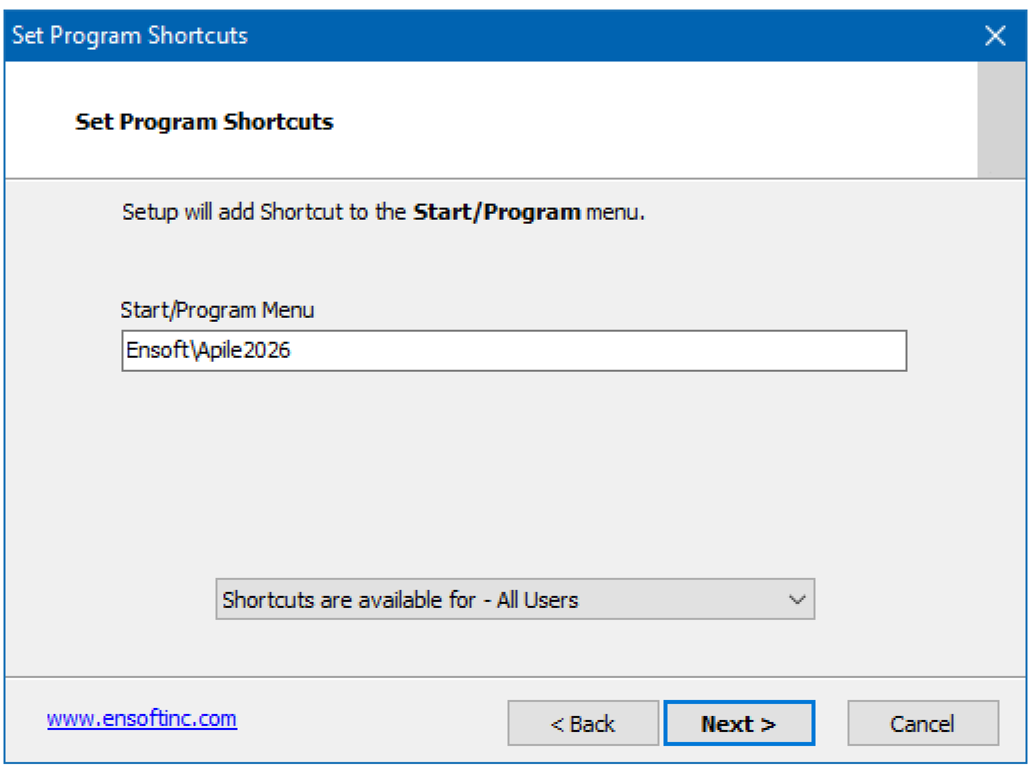


Figure 2.8 Default Shortcut Folder in Windows Start Menu (may change with time)

2.1.2 Installation of Cloud Subscription Version

The latest Ensoft Software updates are compatible with all recent versions of the Microsoft Windows® operating system, including 11, 10. The following guidelines are recommended for the installation of cloud licenses.

1. Download the purchased Ensoft Software from our website using the following link:

   https://www.ensoftinc.com/downloads

   Run (double click) the downloaded executable file and select Next to continue.

2. The user should read the license agreement (partly shown in Figure 2.2). Users may also review the License Agreement online in the following link:

   https://www.ensoftinc.com/doc/Ensoft%20License%20and%20Disclaimer.pdf

   The installer will place the same file (*Ensoft License and Disclaimer.pdf)* in the installation directory. Please click Yes if you agree and would like to proceed.

3. Select Cloud Subscription in Figure 2.4 then click Next. For single-user installations see Section 2.1.1. For network installations see Section 2.1.3.

4. Ensoft currently offers three types of Cloud Subscription Licenses: Personal, Office and Enterprise. The most common selection is Personal/Office since the Enterprise is only for very large customers (see Figure 2.9).

5. The user will be provided with an option to select a drive and directory for the installation of example files (see Figure 2.5). Default installation directory is the following:

   (Root Drive):\Ensoft\Apile2026-Examples

6. The user will also be asked to select a drive and directory for the installation of the software (see Figure 2.6). Default installation directory (varies according to the Windows release where it is installed) is one of the following:

   (Root Drive):\Program Files\Ensoft\Apile2026

   If the desired directory does not exist, the installation program will automatically create a new directory in the chosen hard drive.

6. During installation the user will be asked to set the file extension association for opening APILE v2026 input data files (see Figure 2.7). If the user agrees (leaves the default check mark) then double clicking (or running) any input data file with extensions of the type *filename.ap12d* will start the installed APILE v2026 software.

7. The user will be prompted to confirm the shortcut directory name that will be created in the Windows Start Menu (See Figure 2.8). The default is *Start Menu/Programs/Ensoft/Apile2026*. Windows 11, 10 will automatically create an Ensoft tile with the same shortcuts.

8. After copying files, the installer may check if the user's Windows OS has the necessary Microsoft Visual C++ drivers. If those are not found the user will be prompted to install (Figure 2.9) and must agree to terms and select the Install button. If the drivers are present, the user will be prompted with Figure 2.10 where you can simply select the Close button.

After the installation is finished, it is usually <u>not necessary</u> to reboot Windows for the program to run. The user may run the program by selecting Apile v2026 from the standard links installed in the Microsoft Windows® Start Menu: Start Menu > All Programs > Ensoft > Apile2026

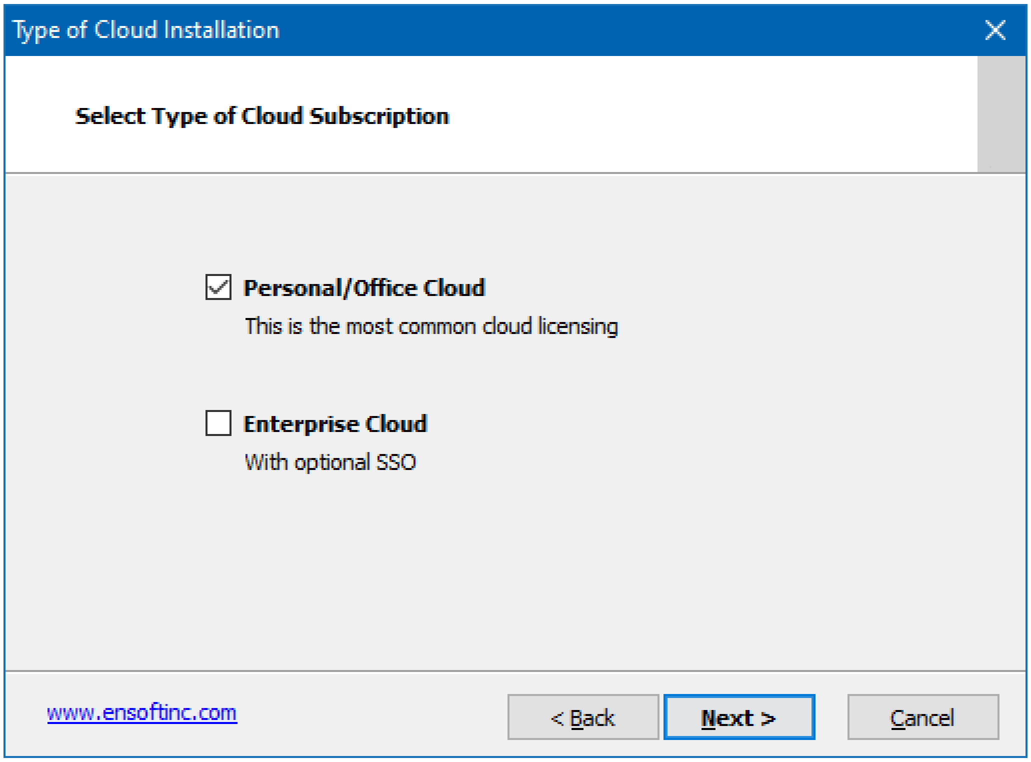


Figure 2.9 Selection of Type of Cloud Subscription (may change with time)

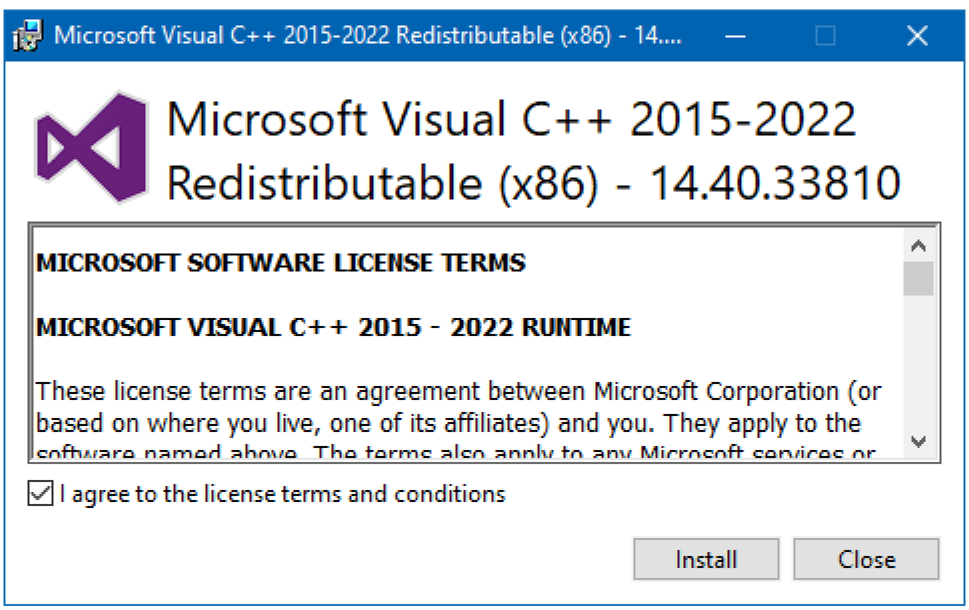


Figure 2.10 Consent for Installation of Microsoft Visual++ Drivers

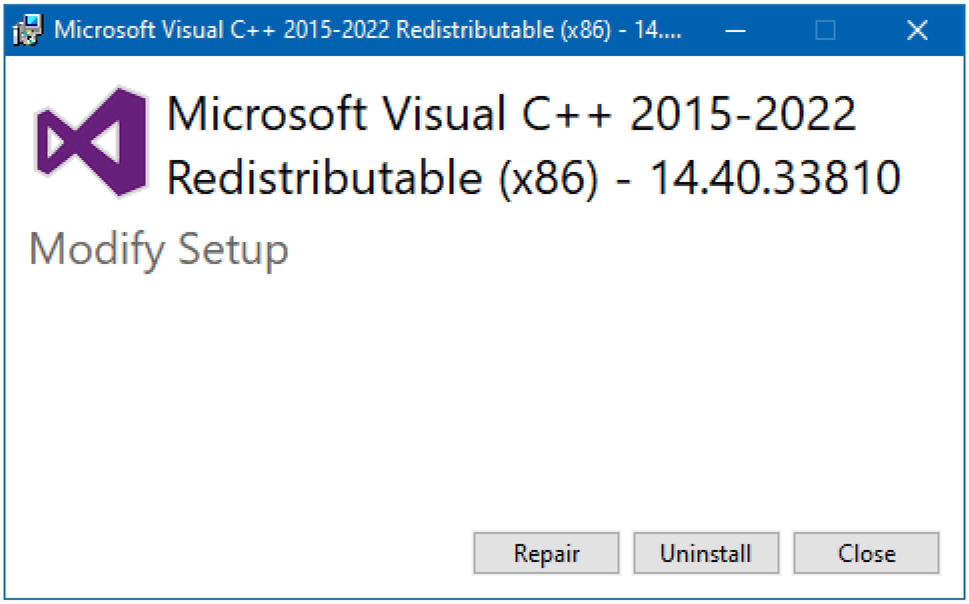


Figure 2.11 Found Installed Microsoft Visual++ Drivers

2.1.3 Introduction of Network Version

Special network licenses and Net USB Key (network hardware key) are available for users that desire to operate APILE on a Windows network. The network version is limited to users within a limited range of IP addresses that are employed at a specified licensed office site.

Network versions of APILE have special subroutines written for installations in “software servers” (License Servers) and for installations of “individual clients” (Client Computers). The “software server” is the computer that will be carrying the network 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 APILE as long as the Net USB Key is attached to a working USB port (or through an USB hub) and the “server” version of the software or of the Ensoft Utilities is installed on its hard drive.

Software “clients” are other computers of the network that are accessed by employees of the licensed office site and that have the software installed as client. Client computers do not need any hardware key or dongle attached to their local system. The program installed in “client computers” will be allowed to run as long as the computer designated as “software server” is accessible on the network with the proper operating system and with its network key secured in place.

2.1.4 Silent Installations of Single, Client or Cloud Licenses

For installation of single-user licenses, cloud subscription licenses and network licenses on local client computers (not on License Server) there is an option for command-based installations that are completely silent (performed without other user input). Instructions for silent installations can be downloaded from the Ensoft web site using the following link:

https://www.ensoftinc.com/doc/Silent_Single-Client-Cloud_Installations.pdf

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

2.1.5 Backup of Original Software

The distributed software may be copied for backup purposes. The program may be installed in several computers. However, unless network or office cloud licenses are purchased, the program will only operate in the computer that carries the appropriate USB Key.

2.1.6 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 APILE menu. Software users may freely download the latest program update from the PRODUCTS > Downloads link in the following site: *https://www.ensoftinc.com/*

2.2 Getting Started

A general diagram showing the menu choices and operational flow chart of program APILE is presented in Figure 2.11. The following paragraphs provide a short description of the operational features of APILE and should quickly enable the user to get started with the program.

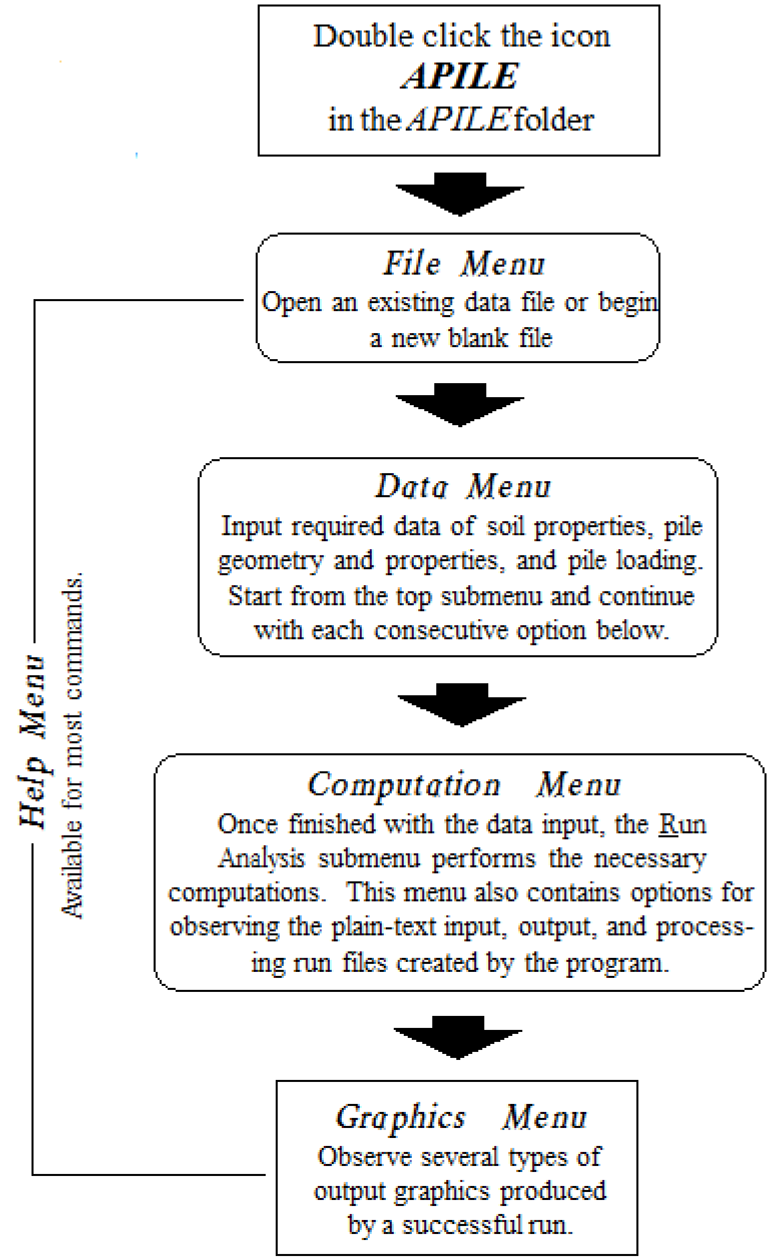


Figure 2.12 Sample organization and operational flow chart

2.2.1 Starting the Program

In the very first start of the program, after a fresh installation, the user will be asked to personalize the installed copy of APILE (Figure 2.12). This dialog allows the user to enter any name to distinguish the software installation. The selected name will be included at the beginning of all output files that are generated by this particular installation of APILE. The selected name can be changed any time afterwards from the Help > User Information menu.

In any software start after the first, the program displays a blank screen containing the following top-menu choices: File, Data, Options, Computation, Graphics, Window, and Help along with a variety of speed buttons (Figure 2.13). If the user starts the software from an existing model (using Windows OS file extension association), the software opens with a background display of main graphical features of the working model.

As a standard Windows feature, pressing the "Alt" key displays the menu operations with underlined letters. Pressing the underlined letter after pressing "Alt" is the same as clicking the operation. For example, to open a New File, the user could press "Alt+F" followed by "N", or "Ctrl+N", or click File > New. Hovering the mouse cursor over a speed button displays a quick reference of its function.

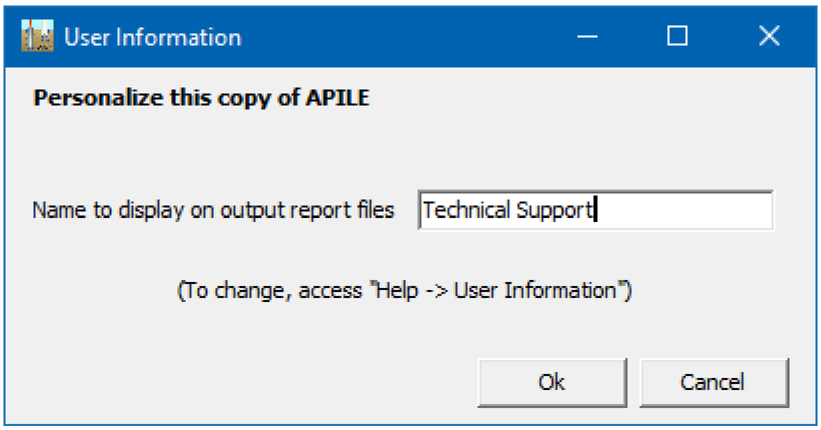


Figure 2.13 User Information on Initial Program Start (after a fresh installation).

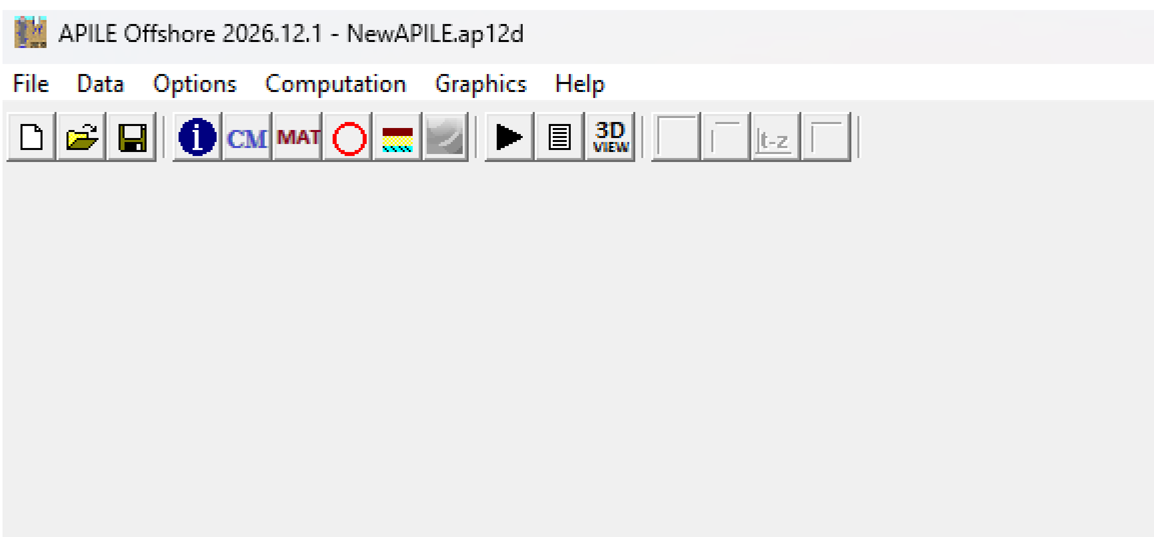


Figure 2.14 Blank Screen on Subsequent Program Starts.

2.2.2 File Management

The File menu option contains five standard entries, as shown in Figure 2.14; they are:

- New to create a new data file.
- Open… to open an existing data file.

- Save to save input data under the current file name.
- Save As… to save input data under a different file name.
- Exit to exit program APILE.
- Other entries include quick access to a history of up to 10 recently-opened files.

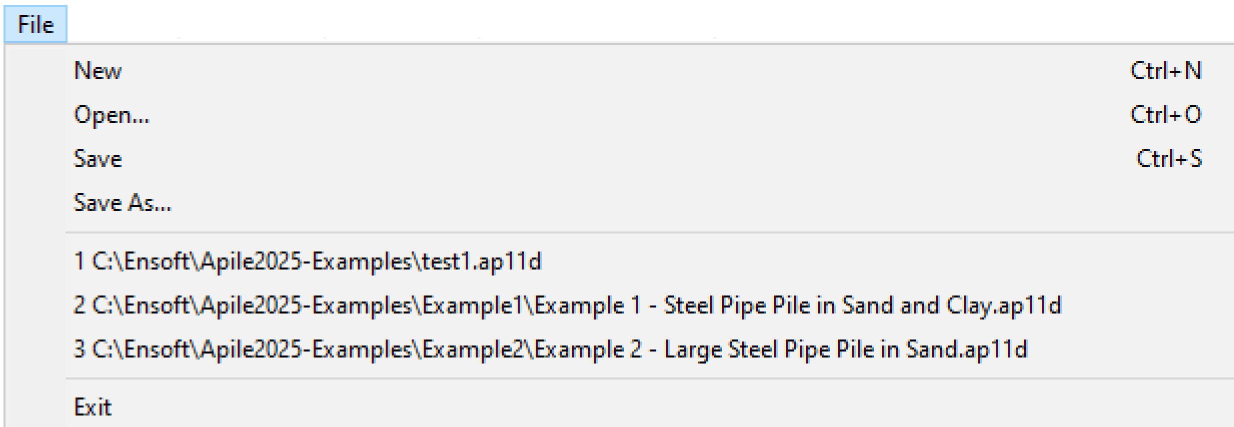


Figure 2.15 Sample File Menu

An output file is created in every new APILE run. A general description of files associated with each example is presented in Table 2.1. These files are not meant to be manually edited.

File Name Extension	Usage Description	File Format	Example Files
*.ap12d	Input-data file	Binary	example1.ap12d example2.ap12d
*.ap11o	Output-data file	Binary	example1.ap11o example2.ap11o

Table 2.1 Files created in APILE runs

2.2.3 Data Menu

The Data menu contains several entries, as shown in Figure 2.15. The entries are listed below, along with a general description of their use. Some entries may be disabled since they depend on other input selections specified under the Data menu.

Title .... to enter a single line of text with a general description for the project.

Computational Method ...the user may select any one of the four (regular version) to eleven (offshore version) methods of internal computation of load-vs-settlement and one or more methods of pile capacity, or the user may choose to input specific values of unit load transfers. The user can also specify in this menu the usage of reduction factors for LRFD analyses.

Pile Material.. .used to enter the material properties of piles such as steel piles, prestressed concrete piles, timber piles, etc. This selection also provides control for values that are used in computations of elastic deformation of the pile.

Pile Section Properties . to describe pile type and dimensions and material properties of piles. This menu also provides a selection of computations of pile plugging.

Soil Layers......this is used to define the type and depth of each soil layer and to enter the associated soil parameters. Users are able to edit layers using the standard APILE table or with the new CPT interpreter (if data was imported from a CPT file).

Import CPT Data .... this submenu is optional and is used to read an external file containing data from the cone penetration test (CPT) which can be analyzed for soil layering into APILE.

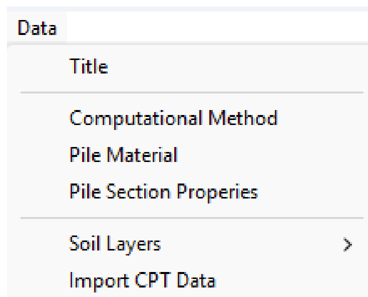


Figure 2.16 Sample Data Menu

2.2.4 Options Menu

The Options menu is provided for the control of program variables and preferences. The listing of menu options is shown in Figure 2.16 and the different choices are briefly described below. The user may select any of the entries without concern for the sequential order.

Units ....the user may select either English Units (using kips, feet and inches) or S.I. Units (using kN, meters and millimeters). English units are enabled, as a default, for all new runs. The user may change the system of units as many times as desired and values that were previously input will be automatically converted by the program to the new selection of units.

Control Options.............the user may select the length of each computation increment and also how often to print results. This menu also allows users to ask the application to print additional *t-z* curves at user-specified depths.

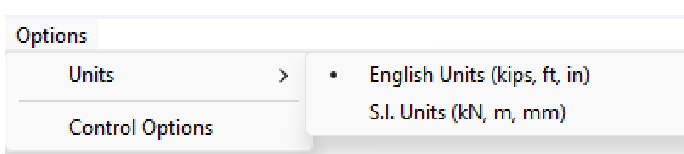


Figure 2.17 Options Menu

2.2.5 Computation Menu

The Computation menu is provided to run the analytical computations after all data are entered and saved. After the computation is executed successfully this menu also provides options for the reviews of plain-text input data, notes produced during computation, and output data. It also provides an option for the graphical observation of the modeled pile and soil layers. Choices under the Computation menu, shown in Figure 2.17, are briefly described below.

Run Analysis.. ....this option is chosen to run the analytical computations. This option should be selected after all data have been entered and saved.

Run Parametric Analysis................. this option is chosen to run the analysis during which a soil layer or pile properties of the base model are modified. This option should be selected after all data have been entered and saved.

View Output Text...........this menu is used to observe, copy to clipboard and/or print the analytical-output data. The option becomes available only after a successful computational run.

3D View...........provides a three-dimensional representation of the modeled pile, soil layers, layer depths, and graphical result plots (for completed analyses).

Generate GRLWeap Data................used to generate a data file that can be imported into the separate GRLWEAP 14 software for studies of pile drivability.

Generate Report in MS-Word..........this selection allows users to export input and output information of the APILE model along with optional output charts into a Microsoft Word file that is pre-formatted for report presentations.

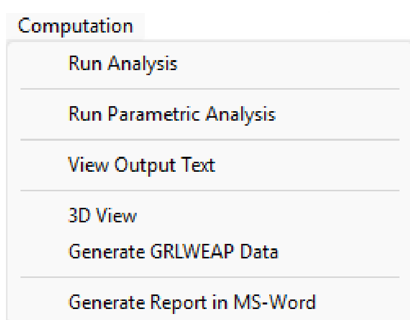


Figure 2.18 Computation Menu

2.2.6 Graphics Menu

The Graphics menu is accessed for a quick observation of plots of output data provided after a successful computational run of an APILE model. Most of the selections below will open the Plot Results interface along with a display of the desired chart.

The observation of output plots under this menu are enabled after a successful computational run. Even after successful runs, some choices in this menu may still be disabled since the output data depends on specifications provided in the input file of each model. The various choices, shown in Figure 2.18, are briefly described below.

Unit Skin Friction vs Depth ....provides a plot of unit load transfers in side resistance (skin friction) versus depth of the modeled pile according to computational methods for pile capacity that were selected by the user.

Accumulated Skin Friction vs Depth…provides a plot of accumulated load transfers in side resistance (skin friction) versus depth of the modeled pile according to computational methods for pile capacity that were selected by the user.

Tip Resistance vs Depth…. provides a plot of ultimate end bearing (tip resistance) versus depth of the modeled pile according to computational methods for pile capacity that were selected by the user.

Total Capacity vs Depth…. provides a plot of the ultimate total capacity (skin friction plus tip resistance) versus depth of the modeled pile according to computational methods for pile capacity that were selected by the user.

Load Distribution…. provides a plot of distributions of axial loads versus depth of the modeled pile according to the computational method for load-vs-settlement that was selected by the user.

Combined Plot…. provides a plot of ultimate skin friction, ultimate tip resistance, and the ultimate total capacity versus depth on a single graph, according to the computational method for load-vs-settlement that was selected by the user.

Axial Load vs Settlement…. provides a plot of the axial loads versus settlement at the pile head based on *t-z* curves and *Q-w* curves, according to the computational method for load-vs-settlement that was selected by the user.

Internally-Generated t-z Curves…. provides a plot of the *t-z* curves generated by the program at the top, the middle, and the bottom of each soil layer, according to the computational method for load-vs-settlement that was selected by the user.

Extra t-z Curves at User-Specified Depths….this menu is only enabled for certain models, it provides a plot of the *t-z* curves generated by the program at user-specified depths.

Internally Generated Q-w Curve…. provides a plot of the *Q-w* (tip resistance vs. movement) that was generated according to the computational method for load-vs-settlement that was selected by the user.

Neutral Plane Analysis (Downdrag – FHWA)…. provides an option to determine the FHWA 2016 approximate method for downdrag design.

Exports Plots to Excel…. allows the user to export some (or all) of the plots above to a pre-formatted excel file. Each plot will be exported to two sheets, one contains the data and the second the chart.

Print Soil Profile….this menu is used to print out an elevation view of the modeled pile along with the soil profile including depths and major mechanical properties of each soil layer.

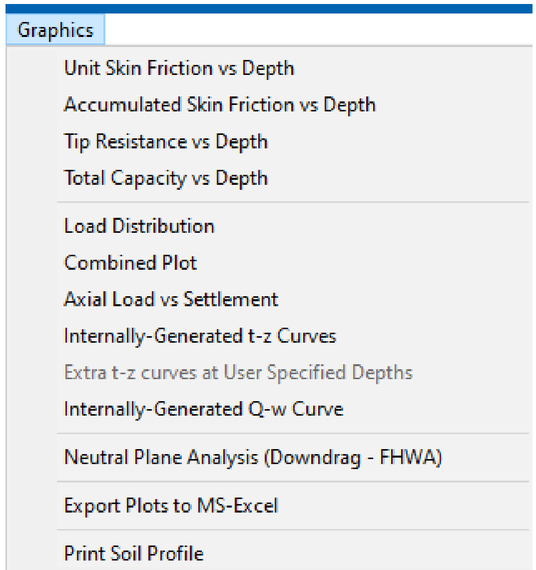


Figure 2.19 Sample Graphics Menu

2.2.7 Help Menu

The Help menu provides access to the software manuals (PDF files) and to some helpful utilities that the user may need when running the program. The software manuals are helpful references on topics such as: using the program, entering data, information about variables used in the program and methods of analyses. Options in the Help menu, shown in Figure 2.20, are briefly described below.

Ensoft Key Inquirer........this choice is only available for USB-based, single-user licenses (not available in local network licenses or cloud licenses). This utility allows the user to check information contained in the USB Key that is attached to the computer in use. With this utility the user can see the following information: dongle serial number and expiration date, licensed program names and type of licenses, maintenance expiration date of each software license, licensed company name, allowed IP subnets. This utility is installed in the selected installation directory with the following filename: *ensoft_key_inquirer_v701.exe* (may change with time). This utility is necessary to perform remote updates of a license with expired maintenance.

Check Network Dongle. this choice is only available in client computers of local network licenses (not available in single-user licenses or cloud licenses). This function calls the utility that is used to check the licensing and to troubleshoot communications with the License Server. This utility is very useful in case of problems in clients when trying to run the licensed software. This utility is installed in the selected installation directory with the following filename: *CheckNetworkDongle_ipv_512.exe* (may change with time).

Cloud License Manager this selection is only available on cloud subscription installations of the software product (it is not available for users with USB-based installations, such as single-user or network licenses). This menu provides access to information and management of cloud subscriptions licenses.

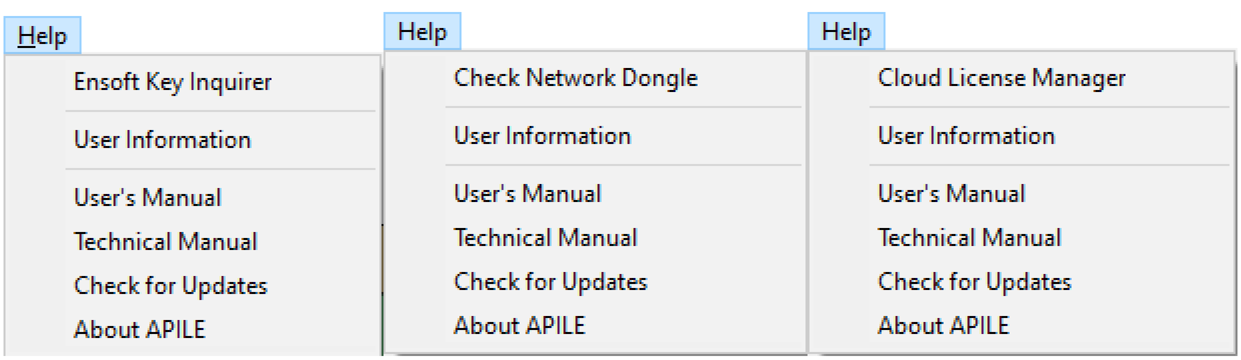
User Information .... this is used to personalize the individual installation of APILE. A screen capture of this dialog was previously shown in Figure 2.12. The user specified entry in this dialog will be included at the beginning of all output files that are generated by this particular installation of APILE.

User's Manual .... this selection calls for any installed PDF reader (Adobe Acrobat, Acrobat Reader or similar) to open the User's Manual. This document is formatted as a protected PDF file with bookmarked table of contents. This manual describes all menu items to use the program, description of data entries and for output tables and graphs. It also contains a chapter with described example problems that help to explain various program features.

Technical Manual .... this selection calls for any installed PDF reader (Adobe Acrobat, Acrobat Reader or similar) to open the Technical Manual. This document is formatted as a protected PDF file with bookmarked table of contents. This manual contains background technical information and references regarding the theoretical methos used within the program.

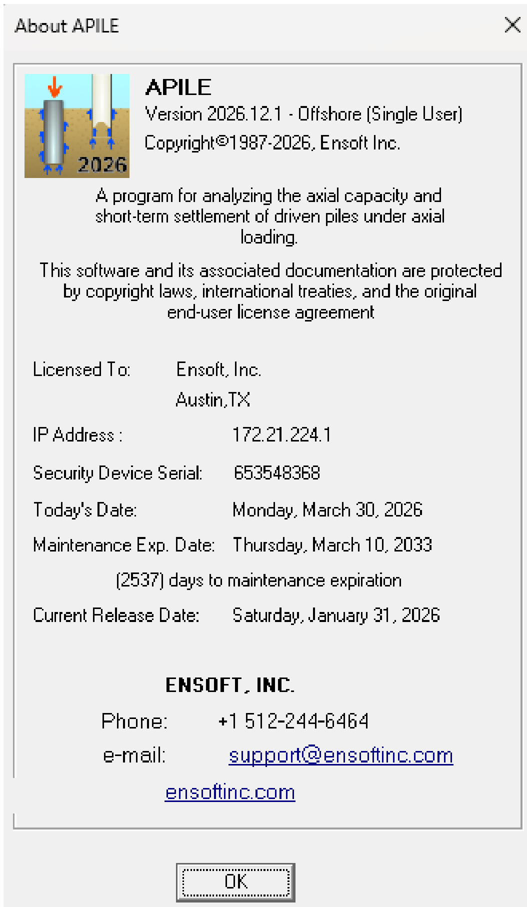
Check for Updates .... starts the default Internet browser on a page that describes information about the user's license (release and maintenance expiration date) as well as the latest release that is available for downloading at the Ensoft site. Users may only run in full mode the maintenance updates that were released before the expiration date of the user's license.

About…............. this command provides a dialog describing the program version, date, and methods for accessing technical support. Other information about the program licensing and maintenance expiration date, program version, and program release date are also shown. Examples of the Help > About dialog for two different licensing options are shown in Figure 2.21.

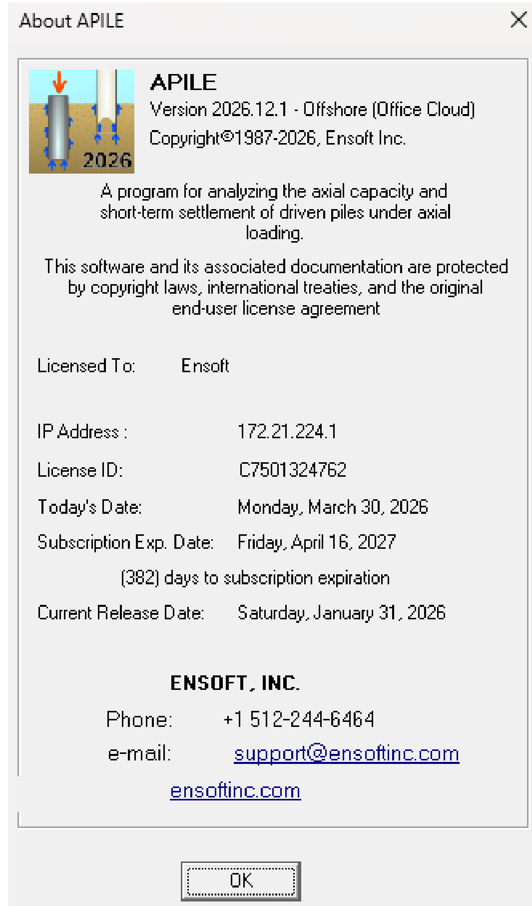


a. Single-User License b. Client on Local Network License c. Cloud Subscription License

Figure 2.20 Help Menu



a. Single-User License



b. Cloud Subscription License

Figure 2.21 Examples of About APILE Dialog

CHAPTER 3. References for Data Input

3.1 File Menu

This menu contains options related to the management of input-data files and to exit the program. Input-data files created for APILE are provided with a standard file-name extension in the form of **filename*.ap12d* (where **filename** represents any allowable file name).

3.1.1 File Menu Speed Buttons

The first group of three speed buttons at the left side of the button bar (shown in Figure 3.1) provides access to the following commands (from left to right): File > New, File > Open, and File > Save.

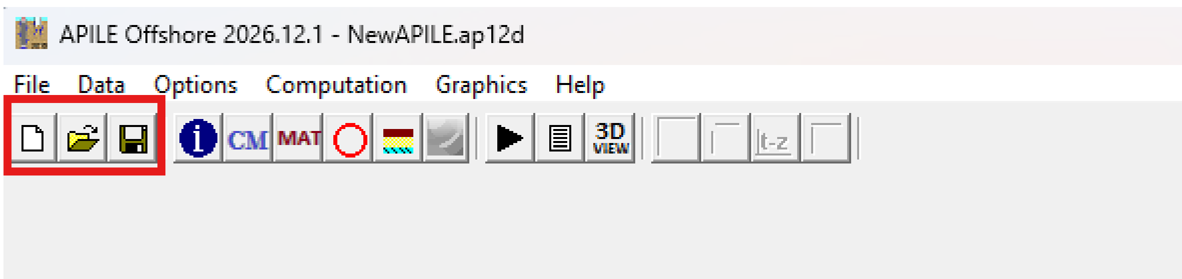
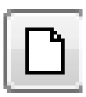


Figure 3.1 Speed Buttons for the File Menu (within red rectangle)

3.1.2 File > New



Once the program is started, default values are used for certain operating parameters and a blank input-data file is created. Selecting New under the File menu resets all APILE variables to either default or blank values, as appropriate. Select this menu option or speed button to start a new data file with default/blank data. This menu option may also be accessed with the Ctrl+N keyboard combination.

3.1.3 File > Open

This is used to open a file that has been previously prepared and saved to disk. The File > Open window dialog, shown in Figure 3.2, is used to browse and open an existing input-data file. By default, this dialog initially opens in the directory where APILE was installed. Standard windows-navigation procedures may be used to locate the name and directory of the desired project data file. This menu option may also be accessed with the Ctrl+O keyboard combination.

Every analytical run of APILE produces several additional files (previously described in Table 2.1 of this manual). The name of the input-data file indicates the names of all related files produced by a successful program run (output, graphics, and temp files). All the additional program files will be created in the same directory as the input data file. Input-data files that are partially completed may be saved and later opened for completion, run, and observation of results.

Opening some partially-completed APILE input files or invalid data files (or files with incorrect data formats) may produce an information window reporting that an "invalid or incomplete" file is being opened (Figure 3.3). The user should click the OK button and all partial-input data that was previously prepared should become available.

The program allows users to read input-data files created by previous APILE versions (**.apd*, **.ap6d*, **.ap7d*, **.ap8d*, **.ap10d,* and **.ap11d* file extensions) by selecting the drop-down arrow at the bottom right corner of the File > Open window screen. The program will automatically convert the opened previous

APILE input file to the current version of APILE when the user saves the opened file. Please note Ensoft application input files, including APILE, are forward compatible but not backward compatible. This means that you cannot open APILE2026 input files using earlier versions of APILE.

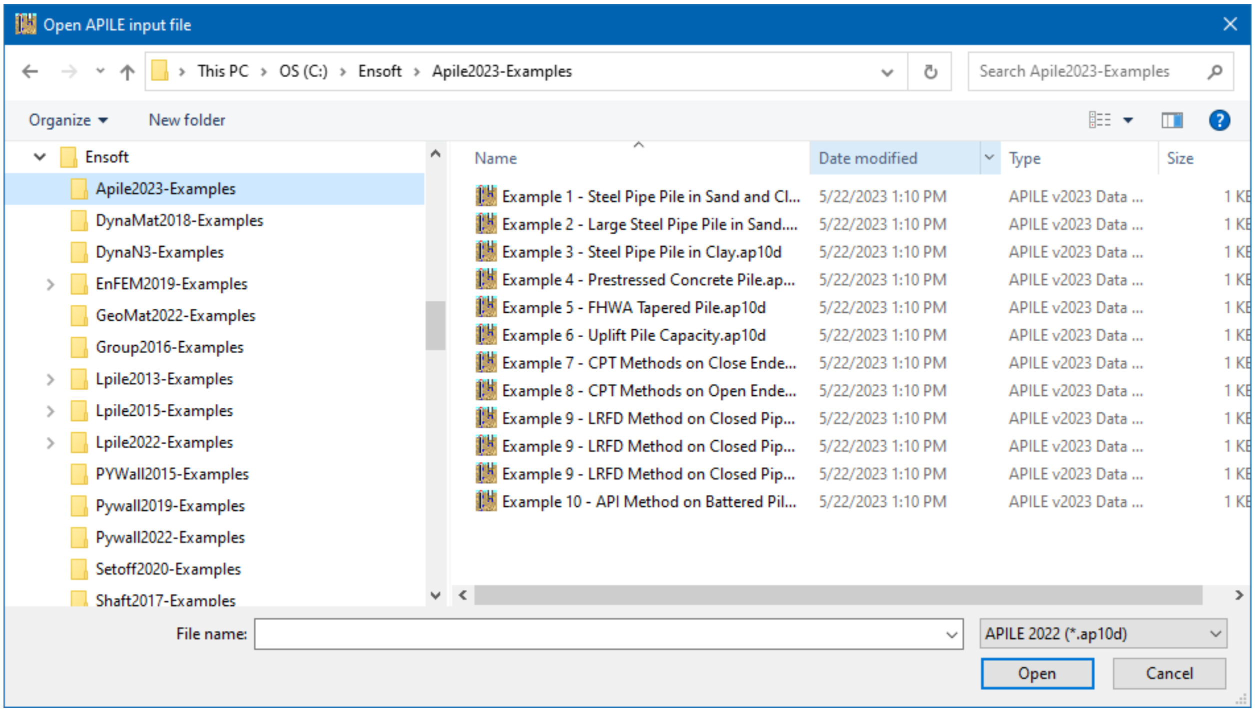


Figure 3.2 File > Open Dialog

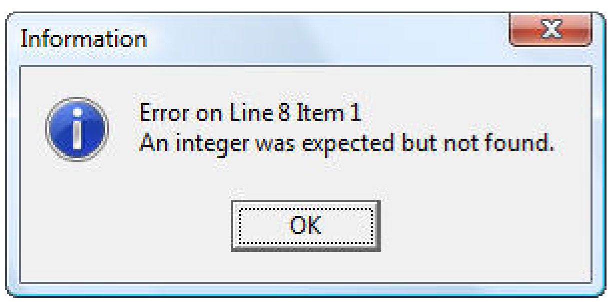
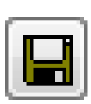


Figure 3.3 Sample message for incomplete or invalid file

3.1.4 File > Save



This selection is used to save input data under the current file name. With this method of storing data to disk, any input data that was previously saved with the same file name is replaced with the current parameters. Input-data files should be saved every time before proceeding with runs for analytical computation. This menu option may also be accessed with the Ctrl+S keyboard combination.

3.1.5 File > Save As

This selection allows the user to save any opened or new input data file under a different file name or different directory. Any input data file saved under an existing file name will replace the contents of the existing file.

3.1.6 File > Exit

This is selected to exit APILE. Any input-data file that was modified and not yet saved to disk will produce a confirmation window before exiting the program (see Figure 3.4).

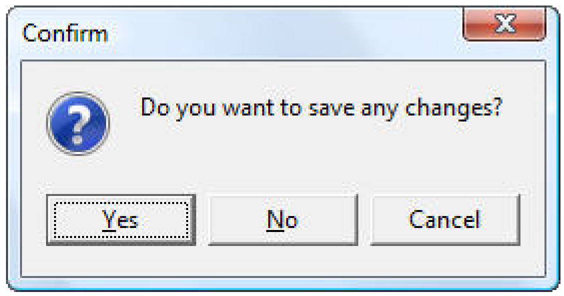


Figure 3.4 Message window advising that changes were not saved to disk

3.2 Data Menu

The input of specific parameters for an application is controlled under options contained within this menu (shown in Figure 3.5). It is recommended that the user choose each submenu and enter parameters in a sequential order starting from the top.

Selecting or clicking any of the submenu choices contained in the Data menu produces various types of windows. As a reminder of standard commands of Microsoft Windows®, open windows may be closed by all or some of the following methods:

- clicking the OK button (if available), or
- clicking the X-box on the upper-right corner of the window, or
- pressing the "Ctrl+F4" keyboard combination, or
- double-clicking the APILE icon on the upper-left corner of the window, or
- clicking once on the APILE icon on the upper-left corner of the window and then choosing Close.

Many sub-windows of the Data menu will show an Add Row, Insert Row and/or Delete Row buttons. The Add Row button always adds new rows at the end after all existing rows. The Insert Row button always inserts a new row below the row where the cursor is located. Clicking on the Delete Row button deletes the row where the cursor is located.

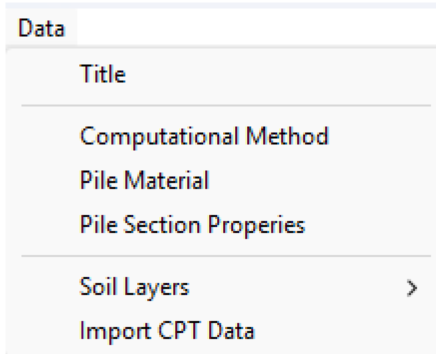


Figure 3.5 Sample Data Menu

3.2.1 Data Menu Speed Buttons

The second group of six speed buttons at the left side of the button bar (shown in Figure 3.6) provides access to the following commands (from left to right): Data > Title, Data > Computation Method, Data > Pile Material, Data > Pile Section Properties, Data > Soil Layers > Edit Soil Layers, and Data > Soil Layers > Edit Soil Layers with CPT. Some of these speed buttons depend on model parameters so some of these buttons can be disabled/enabled depending on selected input data.

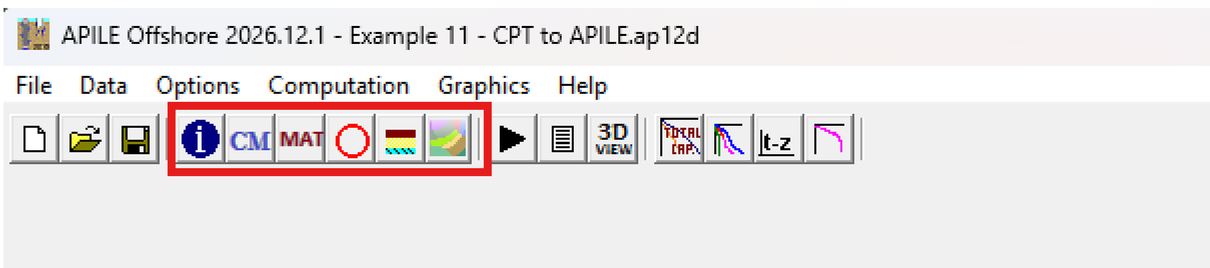
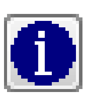


Figure 3.6 Speed Buttons for the Data Menu (within red rectangle)

3.2.2 Data > Title



This selection activates the window shown in Figure 3.7, where the user can enter a line of text containing a general description for the application problem. Any combination of characters may be entered in the text box in order to describe a particular application. The user input will be restrained automatically once the maximum length of text is reached. This is done to prevent the user from going beyond the maximum permissible length of characters allowed for the title line.

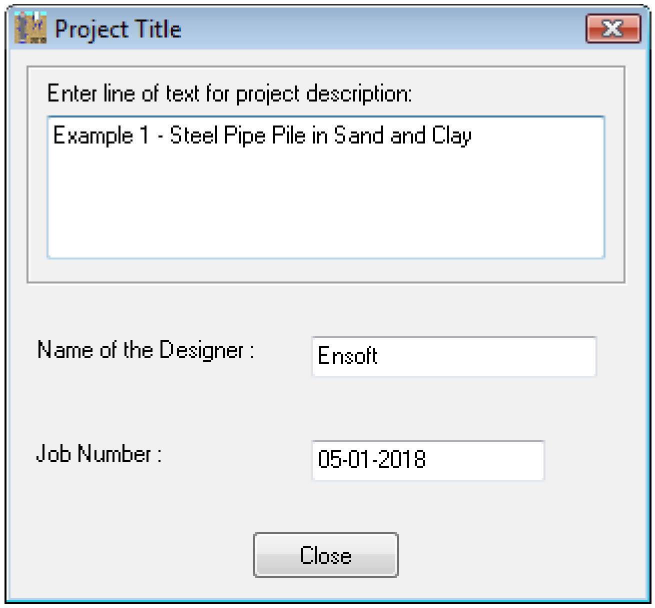


Figure 3.7 Sample Data > Title

3.2.3 Data > Computational Methods

The selection provides a dialog box window shown in Figure 3.8, with three sections: General, Load Settlement and Pile Load Capacity Methods. Some options in the dropdown menu may only exist for the APILE Offshore Version. In this menu you can select the preferred method for computations of load-vs settlement curves (i.e., instructions for generation of *t-z* and *Q-w* curves) and for pile capacity computations.

3.2.3.1 Type of Loading – Compression or Tension

The user may specify either compressive loading or tensile loading with a drop-down menu. If the tensile loading is selected, in the lower Options section of this dialog, the user may enter a reduction factor on side friction – which is applicable only with the API method. For other methods (outside API) this tensile reduction factor is <u>not</u> taken into account since the APILE program will follow the recommendations from each theory (see Chapter 3 of the APILE Technical Manual).

3.2.3.2 Method for Load-vs-Settlement

The computations of load-vs-settlement involves two procedures: i) computation of the unit-load transfers, and ii) computation of the shape of the nonlinear, load-transfer curves (*t-z* and *Q-w*).

The APILE program automatically selects the nonlinear shape of the load-transfer curves (*t-z* and *Q-w*) based on two methods, API RP 2A or Reese/Skempton/Mosher. USACE method uses Reese/Skepmton/Mosher curves, while all other methods use API RP 2A curves.

The Reese/Mosher/Skempton shapes are referenced in Table 3.2. These are the load-transfer curve shapes used with the USACE Method. These curves are described in Chapter 4 of the APILE Technical Manual (Section 4.4 through Section 4.7).

All other Methods (FHWA, Revised Lambda, API, etc) are based on the recommendations from the American Petroleum Institute and thus use the API RP 2A load-transfer curve shapes (API RP 2A-WSD, 2014) which are described in Section 4.8 of the APILE Technical Manual.

Type of Load Transfer	Type of Soil	Method for Shape of Load-Transfer Curve
Side Resistance	Cohesive	Coyle & Reese (1966)
	Cohesionless	Mosher (1984)
End Bearing	Cohesive	Skempton (1951)
	Cohesionless	Vijayvergiya & Mosher (1984)

Table 3.1 Shape of Nonlinear Load-Transfer Curves from Reese/Mosher/Skempton

For computations of unit load transfers, the APILE program offers four methods for the Standard Version and six additional methods for the Offshore Version. As an alternative to those embedded methods, the user may also select to input any arbitrary unit load transfers in skin friction and end bearing at top and bottom of each soil layer in the model.

The automated computation methods for unit load transfers in APILE are the following:

FHWA..............uses recommendations from the Federal Highway Administration (FHWA) of the United States. The theoretical background of this method is included in Section 3.5 of the APILE Technical Manual. The user's selection of this method of load transfer (under Method for Load Settlement) instructs APILE to use this method (FHWA) for computation of capacity ('t' and 'Q' values for the t-z and Q-w curves) but APILE uses the API RP 2A (Section 4.8 of the APILE Technical Manual) for computations of the <u>shape</u> of the load-transfer curves ('z' and 'w' components in the t-z and Q-w curves). This is because the FHWA method doesn't include specific instructions regarding the shape of the load transfer curves.

USACE ....uses recommendations from the United States Army Corps of Engineers. The theoretical background of this method is included in Section 3.4 of the APILE Technical Manual. The user's selection of this method of load transfer (under Method for Load Settlement) instructs APILE to use this method (USACE) for computation of capacity ('t' and 'Q' values for the t-z and Q-w curves) and APILE uses the Method (*) (Reese/Mosher/Skempton in Table 3.2) for the <u>shape</u> of the load-transfer curves ('z' and 'w' components in the t-z and Q-w curves).

Revised Lambda............uses recommendations from Vijayvergiya and Focht (1972), also known as the "*Lambda method*." The theoretical background of this method is included in Section 3.3 of the APILE Technical Manual. The user's selection of this method of load transfer (under Method for Load Settlement) instructs APILE to use this method (Revised Lambda) for computation of capacity ('t' and 'Q' values for the t-z and Q-w curves) but APILE uses the API RP 2A (Section 4.8 of the APILE Technical Manual) for computations of the <u>shape</u> of the load-transfer curves ('z' and 'w' components in the t-z and Q-w curves). This is because the Revised Lambda method doesn't include specific instructions regarding the shape of the load transfer curves.

API RP 2A .....uses *Recommended Practice 2A* of the American Petroleum Institute, also known as the "*revised API method*" (2014). The theoretical background of this method is included in Section 3.2 of the APILE Technical Manual. The user's selection of this method of load transfer (under Method for Load Settlement) instructs APILE to use this method (API RP 2A) for computation of capacity ('t' and 'Q' values for the t-z and Q-w curves) and APILE uses the API RP 2A-WSD (Section 4.8 of the APILE Technical Manual) for the shape of the load-transfer curves ('z' and 'w' components in the t-z and Q-w curves).

Load Transfers Specified by User…in addition to the internal methods of computations provided by the program, the user also has the option to specify any values of load transfers by selecting this method of computation. The user's selection of this method of load transfer (under Method for Load Settlement) instructs APILE to use this method (Specified by User) for computation of capacity ('t' and 'Q' values for the t-z and Q-w curves) but APILE uses the API RP 2A (Section 4.8 of the APILE Technical Manual) for computations of the shape of the load-transfer curves ('z' and 'w' components in the t-z and Q-w curves).

NGI ....(available only for the "APILE Offshore" version) uses CPT-based semi-empirical formulations recommended by the Norwegian Geotechnical Institute in 1999. The theoretical background of this method is included in Section 3.6 of the APILE Technical Manual. The user's selection of this method of load transfer (under Method for Load Settlement) instructs APILE to use this method (NGI) for computation of capacity ('t' and 'Q' values for the t-z and Q-w curves) but APILE uses the API RP 2A (Section 4.8 of the APILE Technical Manual) for computations of the shape of the load-transfer curves ('z' and 'w' components in the t-z and Q-w curves). This is because the NGI method doesn't include specific instructions regarding the shape of the load transfer curves.

ICP/MTD ....(available only for the "APILE Offshore" version) uses CPT-based semi-empirical formulations recommended by the Imperial College in 2005. The theoretical background of this method is included in Section 3.7 of the APILE Technical Manual. The user's selection of this method of load transfer (under Method for Load Settlement) instructs APILE to use this method (ICP/MTD) for computation of capacity ('t' and 'Q' values for the t-z and Q-w curves) but APILE uses the API RP 2A (Section 4.8 of the APILE Technical Manual) for computations of the shape of the load-transfer curves ('z' and 'w' components in the t-z and Q-w curves). This is because the ICP/MTD method doesn't include specific instructions regarding the shape of the load transfer curves.

FUGRO...........(available only for the "APILE Offshore" version) uses CPT-based semi-empirical formulations recommended by Fugro in 2004. The theoretical background of this method is included Section 3.8 of the APILE Technical Manual. The user's selection of this method of load transfer (under Method for Load Settlement) instructs APILE to use this method (FUGRO) for computation of capacity ('t' and 'Q' values for the t-z and Q-w curves) but APILE uses the API RP 2A (Section 4.8 of the APILE Technical Manual) for computations of the shape of the load-transfer curves ('z' and 'w' components in the t-z and Q-w curves). This is because the FUGRO method doesn't include specific instructions regarding the shape of the load transfer curves

UWA ....(available only for the "APILE Offshore" version) uses CPT-based semi-empirical formulations recommended by the University of Western Australia (UWA), Perth in 2005. The theoretical background of this method is included in Section 3.9 of the APILE Technical Manual. The user's selection of this method of load transfer (under Method for Load Settlement) instructs APILE to use this method (UWA) for computation of capacity ('t' and 'Q' values for the t-z and Q-w curves) but APILE uses the API RP 2A (Section 4.8 of the APILE Technical Manual) for computations of the <u>shape</u> of the load-transfer curves ('z' and 'w' components in the t-z and Q-w curves). This is because the UWA method doesn't include specific instructions regarding the shape of the load transfer curves

UCPT ....(available only for the "APILE Offshore" version) uses CPT-based semi-empirical formulations recommended by the Joint Industry Project which was also known as the Unified CPT Method (Lehane et al. 2017). The theoretical background of this method is included in Section 3.10 of the APILE Technical Manual. The user's selection of this method of load transfer (under Method for Load Settlement) instructs APILE to use this method (UCPT) for computation of capacity ('t' and 'Q' values for the t-z and Q-w curves) but APILE uses the API RP 2A (Section 4.8 of the APILE Technical Manual) for computations of the <u>shape</u> of the load-transfer curves ('z' and 'w' components in the t-z and Q-w curves). This is because the UCPT method doesn't include specific instructions regarding the shape of the load transfer curves

ALM ....(available only for the "APILE Offshore" version) uses CPT-based semi-empirical formulations recommended by Alm & Hamre, in 1998 and 2001. The theoretical background of this method is included in Section 3.11 of the APILE Technical Manual. The user's selection of this method of load transfer (under Method for Load Settlement) instructs APILE to use this method (A&H) for computation of capacity ('t' and 'Q' values for the t-z and Q-w curves) but APILE uses the API RP 2A (Section 4.8 of the APILE Technical Manual) for computations of the <u>shape</u> of the load-transfer curves ('z' and 'w' components in the t-z and Q-w curves). This is because the A&H method doesn't include specific instructions regarding the shape of the load transfer curves

Please note that selecting a Load Settlement Method will automatically include the same method in Load Capacity Method.

Use reduced t-z and Q-w unit tip transfers

Unchecked .....if unchecked, will use the LRFD factors (on Side Friction and End Bearing) that are inputted by the user for each soil layer under Data > Soil Layers (Side Friction and End Bearing Reduction Factors rows) and apply them <u>only to pile capacity and not to *t-z* and *Q-w* curves</u>. This is the APILE default and the expected selection for most applications, even for users of the LRFD method from AASHTO. This is because LRFD resistance factors are only applicable to pile capacity and not to load-vs-settlement.

Checked..........if checked, will use the LRFD factors (as *t*-multipliers for *t-z* curves and as *Q*-multipliers for *Q-w* curves) that are inputted by the user for each soil layer under Data > Soil Layers (Side Friction and End Bearing Reduction Factors rows). Please notice that APILE v2026 also allows users to specify additional t-z and Q-w multipliers under Options > Control Options > t-z and Q-w Factors. Those factors are also used when specified by the user so they are multiplied by the factors under Data > Soil Layers for the entries in the last two columns. This selection may be preferred by users for special analytical cases, such as hypothetical computations of load-vs-settlement for evaluations of losses of strength during pile driving or to match measured load-test data.

3.2.3.3 Pile Load Capacity Methods

For computations of axial pile capacity, the APILE program offers four methods for the Standard Version and six additional methods for the Offshore Version. Alternative to those embedded methods, the user may also select to input any arbitrary unit load transfers in skin friction and in end bearing at the top and bottom of each soil layer in the model. The user may select a single method, several, or all methods so as to compare results from various recommendations. APILE automatically selects the method that is selected by the user for computations of load-vs-settlement. The method used for load settlement cannot be unselected from load capacity method.

The automated computation methods for pile capacity in APILE are the following:

FHWA.............uses recommendations from the Federal Highway Administration (FHWA) of the United States. The theoretical background of this method is included in Section 3.5 of the APILE Technical Manual.

USACE ....uses recommendations from the United States Army Corps of Engineers. The theoretical background of this method is included in Section 3.4 of the APILE Technical Manual. For this particular method, the user is offered an additional control regarding the critical depth that should be used in sand layers (see Section 3.4 of the APILE Technical Manual).

Critical Depth for Sand...........For design purposes, USACE established that the skin friction of piles in sand increases linearly to an assumed critical depth (D_c) and then remains constant below that depth. APILE provides the users with some control regarding this limitation to increases in load transfers of side resistance in sand.

10-20 Pile Diameter Based on Density With this selection, APILE will use the original USACE code recommendations with a critical depth (D_c) that depends on sand density, which is equal to 10 pile diameters in loose sand, 15 pile diameters in medium sand and 20 pile diameters in dense sand. For multiple layers, the criteria that is used depends on the soil layer at the pile tip and the computations of depth always starts from ground surface.

Effective Stress Reaching 3,500 psi (185 kPa)…With this selection, APILE will use a critical depth equal to the one where the effective stress ($\gamma' z$) reach 3,500 lb/in^2 (185 kPa). This selection has been opted for practical reasons by some engineers when modeling multiple soil layers.

User-Specified Critical Depth…With this selection, APILE will use a critical depth that is here entered by the user, in ft or meter. This option is provided by APILE since some engineers that employ the USACE method may not want to limit the increases of transfers in side resistances in sand (thus entering a depth that is equal to the pile length) or want to see the effects of entering a different depth than those from the original USACE method.

Use Long-Pile Option (for Alpha)…A check mark on this selection box instructs APILE to calculate values of α (alpha) for side resistance in cohesive soils that correspond to long piles. If this box has no checkmark, the program will calculate regular alpha values as defined in Figure 3.5 of the Technical Manual. If this box has a checkmark, then the program will calculate long-pile alpha (α_1 and α_2) values as defined in Figure 3.6 of the Technical Manual.

Revised Lambda............uses recommendations from Vijayvergiya and Focht (1972), also known as the "*Lambda method*." The theoretical background of this method is included in Section 3.3 of the APILE Technical Manual.

API RP 2A .....uses *Recommended Practice 2A* of the American Petroleum Institute, also known as the "*revised API method*" (2007). The theoretical background of this method is included in Section 3.2 of the APILE Technical Manual.

Load Transfers Specified by User…in addition to the internal methods of computations provided by the program, the user also has the option to specify any values of load transfers by selecting this method of computation. With this selection, the user can enter unit load transfers in skin friction and in end bearing for the top and bottom of each soil layer under Data > Soil Layers > Edit Layer x.

NGI ....(available only for the "APILE Offshore" version) uses CPT-based semi-empirical formulations recommended by the Norwegian Geotechnical Institute in 1999. The theoretical background of this method is included in Section 3.6 of the APILE Technical Manual.

ICP/MTD ....(available only for the "APILE Offshore" version) uses CPT-based semi-empirical formulations recommended by the Imperial College in 2005. The theoretical background of this method is included in Section 3.7 of the APILE Technical Manual.

Options for ICP/MTD For this particular method, the user must also select whether the loading produces drained or undrained conditions for end bearing in clay layers (see Section 3.7.3.2 of the APILE Technical Manual):

Use Drained Condition for Clay some users tend to evaluate long-term behavior by the assumption of drained conditions in the cohesive soil.

Use Undrained Condition for Clay this is the default and most common condition, though some users relate this condition to short-term responses.

FUGRO...........(available only for the "APILE Offshore" version) uses CPT-based semi-empirical formulations recommended by Fugro in 2004. The theoretical background of this method is included Section 3.8 of the APILE Technical Manual.

UWA ....(available only for the "APILE Offshore" version) uses CPT-based semi-empirical formulations recommended by the University of Western Australia (UWA), Perth in 2005. The theoretical background of this method is included in Section 3.9 of the APILE Technical Manual.

UCPT ....(available only for the "APILE Offshore" version) uses CPT-based semi-empirical formulations recommended by the Joint Industry Project which was also known as the Unified CPT Method (Lehane et al. 2017). The theoretical background of this method is included in Section 3.10 of the APILE Technical Manual.

A&H ....(available only for the "APILE Offshore" version) uses CPT-based semi-empirical formulations recommended by Alm & Hamre, in 1998 and 2001. The theoretical background of this method is included in Section 3.11 of the APILE Technical Manual.

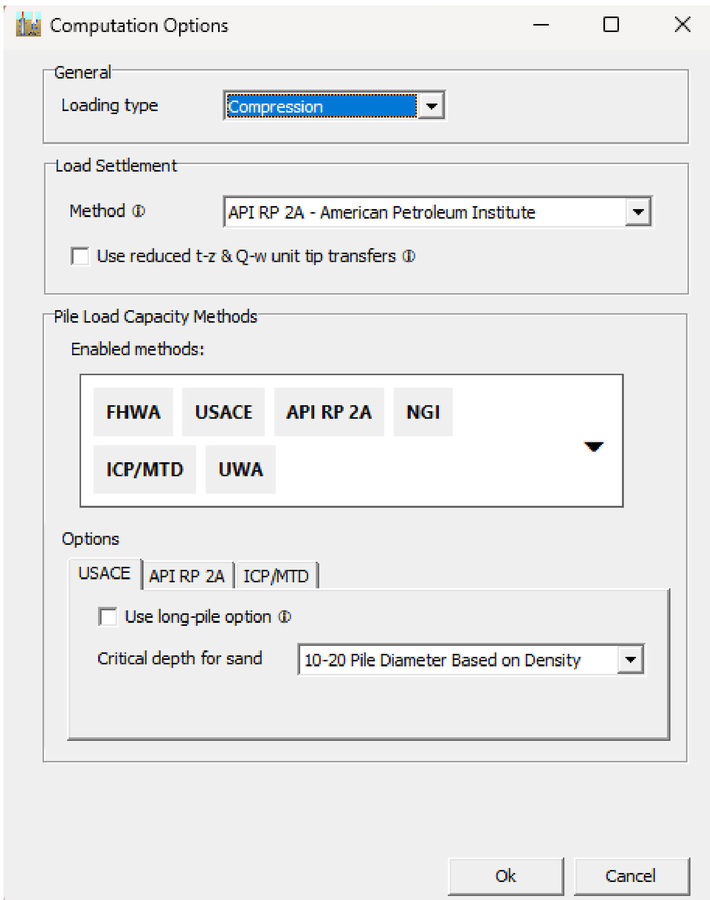


Figure 3.8 Data > Computational Methods

3.2.4 Data > Pile Material

This entry allows the user to select pile material that are used for the driven pile. An illustration of the Pile Material window for an example application is shown in Figure 3.9. A general description for the data needed in the Data > Pile Material submenu is listed below.

The entries in this section are only used to calculate the elastic deformation of the pile (which has a direct effect on load-vs-settlement) and thus do not have any effect in computations of pile capacity.

Elastic Modulus …this number (always positive) represents the elastic modulus of the pile. The elastic modulus of the pile is used for load-vs-settlement analysis to calculate the elastic deformation of the pile. The English unit for this variable is "psi" or "lb/in^2" while "kPa" or "kN/m^2" is used for SI units.

3.2.4.1 Cross-sectional Area

Auto-Compute…the selection of option instructs APILE to calculate a cross-sectional area of the pile automatically based on input from the user under Data > Pile Section Properties (Outer Diameter and Inner Diameter) or under (Non-circular Pile Properties: Tip Area). Notice that for H piles and pipe piles the user may select a close-ended section for capacity analysis but should use only the metal (steel) area for elastic deformation. For those cases, the user may need to enter a different area using the next option below. The automatically calculated entry in this radio button is provided in units of "in^2" when using English units or in "m^2" when using SI units.

Use-specified Constant…the selection of this option instructs APILE to use any cross-sectional area that is here entered by the user. This is particularly important for pipe piles and H piles (or wide flanges) since the value that is here entered is normally only the metal (steel) area, even if the pile is closed ended for capacity calculations. For solid piles (concrete/timber) the value that is here entered is the gross cross-sectional area. The entry shall be provided in units of "in^2" when using English units or in "m^2" when using SI units.

User-specified Variable …the selection of this option instructs APILE to use the variations of cross-sectional areas that are here entered by the user. For proper computations of elastic deformation with any type of tapered pile, the user must select this option and enter the cross-sectional areas in the provided table. A minimum of two entries (top and bottom of section or pile) must be specified and APILE interpolates linearly between entries.

Distance from pile head in the presented table shall be provided in units of "ft" when using English units or in "m" when using SI units. The entries of Cross-section Area in this table shall be provided in units of "in^2" when using English units or in "m^2" when using SI units.

3.2.4.2 Notes for Self-Weight of Piles

The self-weight (or unit weight) of the modeled pile is automatically calculated by APILE and added to the uplift capacity. Internal self-weight calculations are based on the reference values shown in Table 3.3. Weight of water is subtracted when the pile is below the water table, which defined when the user-specified unit weight of soil is below 75 lb/ft^3 (12 kN/m^3). Calculated self weight is printed in output text when analyzing for uplift.

Pile Material	Self Weight		Pile Types
	(lb/ft^3)	(kN/m^3)	
Steel	490	77	Steel Pipe Piles, H-Piles, Steel Piles, Tapered Monotube, Raymond
Concrete	150	23.6	Precast Concrete Piles
Timber	50	7.9	Timber Piles

Table 3.2 Notes about Self Weight for Uplift Capacity

Self weight of the modeled pile is not taken into account for compression loads since the influence is minimal and often ignored. If needed, users can subtract a calculated weight (submerged or not, as appropriate) from the compression capacity provided by APILE.

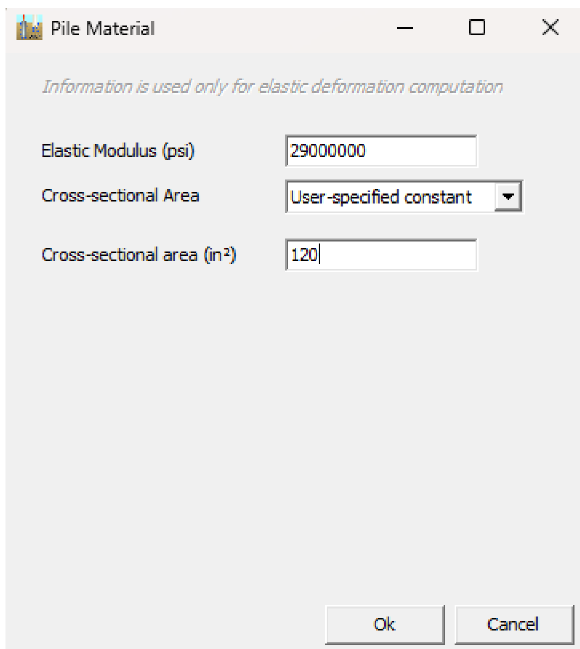
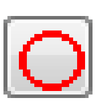


Figure 3.9 Data > Pile Material

3.2.5 Data > Pile Section Properties



This selection is automatically enabled if the user selected to analyze a pile type. This submenu option allows the user to input dimensions and section properties for piles with circular cross sections. A general description for the data needed under each entry of the Data > Pile Properties submenu option is listed below and shown in Figure 3.11.

3.2.5.1 Pile Type

The user may select one of the following pile types:

Steel Pipe or Non-tapered Monotube… includes any steel pile with circular section or for circular tubing. Piles with a taper (changing diameter) can be considered here but the extra load transfer from the tapered portion will be ignored when using this selection.

Timber…this selection is for timber piles with uniformly varying circular section (more common) but also applicable to straight timber (not used often). The theory for extra load transfer from the angle of pile taper is only applicable to the FHWA method (see Section 3.5 of the APILE Technical Manual). In addition to elastic deformation, a distinction for the response of timber piles (based on pile material) is also provided by the USACE method (see Section 3.4 of the APILE Technical Manual).

Precast Concrete (tubular)…this is for any type of circular concrete piles. The user may also select if Open-Ended Pile or Close-Ended Pile (see comments above).

Precast Concrete (non-tubular)…this is for any type of non-circular concrete piles. For non-tubular concrete piles, users may not specify whether the pile is open-ended or close-ended.

Raymond Step-Taper…this selection is for Raymond steel piles with uniformly varying circular section. The theory for extra load transfer from the angle of pile taper is only applicable to the FHWA method (see Section 3.5 of the APILE Technical Manual). For this pile type, the angle of pile taper should be entered by the user in degrees and is measured from the vertical (less than 90 degrees), where an entry of 0 indicates a straight pile.

Raymond Uniform Taper…this selection is for Raymond steel piles with uniformly varying circular section. The theory for extra load transfer from the angle of pile taper is only applicable to the FHWA method (see Section 3.5 of the APILE Technical Manual). For this pile type, the angle of pile taper should be entered by the user in degrees and is measured from the vertical (less than 90 degrees), where an entry of 0 indicates a straight pile.

H-Piles/Steel…this selection includes any steel pile that is <u>not circular</u> in section, such as H-piles or wide flanges that are used as driven piles.

Straight/Tapered Monotube Pile…this selection is for steel piles with varying circular section. The theory for extra load transfer from the angle of pile taper is only applicable to the FHWA method (see Section 3.5 of the APILE Technical Manual). For this pile type, the angle of pile taper should be entered by the user in degrees and is measured from the vertical (less than 90 degrees), where an entry of 0 indicates a straight pile.

Total Pile Length

This is equal to the summation of the stickup length (if any) plus maximum penetration length that is expected for the pile. The program will compute side resistance and end bearing at every depth interval until reaching the specified total pile length.

The load-vs-settlement curve will also be computed based on the total pile length. For the final design, the user may need to enter the exact total length in order to generate proper load-vs-settlement data. The English unit for this variable is “ft”, while “meter” is for the SI unit.

Pile Stickup Length

This input represents the length of pile that is sticking up above ground level. This length is only used in computations of elastic shortening since no axial load transfer occurs above ground. The English unit for this variable is "ft" while "meter" is for the SI unit.

Zero-Friction Length

This number (always positive) represents the length of pile immediately below grade level that is declared as noncontributing to side resistance. The English unit for this variable is "ft" while "meter" is for the SI unit.

Batter Angle

This is the batter angle that should be entered by the user in degrees and measured as deviation from the vertical (less than 90 degrees), where an entry of 0 indicates a vertical/straight pile.

Outer Diameter

This is the outside diameter that will be used in the computations for circular piles. The English unit for this variable is "inch", while "millimeter" is for the SI unit.

Inner Diameter

This is the inside diameter that will be used in the computations for circular piles. The English unit for this variable is "inch", while "millimeter" is for the SI unit.

This entry is disabled for pile types where it is not applicable, such as concrete, Raymond, timber or tapered monotube piles. For close-ended pipe piles, the inner diameter can be entered as zero or the user may enter an inner diameter and select "plugged" condition at the bottom of this window screen. However, the inner diameter entry for close-ended piles is used to calculate the Cross Section Area (when selecting Data > Pile Material > Auto Compute). User must enter valid Inner Diameter for those cases.

The APILE program computes skin friction on both outside and inside area for pipe piles. In clay layers, the user-specified remolded shear strength is used to compute the inside skin friction.

Taper Angle

This entry is disabled unless the Pile Type includes a Taper. For any pile type selected as tapered, the angle of pile taper should be entered by the user in degrees and is measured from the vertical (less than 90 degrees), where an entry of 0 indicates a non-tapered (straight) pile. The analysis of tapered piles is only covered by the FHWA codes (Data > Computational Method > Load Capacity Methods). For capacity computations in methods other than FHWA, the APILE software will use the reduced end bearing that corresponds to the area at the tip of the pile. However, for side resistance (in methods other than FHWA), the program will use for the complete pile length the surface area that corresponds to the top diameter.

Straight Length

This entry is disabled unless the Pile Type includes a Taper. For tapered piles, this option specifies the portion of the pile, measured from the pile head, that is straight before tapering starts to take effect.

Open-Ended Pile

For Steel Pipe or Non-tapered Monotube and for Precast Concrete (tubular) the user may place a check mark on this entry to specify that the pipe pile is driven open ended. With an Open-Ended Pile the user will have the option to select a method to calculate the internal pile plug. For the FHWA method (see Section 3.5 of the APILE Technical Manual), this entry also determines the influence in pile capacity due to the displaced volume.

Plugged/Unplugged Conditions

This entry is only shown for pipe piles, where the user is provided with controls for the load transfers from the internal pile plug. This entry is not shown in pile types where it is not applicable, such as concrete, Raymond, timber or tapered monotube piles.

For close-ended pipe piles, the user may enter an inner diameter of zero or the user may enter a value for inner diameter and select the "plugged" condition. Both methods provide the same results for close-ended pipe piles.

For practical reasons, in open-ended piles with Auto Compute the internal side friction is added to the end bearing. This is partly because in the APILE program the end bearing plus internal side friction are added together until a plug forms (until it reaches the equivalent end bearing of a close-ended pipe).

In the CPT-based methods (NGI 99, ICP/MTD, FUGRO and UWA) for APILE Offshore the user is required to specify either plugged or unplugged condition for computations of static capacity on open-ended pipe piles. APILE will determine the plugged or unplugged conditions for the CPT-based methods based on the internal computations of pile plug (when users select Auto Compute).

Lower End Section Inner Diameter (EID)

In open-ended pipe piles, occasionally, a thick-walled section is used in the lower end of the piles to prevent damage during driving. This enlarged-end section is usually referred to as "driving shoe."

The user may specify in this entry a value for the inner diameter of a thick-walled end section. The inner diameter of the end section must be entered in inches when using English units or millimeters when using SI units. Entering any value different than zero for EID instructs APILE to also use the next entry (ESL) since internal load transfers in side resistance (on open-ended piles) are ignored after (above) the ESL length.

This value can be left as zero when the pile section is uniform along the complete length. This entry is disabled for close-ended piles.

Lower End Section Length (ESL)

In direct relationship to the Lower End Section Inner Diameter (see previous section), the user here specifies the length of the thick-walled end section of the pile. Again, this length is specified to be zero if a driving shoe is not used during pile driving (for uniform piles). The English unit for this variable is "ft", while "meter" is for the SI unit. This entry is disabled for close-ended piles.

Internal load transfers in side resistance (on open-ended piles) are ignored after (above) this Lower End Section Length (ESL). This is because the soil is highly disturbed after the change in pile diameter (from a smaller to a larger inner diameter, or after an internal stiffener). If the user wants to keep considering internal side resistances even after the change in diameter (from the driving shoe) then the user could enter a fictitiously long value for Lower End Section Length (ESL).

Non-circular Properties: Cross-section Perimeter

The perimeter is used by the program for computations of skin friction. For H-piles, most users would conservatively input the perimeter of the rectangular box formed between the flanges. The English unit for this variable is "inch", while "millimeter" is for the SI unit.

Non-circular Properties: Tip Area

The tip area for the noncircular section is used by the program for computations of tip resistance (resistance in end bearing) and also influences side resistance for certain Methods of Pile Capacity. For H-piles, most users would input the area of the rectangular box formed between the flanges ('plugged' H pile). However, in very soft clay the soil between the flanges will probably not plug the H-pile and it is thus recommended to be more conservative using only the cross-sectional area of the metal ('unplugged' H pile).

The English unit for this variable is "inch", while "millimeter" is for the SI unit. This entry is used to calculate the Cross Section Area (when selecting Data > Pile Material > Auto Compute) that is displayed as an alternative for computations of elastic deformations of the pile.

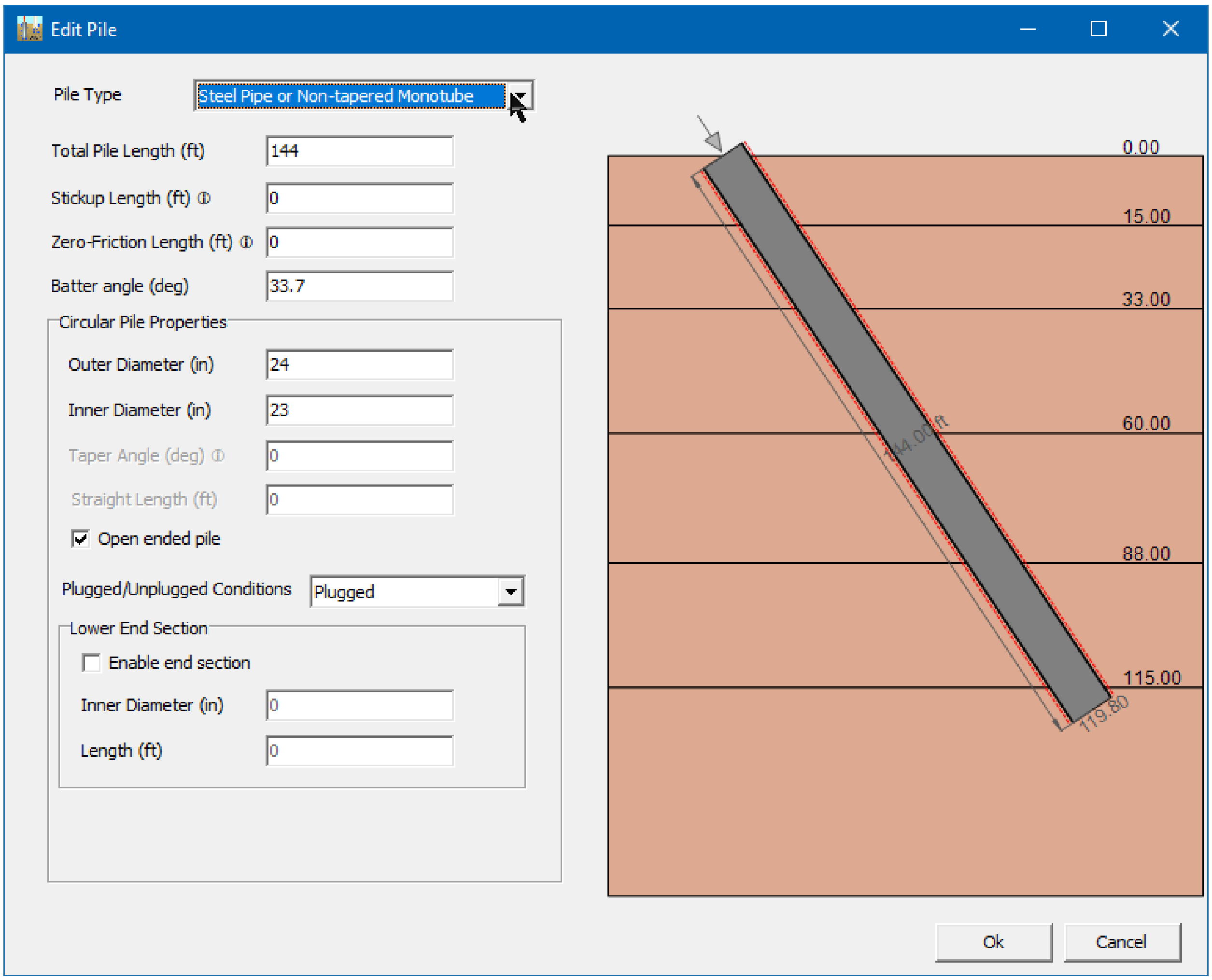


Figure 3.10 Sample Data > Pile Section Properties

For H-Piles/Steel, users may use the provided utility for importing suggesting cross-sectional perimeter and areas (Figure 3.11). Removing the check mark on Use predefined allows the user to edit any of the values.

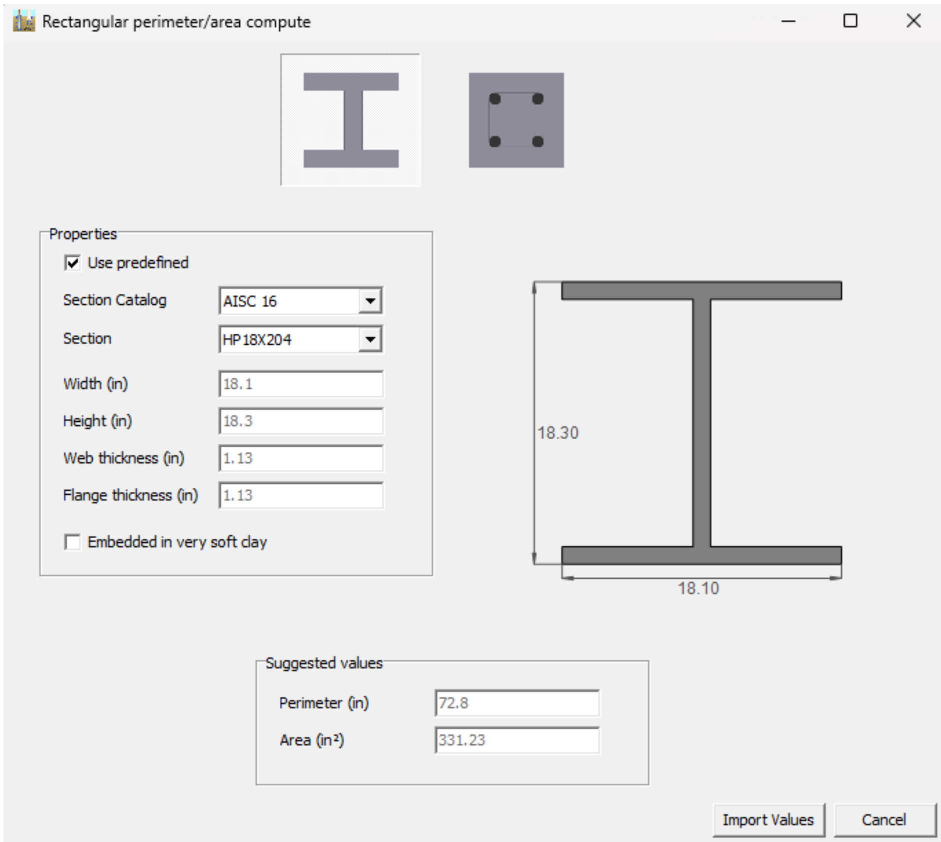
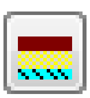


Figure 3.11 Utility for estimating cross-sectional area and perimeters

3.2.6 Data > Soil Layers



This selection allows the user to enter a layering system and to specify the different types of soil and their mechanical properties. Users are able to edit soil layers using the Standard APILE Soils Table (Edit Soil Layer Table) or with the new CPT (Cone Penetration Test) Interpreter (Edit Soil Layers with CPT). The latter CPT Interpreter option is only available in models where layering data was imported from a CPT file.

3.2.6.1 Editing Soil Layers with Standard APILE Soils Table

An illustration of the Soil Layers > Edit Soil Layer Table window using the standard APILE Soil Tables for an example application is shown in Figure 3.13.

This dialog is broken into two parts:

- On the left side of the window, soil layering is defined.
- On the right, layer properties for the selected layer are displayed. In general, values consist of entry fields for the top and bottom of the soil layer. The user may enter different

parameters for the top and the bottom of each layer. The program will linearly interpolate the data for any point between those two depths. The following sections will provide general description on data needed for each soil type.

Preview

This column provides a preview of the soil layer properties color coded based on select soil type. Please note that currently, number of soil layers that may be used in APILE is limited to 40.

Inputs of mechanical properties for the different types of soil layers are explained in Section 3.2.8.2 to Section 3.2.8.4 of this Manual.

The Append Layer button inserts a new soil layer at the bottom of the profile that is already defined. The Insert Layer button inserts a new soil layer immediately below the layer where the current row is selected. The Delete Layer(s) deletes the selected layers in the table.

Depth at Bottom of Each Layer

Values for the bottom of each soil layer are entered with respect to an origin of coordinates set at the ground surface and positive downwards. As a minimum, the bottom of the last soil layer must be two pile diameters deeper than the depth of the modeled pile. This is because the APILE program, for computations of end bearing, uses an average of soil properties within 1.5 pile diameters above and below the pile tip.

Soil Type

There are two internal types of soils that may be specified for program APILE. The user specifies the desired soil type using a dropdown list with the following choices:

Code Number	Internal Soil Type
1	Sand
2	Clay
3	Silt*

Silt is only available for models with the USACE method.

3.2.6.2 Common Soil Layer properties

Max. Side Friction

In this entry the user may specify the maximum value of skin-friction transfer that is permissible for a given stratum. The APILE program will compare its internally-computed value (according to the selected design method) with the maximum provided by the user in this entry and use the smaller of these two values for the final computation. If the user does not want to add any restriction on the computed value from APILE, leave this entry to be auto computed.

Max. End Bearing

In this entry the user may specify the maximum value of end-bearing transfer that is permissible for a given stratum. The APILE program will compare its internally-computed value (according to the selected design method) with the maximum provided by the user in this entry and use the smaller of these two values for the final computation. If the user does not want to add any restriction on the computed value from APILE, leave this entry to be use internally-computed values.

Side Friction Reduction/Resistance Factor

This entry is provided for entering a factor or multiplier that applies to one of the following conditions:

- An LRFD resistance factor on side friction (if the user unchecked the checkbox button Data>Computational Method>Load Settlement>Use Reduced t-z & Q-w unit tip transfers), or
- A *t*-multiplier/factor in the *t-z* curves (if the user selected the checkbox button Data>Computational Method>Load Settlement>Use Reduced t-z & Q-w unit tip transfers).

Enter 1.0 (default) for no reductions on the computed values of side friction.

End Bearing Reduction/Resistance Factor

This entry is provided for entering a factor or multiplier that applies to one of the following conditions:

- An LRFD resistance factor on tip resistance (if the user unchecked the checkbox button Data>Computational Method>Load Settlement>Use Reduced t-z & Q-w unit tip transfers), or
- A *Q*-multiplier/factor in the *Q-w* curves (if the user selected the checkbox button Data>Computational Method>Load Settlement>Use Reduced t-z & Q-w unit tip transfers).

Enter 1.0 (default) for no reductions on the computed values of tip resistance.

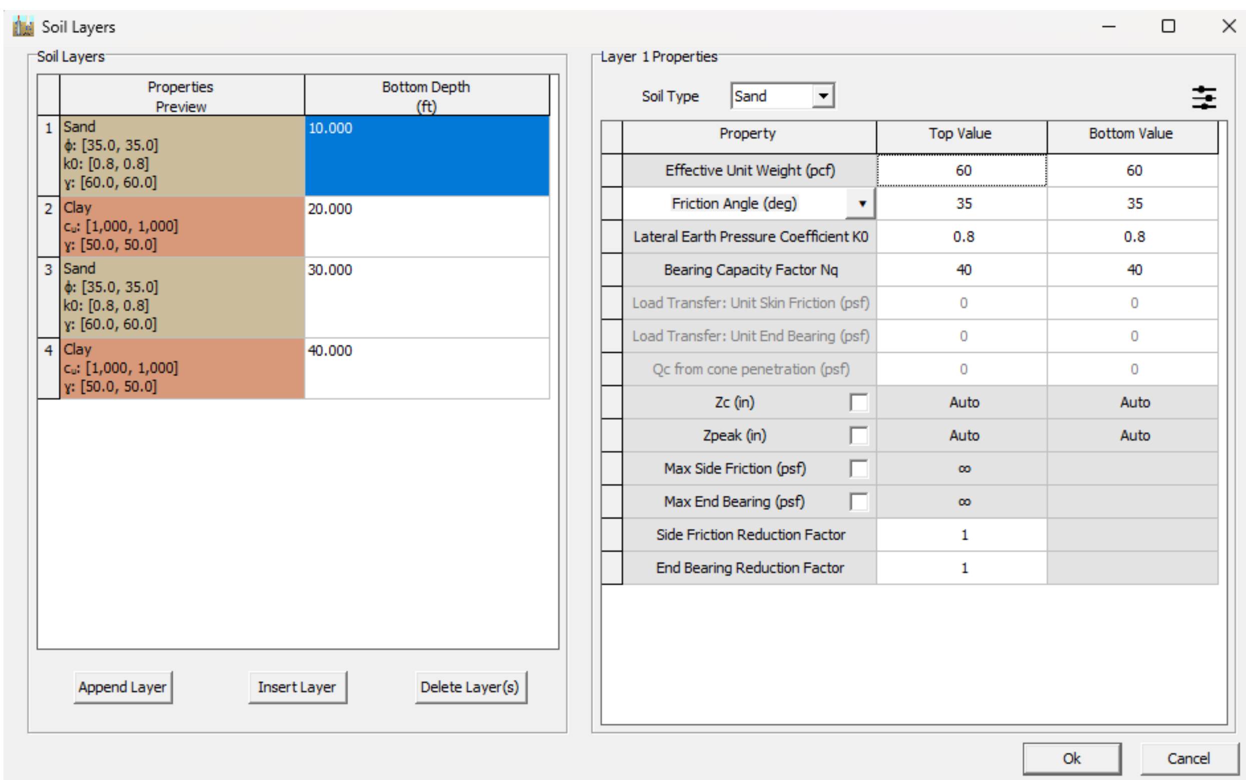
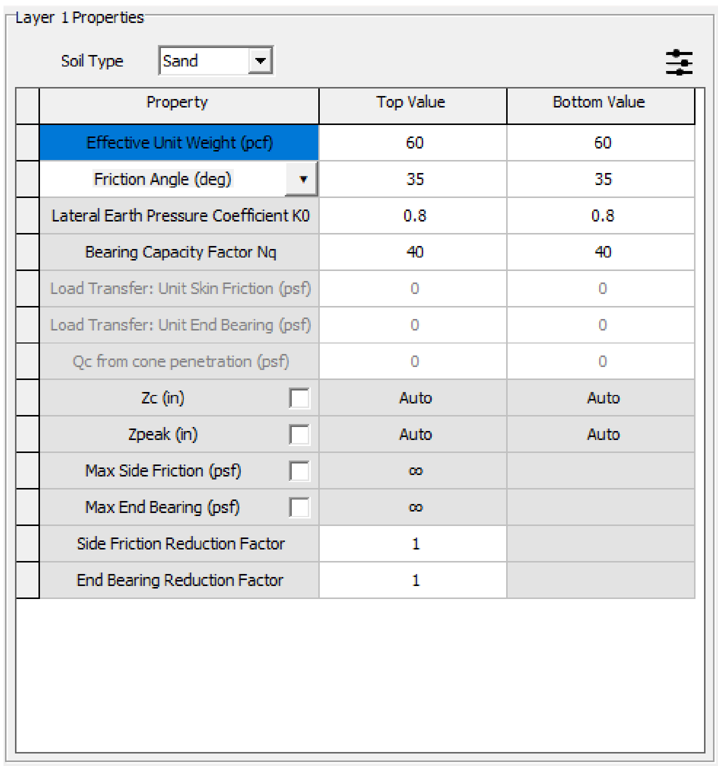


Figure 3.12 Sample Data > Soil Layers > Edit Soil Layer Table (using APILE Tables)

3.2.6.3 Soil Data for Sand Layers

A sample input view for this soil type is shown in Figure 3.14. Notice that some of the input parameters may be grayed out (inactive), since they depend on input-data selections specified under the Data > Computational Methods menu. Inactive/disabled (grayed out) parameter parameters are not necessary and thus not taken into account for the model that is being evaluated.

The required properties for sand layers are explained below. Values are entered for top and bottom of each layer, the APILE program automatically interpolates linearly the intermediate values between those entries. Notice that for computations of end bearing, APILE uses by default an average of soil properties within 1.5 pile diameters above and below the pile tip (which may be modified by the user under the Options > Control Options > Average Depth to Estimate Tip Resistance).



Property	Top Value	Bottom Value
Effective Unit Weight (pcf)	60	60
Friction Angle (deg)	35	35
Lateral Earth Pressure Coefficient K0	0.8	0.8
Bearing Capacity Factor Nq	40	40
Load Transfer: Unit Skin Friction (psf)	0	0
Load Transfer: Unit End Bearing (psf)	0	0
Qc from cone penetration (psf)	0	0
Zc (in)	Auto	Auto
Zpeak (in)	Auto	Auto
Max Side Friction (psf)	∞	
Max End Bearing (psf)	∞	
Side Friction Reduction Factor	1	
End Bearing Reduction Factor	1	

Figure 3.13 Sample soil data for sand layers

Effective Unit Weight

These entries are required (enabled) for all sand models and correspond to values of effective unit weight of the soil. The effective unit weight is equal to the total unit weight when above the water table and equal to the submerged unit weight when below the water table. Values for the top and bottom of the layer are entered in standard units of force per unit volume (either lb/ ft^3 (pcf) or kN/ m^3).

Friction Angle

These entries are required (enabled) for all sand models and correspond to values of the internal angle of friction (also known as friction angle or ϕ angle) for the top and bottom of the sand layer. It is recommended that the user enters actual values of Friction Angle using the standard units of degrees.

If the actual Friction Angle values are not available, the user may alternatively enter Blow Count values from Standard Penetration Tests (SPT). For friction transfers (transfers in side resistance), APILE converts internally between the user-specified values of Blow Counts from SPT to equivalent Friction Angle using the general relationship reported by AASHTO 2012 (modified after Bowles, 1977) that is shown in Table 3.4. As shown in the first column title in Table 3.4, the entries of Blow Counts from SPT are expected to be for N_{60}.

Please notice that releases of APILE prior to v2019 used the older correlation shown in Table 3.5 after Gibbs and Holtz, 1957. Properties estimated from these correlations tend to have greater variability than actual laboratory measurements. Some geotechnical manuals recommend that properties estimated from correlation to in-situ field tests or to laboratory tests should be based on multiple measurements within the geologic unit. Users should consult the accompanying Technical Manual for other comments of side resistance in sand layers (for each method).

When the user provides values of Blow Count the computer program APILE uses those values for computations of end bearing following equations and limits specified in the Technical Manual (comments of end bearing in sand layers).

N_{60} from SPT (blows/ft)	Overburden Stress		
	0 lb/in^2	20 lb/in^2	40 lb/in^2
	Friction Angle ϕ (degrees)		
<4	25	27.5	30
4	27	29.5	32
10	30	32.5	35
30	35	37.5	40
50	38	40.5	43

Table 3.3 Current correlation between SPT N and ϕ used by APILE for transfers in side resistance (AASHTO, 2012)

The kinetic energy delivered to the sampler varies with hammer type (*i.e.*, donut, safety, automatic) hammer manufacturer, hammer maintenance, and operator performance. The average energy efficiency is defined as the ratio of measured kinetic energy to potential energy expressed as a percentage. Research has shown that average energy efficiency is approximately 60 percent in U.S. practice and, therefore, SPT correlations have been developed on the basis of a standard-of-practice corresponding to 60 percent efficiency. The energy efficiency of each SPT hammer and operator can be measured for calibration according to procedures given in ASTM D-4633. Field N-values are then adjusted to the equivalent value corresponding to 60 percent efficiency as follows:

$$N_{60} = N\left(\frac{ER}{60}\right) \tag{3.1}$$

where: N_{60} = N value corrected to 60 percent efficiency, N = field measured SPT N-value, and ER = energy efficiency (%) as determined by measurements in accordance with ASTM D-4633.

N (SPT) blows/ft	Overburden Stress, lb/in^2 0	20	40
	Values of ϕ, degrees		
0	0		
2	32		
4	34		
6	36	30	
10	38	32	31
15	42	34	32
20	45	36	34
25		37	35
30		39	36
35		40	36
40		41	37
45		42	38
50		44	39
55		45	39
60			40
65			41
70			42
75			42
80			43
85			44
90			44

Table 3.4 Older relationship between N and ϕ (Gibbs and Holtz, 1957)

Lateral Earth Pressure Coefficient K_o (API, USACE and Lambda Methods)

Entries for K_o are required (enabled/active) only for models using the API, USACE and/or Revised Lambda methods (Data > Computational Methods > Pile Load Capacity Methods). These entries represent values of the lateral earth pressure coefficient, K_o, for the top and bottom of the sand layer. These entries are disabled (grayed out) if those methods are not selected by the user.

APILE will estimate K_o values and print them on the output text file when the user leaves the default value of 0 for this entry. In models that include more than one method (mixed methods), the K_o values that are calculated internally within APILE are assigned to all methods. It is recommended that the user computes outside APILE the K_o values that correspond to the Top and Bottom of each soil layer (again, in mixed methods, the same user-specified values will be used for all methods).

These entries represent values of the lateral earth pressure coefficient, K_o, for the top and bottom of the sand layer. Values for K_o depend on the relative density of the sand and the process by which the sand deposits were formed. If the sand deposits did not receive any artificial compaction, values of K_o range from about 0.40 for loose to 0.50 for dense sand. Artificial compaction or tamping may increase K_o values to 0.80.

The earth pressure coefficient, K_o, is used to calculate the skin friction in granular soils. A K_o of 0.8 is recommended for open-ended pipe piles that are driven unplugged for loadings in both tension and compression. A K_o of 1.0 is recommended for full-displacement piles.

Bearing Capacity Factor, N_q (API and Lambda Methods)

Entries for N_q are required (enabled/active) for models using the API and Lambda methods (Data > Computational Methods > Pile Load Capacity Methods). These entries are disabled (grayed out) if one of these methods is not selected by the user. When other methods are used, merely for comparative purposes, the N_q values are assigned internally within APILE.

APILE will estimate values of N_q and print them on the output text file when the user leaves the default value of 0 for this entry. However, it is recommended that users enter their own estimate of N_q values for the top and bottom of each applicable layer.

The N_q factor is used to calculate the end-bearing capacity of piles in granular soils. Recommended values of N_q and maximum unit end bearing are provided in Table 3.6.

Soil	N_q	Limiting q, kips/ft^2 (MPa)
Very loose to medium, sand to silt	8	40 (1.9)
Loose to dense, sand to silt	12	60 (2.9)
Medium to dense, sand to sand-silt	20	100 (4.8)
Dense to very dense, sand to sand-silt	40	200 (9.6)
Dense to very dense, gravel to sand	50	250 (12.0)

Table 3.5 Guidelines for tip resistance in siliceous soil

Load Transfer: Unit Skin Friction and Unit End Bearing

These entries are enabled if the user selects Load Transfers specified by User under the Data > Computational Method > Pile Load Capacity Methods The user-specified values in these entries are not used in any other method. Values are entered in standard units of force per unit area (either lb/ft^2 (psf) or kN/m^2 (kPa)).

Q_c from Cone Penetration

Entries for Q_c are required (enabled/active) only for APILE Offshore Version and for models using CPT-based methods such as NGI 99, MTD, Fugro and/or UWA methods (Data > Computational Methods > Pile Load Capacity Methods). These entries are disabled (grayed out) in APILE Standard Version and if a CPT-based method is not selected by the user.

The user can enter Q_c values for the top and bottom of each sand layer using standard units of force per unit area (either lb/ ft^2 or kN/ m^2). The Q_c values are used to calculate the end bearing in granular soils according to the recommendations provided by each CPT-based method as explained in Chapter 3 of the separate Technical Manual.

Zc

Entries for Zc are required (enabled/active) only for models using the USACE method for load settlement (Data > Computational Methods > Load Settlement) for *Q-w* curves. Leaving this entry set to Auto instructs APILE to use the default of 5 percent of the pile outer diameter (i.e., $Z_c/D=0.05$).

Z Peak

Entries for Z_{peak} are required (enabled/active) for models using the API method (any method outside USACE) for load settlement (Data > Computational Methods > Load Settlement) for *t-z* curves. These entries are disabled (grayed out) if the USACE method is selected by the user.

The user can enter a value for the Z_{peak} variable for the API Load Settlement Method as explained in Section 4.8.1 of the APILE Technical Manual. Leaving this entry set to 'Auto' instructs APILE to use the default of one percent of the pile outer diameter (i.e., $Z_{peak}/D=0.01$) as recommended by API RP 2A-WSD (2014) for routine design purposes. However, there is significant uncertainty on this value and it ranges from 0.25% to 2.0% of the pile diameter. Values other than the APILE default may be considered in cases where axial pile stiffness is critical in the model/design.

3.2.6.4 Soil Data for Clay Layers

A sample dialog box for this soil type is shown in Figure 3.15. Notice that some of the input parameters may be grayed out (inactive/disabled), since they depend on input-data selections specified under the Data > Computational Methods menu. Inactive/disabled (grayed out) parameter parameters are not necessary and thus not taken into account for the model that is being evaluated.

The required properties for clay layers are explained below. Values are entered for top and bottom of each layer (respectively, Top Value and Bottom Value columns), the APILE program automatically interpolates linearly the intermediate values between those entries. Notice that for computations of end bearing, APILE uses by default an average of soil properties within 1.5 pile diameters above and below the pile tip (which may be modified by the user under the Options > Control Options > Average Depth to Estimate Tip Resistance).

Effective Unit Weight

These entries are required (enabled) for all clay models and correspond to values of effective unit weight of the soil. The effective unit weight is equal to the total unit weight when above the water table and equal to the submerged unit weight when below the water table. Values for the top and bottom of the layer are entered in standard units of force per unit volume (either lb/ ft^3 or kN/ m^3).

Undrained Shear Strength

These entries are required (enabled) for all clay models and correspond to values of the undrained shear strength at the top and bottom of the clay layer. Ordinarily, these values are taken as one half of the compression strength of samples obtained from unconsolidated-unconfined triaxial tests. Values for the top and bottom of the layer are entered in standard units of force per unit area (either lb/ ft^2 or kN/ m^2).

Remolded Shear Strength

Entries for Remolded Shear Strength are available (enabled/active) only for models with Open-Ended Piles (under Data > Pile Material either Steel Pipe Piles or Precast Concrete). These entries are disabled (grayed out) if those pile types are not selected by the user.

When a pipe pile is driven into clay soils, the clay inside the pipe forms a plug. The plugged clay may be remolded during the driving process. The Remolded Shear Strength variable represents the values for the shear strength that will be used for computing the side friction from the remolded soil plug inside the pipe pile.

Load Transfer: Unit Skin Friction and Unit End Bearing

These entries are enabled if the user selects Load Transfers specified by User under the Data > Computational Method > Pile Load Capacity Methods. The user-specified values in these entries are not used in any other method. Values are entered in standard units of force per unit area (either lb/ft^2 (psf) or kN/m^2 (kPa)).

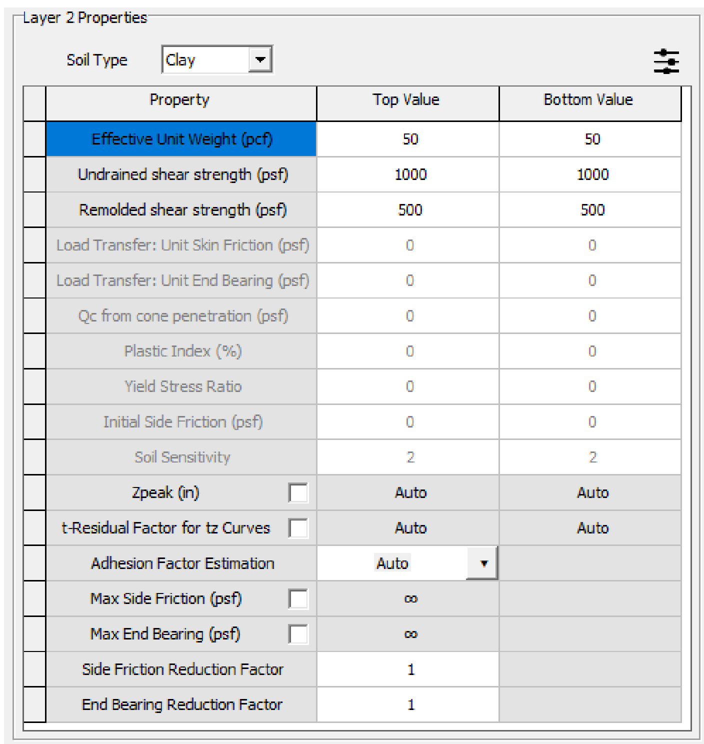


Figure 3.14 Sample soil data for clay layers

Data for APILE Offshore Methods

The following entries are required (enabled/active) only for APILE Offshore Version and for models using CPT-based methods such as NGI, MTD, Fugro and/or UWA methods (Data > Computational Methods > Pile Load Capacity Methods). These entries are disabled (grayed out) in APILE Standard Version and if a CPT-based method is not selected by the user.

Q_c from Cone Penetration Data

The user should enter Q_c values for the top and bottom of each clay layer using standard units of force per unit area (either lb/ ft^2 or kN/ m^2). The Q_c values are used to calculate the end bearing according to the recommendations provided by each CPT-based method as explained in Chapter 3 of the separate Technical Manual.

Plasticity Index

The user should enter Plasticity Index values in percentage (%) for the top and bottom of each clay layer. As explained the Technical Manual, the NGI method uses the Plasticity Index (referenced as 'Plastic Index, I_p') to calculate the β^{NC} value (for side friction). The other CPT-based methods use the Plasticity Index to calculate the interface angle of friction δ_f as recommended by the ring shear interface results $\delta_{ultimate}$ in clays after Saldivar-Moguel (2002) and Shell UK Ltd (recommended in ICP documentation).

Yield Stress Ratio (YSR)

The Yield Stress Ratio is not necessary (grayed out/disabled) for the NGI (Norwegian Geotechnical Institute) method but available (active) for all other APILE Offshore methods. Yield Stress Ratio is defined as the ratio of effective vertical yield stress (σ'_{vy}) to the vertical in situ effective stress (σ'_{vo}). The similar *OCR* (over-consolidation ratio) is defined as the ratio of vertical maximum pre-consolidation effective stress (σ'_{vc}) to the vertical in situ effective stress (σ'_{vo}). Yield Stress Ratio is also named as 'Apparent OCR' in some literature, but generally Yield Stress Ratio is greater than *OCR*.

Soil Sensitivity

The Soil Sensitivity a dimensionless positive number representing the loss of strength in cohesive soils due to disturbance or remolding. In earlier versions of APILE, this value was implicitly assumed to be the ratio of the Undrained Shear Strength to Remolded Shear Strength. This Soil Sensitivity parameter is used in MTD, Fugro, UWA, A&H, and UCPT computation methods.

Initial Side Friction

The Initial Side Friction entry is only available (enabled/active) for the ALM (Alm & Hamre) method and disabled (inactive) for all other APILE Offshore methods. The user should enter values of this parameter for the top and bottom of each clay layer using standard units of force per unit area (either lb/ ft^2 or kN/ m^2). When left as Auto this entry is computed per guidelines from the Alm & Hamre criteria mentioned in the Technical Manual.

Z Peak Value for t-z Curves, z_{peak}

Entries for Z_{peak} are required (enabled/active) for models using the API method (any method outside USACE) for load settlement (Data > Computational Methods > Load Settlement) for *t-z* curves. These entries are disabled (grayed out) if the USACE method is selected by the user.

The user can enter a value for the Z_{peak} variable for the API Load Settlement Method as explained in Section 4.8.1 of the APILE Technical Manual. Leaving this entry as Auto instructs APILE to use the default of one percent of the pile outer diameter (i.e., $Z_{peak}/D=0.01$) as recommended by API RP 2A-WSD (2014) for routine design purposes. However, there is significant uncertainty on this value and it ranges from 0.25% to 2.0% of the pile diameter. Values other than the APILE default may be considered in cases where axial pile stiffness is critical in the model/design.

t Residual Value for t-z Curves, t_{res}

Entries for t_{res} are required (enabled/active) for models using the API method (any method outside USACE) for load settlement (Data > Computational Methods > Load Settlement) for *t-z* curves. These entries are disabled (grayed out) if the USACE method is selected by the user.

The user can enter a value for the t_{res} variable for the API Load Settlement Method as explained in Section 4.8.1 of the APILE Technical Manual. Leaving this entry as Auto instructs APILE to use the default of 0.9 t_{max} (i.e., $t_{res} = 0.9\ t_{max}$) as recommended by API RP 2A-WSD (2014) as upper range for clays. The user may select to enter the lower range of 0.7 (i.e., $t_{res} = 0.7\ t_{max}$) or anything in between.

Adhesion Factor Estimation

Entries for Adhesion Factor are required (enabled/active) only for models using the FHWA method for pile capacity (Data > Computational Methods > Pile Load Capacity Methods). These entries are disabled (grayed out) if other methods are selected by the user.

With this entry, the select can choose the graph that is used to estimate the Adhesion Factor. Further details are described in Section 3.5.3 of the Technical Manual. The options are (reference Graphs A, B, C, and D for each option are provided by the Show Graph button):

0 – Default/Auto. Program will choose the method based on the layout of the soil layers.
1 – Using Tomlinson Graph A
2 – Using Tomlinson Graph B
3 – Using Tomlinson Graph C
4 – Using Tomlinson Graph D

3.2.6.5 Soil Data for Silt Layers

This soil type is available for models using the USACE method (on its own, not with others) for load settlement (Data > Computational Methods > Method for Load Settlement) and for pile capacity (Data > Computational Methods > Method for Pile Capacity). This soil type is not visible if any other method is selected by the user (even if combined with the USACE method).

A sample input options for this soil type is shown in Figure 3.16. The required properties for silt layers are explained below. Values are entered for top and bottom of each layer, the APILE program automatically interpolates linearly the intermediate values between those entries. Notice that for computations of end bearing, APILE uses by default an average of soil properties within 1.5 pile diameters above and below the pile tip (which may be modified by the user under the Options > Control Options > Average Depth to Estimate Tip Resistance).

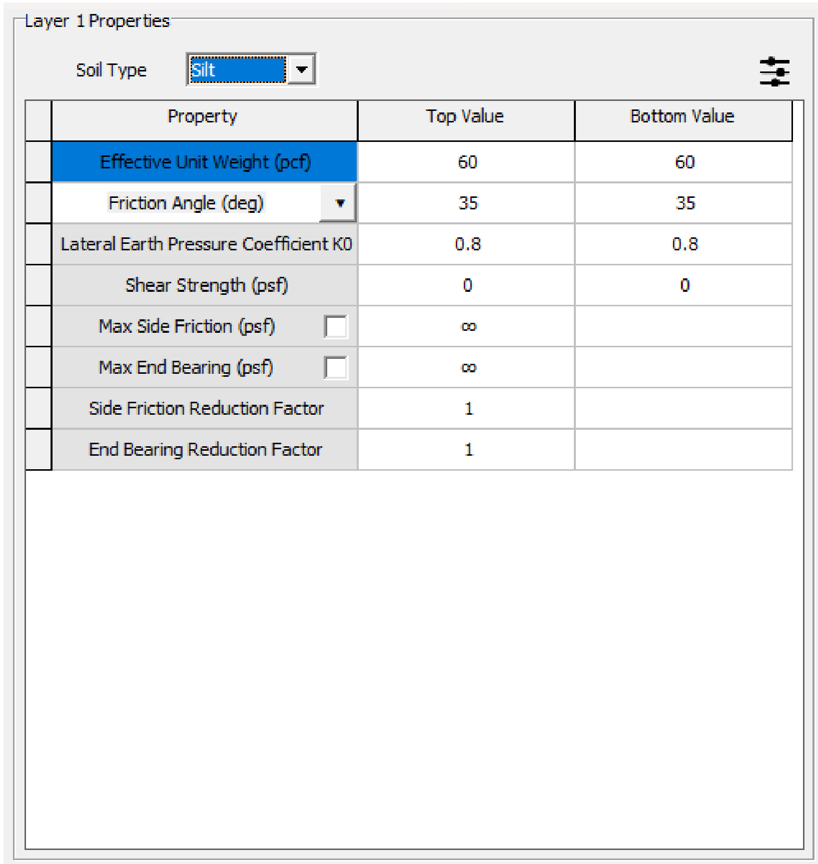


Figure 3.15 Sample soil data for silt layers

Please notice that releases of APILE prior to v2019 used the older correlation shown in Table 3.5 after Gibbs and Holtz, 1957. Properties estimated from these correlations tend to have greater variability than actual laboratory measurements. Some geotechnical manuals recommend that properties estimated from correlation to in-situ field tests or to laboratory tests should be based on multiple measurements within the geologic unit. Users should consult the accompanying Technical Manual for other comments of side resistance in sand layers (for each method).

When the user provides values of Blow Counts from SPT the computer program APILE uses those values for computations of end bearing following equations and limits specified in the Technical Manual (comments of end bearing in sand layers).

Lateral Earth Pressure Coefficient, K_o

These entries represent values of the lateral earth pressure coefficient, K_o, for the top and bottom of the silt layer. The earth pressure coefficient, K_o, is used to calculate the skin friction. USACE recommends a K_o value of 0.8 for compression and a value that ranges from 0.5 to 0.7 for tension.

Shear Strength

These entries correspond to values of the undrained shear strength at the top and bottom of the silt layer. Ordinarily, the values of effective cohesive strength (c) are obtained from the direct shear test or the triaxial consolidated drained test. Values for the top and bottom of the layer are entered in standard units of force per unit area (either lb/ ft^2 or kN/ m^2).

3.2.6.6 Editing Soil Layers with CPT Interpreter

The Data > Soil Layers > Edit Soil Layers with CPT menu is only available (enabled) if the user previously selected to Data > Import CPT Data from a cone penetration test. The menu and option to edit data with CPT is otherwise unavailable (grayed out). Users should check the next Section 3.2.9 to see how to Data > Import CPT Data from a cone penetration test.

An illustration of the Data > Soil Layers > Edit Soil Layers with CPT for an example application is shown in Figure 3.17. The figure also provides a reference for the organization of data and some of the main commands.

The left side of the screen shows the CPT data in graphical form. At bottom left, users can select the desired parameter to display in the graph. The parameters are separated between Imported values (Q Tip and Side friction) and Interpreted values (Unit Weight, Undrained Shear Strength, Friction Angle, and N(60)).

Suggested steps for newly imported CPT data (with no defined soil layers):

1. Users may first choose to display the plot of an Interpreted parameter that can help to define the soil layers. Choosing Undrained Shear Strength or Friction Angle can help the user to define the general depths for cohesive (Clay) and/or cohesionless (Sand) layers.
2. The user clicks the green + icon on the upper right to create soil layers and enters the appropriate depth of the bottom of each layer.
3. For each defined layer, click the drop down under Soil Type to select either Clay or Sand layer.
4. Click on button labeled Fill layers with CPT data so that CPT data (Imported and Interpreted) is used to fill applicable variables for top and bottom of each defined soil layer.
5. Select each soil layer (double click on left graph or at row on top table) and edit the layer properties to rounded and desired values (users may select averaged or lower-case envelopes to fit imported/interpreted parameters for each layer).
6. Click Ok button and select Yes to transfer edited soil data (overwrite) to APILE.
7. Select Data > Soil Layers > Edit Soil Layer Table to make refined edits of each soil layer with APILE.
8. Select Data > Soil Layers > Edit Soil Layers with CPT to make any further checks or edits using the CPT comparisons.

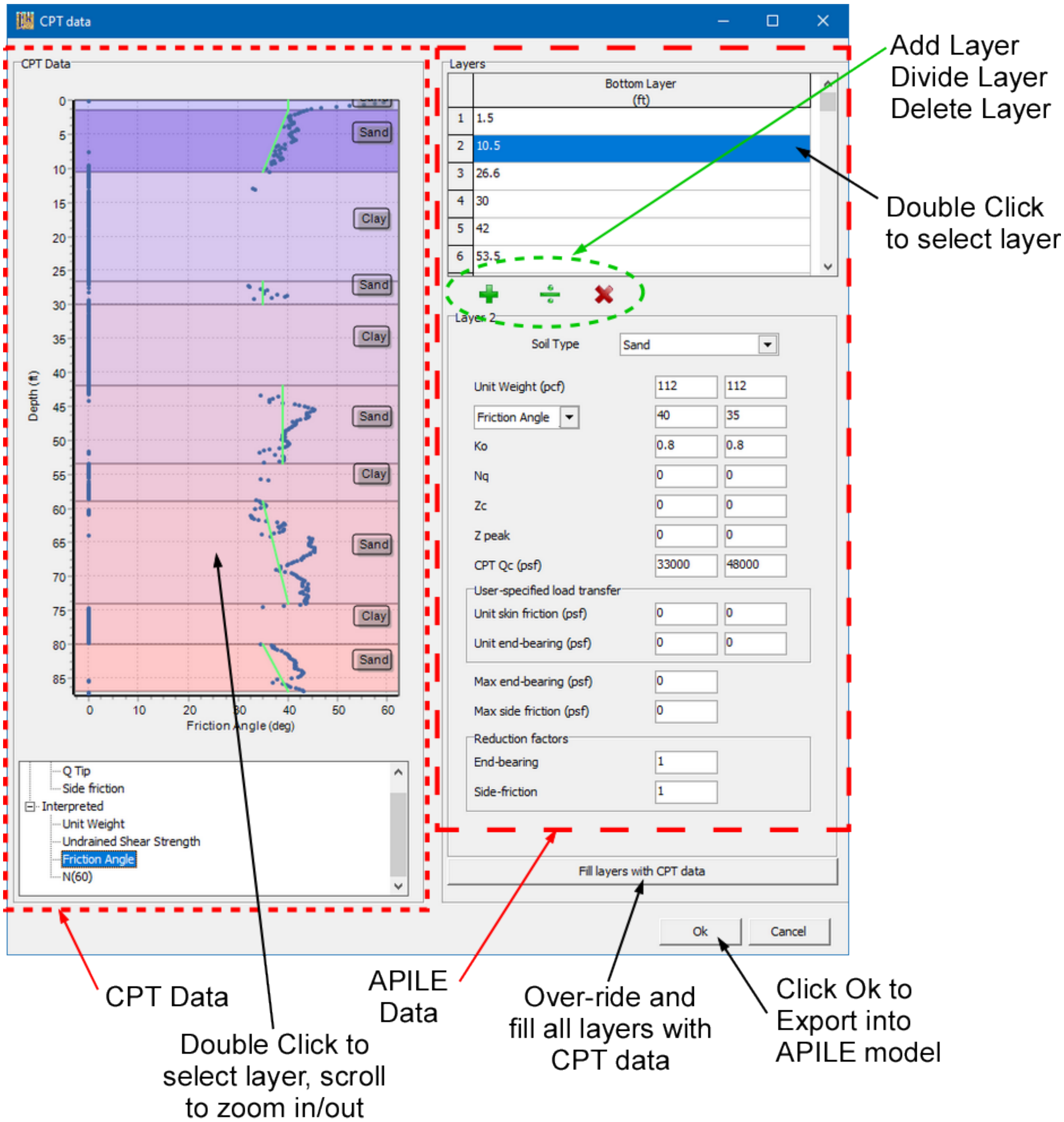


Figure 3.16 Sample File & Commands for Edit Soil Layers with CPT

3.2.7 Data > Import CPT Data

This selection allows the user to browse to an external file that contains ASCII (text) data from a cone penetration test (CPT) from any equipment manufacturer. An example of CPT data captured in metric units (which also uses the period as decimal character) is included in Figure 3.18. This figure also contains additional information regarding features of the Import CPT Data dialog screen.

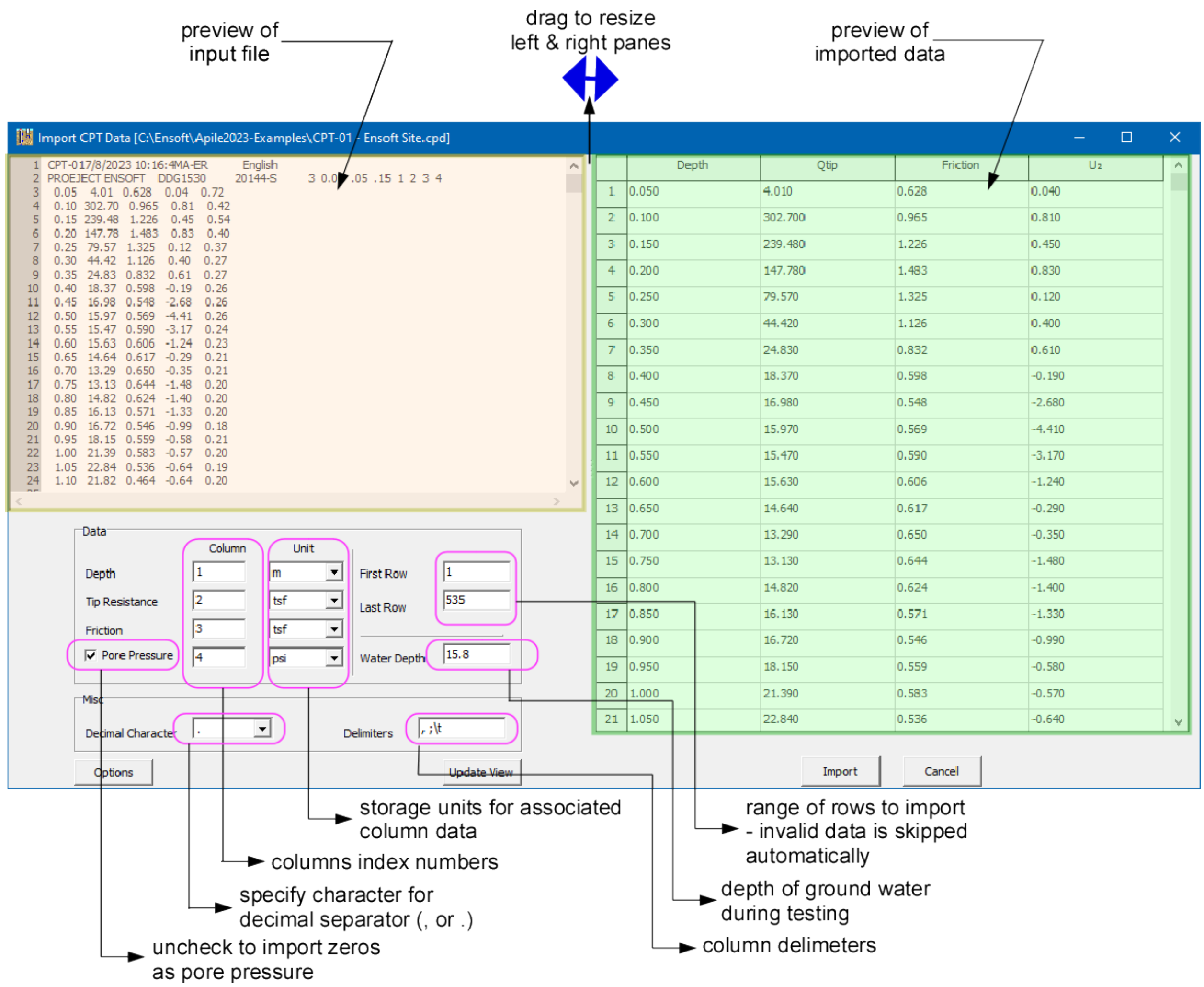


Figure 3.17 CPT Data Import Dialog

When first triggered, the Import CPT Data dialog tries to automatically select the best configuration for the data, and displays the data to be imported on the right pane. This preview pane of data to be imported can be updated at any time with the Update View button (middle of dialog, at bottom).

Using default values, the CPT data importer in APILE is normally able to open and interpret any CPT data file format, so as to recognize its organization of data and units. As indicated in Figure 3.18, the organized imported data is displayed on the table to the right of the screen (green shaded).

On the CPT data file to be imported, APILE requires the three or four entries per CPT record that are listed in Table 3.7. The following limitations are required for the source CPT data file:

- each record is written on a single line,
- each record is identifiable using a "depth" entry/parameter,
- records are sorted in ascending order of depth,
- three or four entries/parameters are listed per record (entries/parameters are shown in Table 3.7, they can be listed in any column order).

If the import data file does not satisfy the above criteria, it must be first manually adjusted before attempting to import it to APILE. If duplicate depth values (up to a tolerance) are present, only the first record (as read from top to bottom) is imported and other records with the same depth value are ignored. Each entry/parameter is identified by a column number and must be associated with a specific unit of measurement. Note that the separation of columns depends on the choice of Delimiters (bottom of Figure 3.18) that are specified by the user.

The units of the CPT data will be converted to the units that were selected by the user in the APILE model where the data is being imported. Existing data of the APILE model, outside soil layers, are not changed but rather complemented by the newly imported CPT soil data.

Users should verify that the data organization, units and values that are shown on the right table panel in Figure 3.18 are in accordance to the references provided by the CPT equipment manufacturer (or service agency). If the data was not recognized properly, the user should manually adjust the interpretation by changing the parameters that are shown at the bottom left of the screen in Figure 3.18. For any change to be effective, the user must select the desired entries and then click the Update View button in the lower middle.

Entry/Parameter	Description
Depth	Depth where the CPT readings took place. These entries are expected to be unique and sorted in ascending order from top to bottom.
Tip Resistance	Recorded tip resistance at each depth, in units of force per unit area. Once imported, these values are stored under the Q_{tip} or Q_c column/values in the import data table.
Friction	Recorded friction at each depth, in units of force per unit area. Once imported, these values are stored under the Friction or F_s column/values in the import data table.
Pore Pressure (optional)	Recorded hydrostatic pressure at each Depth, in units of force per unit area. Once imported, these values are stored under the U_2 column/values in the import data table. If the checkbox is not selected, pore pressure is imported to be zero for all records.

Table 3.6 Required Input Entries/Parameters on Source CPT Data File

3.2.7.1 Manual Adjustments of CPT Data

Some references for manual adjustments of data recognition (under the Data header in Figure 3.18) are as follows:

Main variables of Depth, Tip Resistance and Friction are normally provided by all CPT data files. Users can enter the proper order of these variables by changing the assigned Column number. Users may also change the units that are assigned to these variables by clicking and selecting in the drop down under Unit. Many CPT data files use mixed English and SI units.

One or more secondary variables may also be included in the CPT data file. The sample includes the variable Pore Pressure which may optionally be used during interpretations (users may also choose to remove the check mark and APILE will use zero for all pro pressure). Any other secondary variables contained in the CPT data file may be shown on the left table but will be ignored (not used) when importing into APILE (not shown on the interpreted table at the right side of the screen).

In the First Row and Last Row entries the user can specify which row on the left table has the first valid data entry (outside titles or comment fields/rows) and which has the last valid data entry (before ending/closing notes that maybe included in the CPT data file). Data lines that are found to not satisfy the required input properties are automatically discarded.

The Water Depth entry is left as zero by default but users are strongly encouraged to edit and enter the appropriate value if they know the depth to the water table during the field investigation (using the same units as Depth field). This information is normally not included in the CPT data file but usually measured and registered in the CPT field logs.

The user may select the Decimal Character, either period (dot) (.) or comma (,) that applies to their CPT data. This is useful for tests done in certain countries that also use the metric system.

The Delimiters entries indicate the characters that may be used in the CPT data file to separate columns of data. By default, the program includes a comma (,), space ( ), semi colon (;) and the tab (\t) indicators to separate variables included in the CPT data file.

3.2.7.2 Options Button

A sample of the selections under the Options button is shown in Figure 3.19. This button allows the user to select and enter various parameters that are used for interpretation of the CPT data.

The drop down for Friction Angle Method allows the user to select one of three different methods for the interpretation of friction angles:

Mayne (2006) as described in: Mayne. P.W. *Cone Penetration Testing*, *A Synthesis of Highway Practice*, NCHRP Synthesis 368, Transportation Research Board, Washington, DC, 2007.

Kulhawy & Mayne (1990) as described in: Kulhawy. F.H. and P.W. Mayne. *Manual on Estimating Soil Properties for Foundation Design*, Report EPRI EL-6800, Electric Power Research Institute, Palo Alto, CA, 1990.

Robertson & Companella (1983) as described in: Robertson. P.K., Campanella, R.G., Gillespie, D., and Greig, J., 1986. Use of Piezometer Cone Data. IN-SITU ’86, Use of In-situ testing in Geotechnical Engineering, GSP 6, ASCE, Reston, VA, Specialty Publication, SM 92, pp 1263-1280.

The N_{kt} Value is a cone factor used to obtain the estimated undrained shear strength of clays:

$$c_u = (q_t - \sigma_v) / N_{kt}$$

Where q_t is the corrected cone resistance, σ_v is the vertical stress and c_u is the undrained shear strength of the clay.

The N_{kt} Value usually varies from 10.5 to 18 and depends on the type of clay. Users may enter a Fixed value or may select for the program to Auto Compute. The Auto Compute uses the formulation suggested by Robertson & Cabal (2022):

$N_{kt} = 10.5 + 7 \log_{10} (F_R)$ (used for $F_R > 0$), where F_R is a *Normalized Friction Ratio* that is calculated internally based on other parameters.

The Net Area Ratio of Cone Tip is a parameter used to obtain the corrected cone resistance:

$$q_t = q_c + u_2 (1+ a)$$

Where q_t is the corrected cone resistance, q_c is the measured cone resistance, u_2 is the pore water pressure (see Pore Pressure in Section 3.2.9.1) and a is the Net Area Ratio of Cone Tip.

The 0.78 used by default is a common value for Net Area Ratio of Cone Tip. However, this value usually varies from 0.70 to 0.85 and should be obtained from the CPT manufacturer.

Users should read the referenced literature above for specifics about each method and parameter. If the user needs further description and control of the various intermediate parameters, they should investigate the separate EnCPT software which provides an enhanced version of the CPT Interpreter that is included with APILE: https://www.ensoftinc.com/products/encpt/

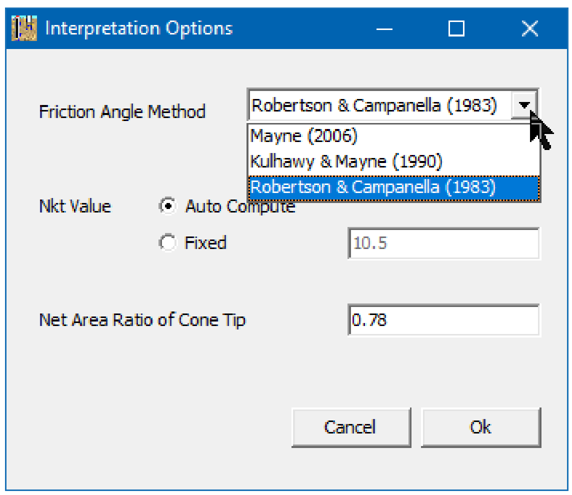


Figure 3.18 Sample Options button for Import CPT Data

3.3 Options Menu

3.3.1 Options > Units

This selection provides the user with a choice of input data in English Units, and S.I. Units (international units) as shown in Figure 3.20. In general, the following specific units of measurements are used frequently in the program:

Units	**Length**	**Force**	**Stress/Modulus**
English	foot (ft)	pounds (lbs)	psf or psi
International	meters (m)	kiloNewtons (kN)	kPa

The user should always check the unit descriptions which are associated to each variable in the program interface. For instance, *psi* instead of *psf* is used for the elastic modulus of pile material (Data > Pile Material > Elastic Modulus).

The user may change from one system of units to the other as many times as desired. The program will automatically convert all the appropriate input that was already specified by the user before the time of selection of a different system of units. Small rounding differences may appear if multiple changes of units are performed. The user must always check that input data have been converted appropriately.

By default, APILE always starts a new model in English Units. The selection of the desired units is important prior to importing CPT data (Data > Import CPT Data) since the imported values will always be converted to the units that were previously selected in the APILE model.

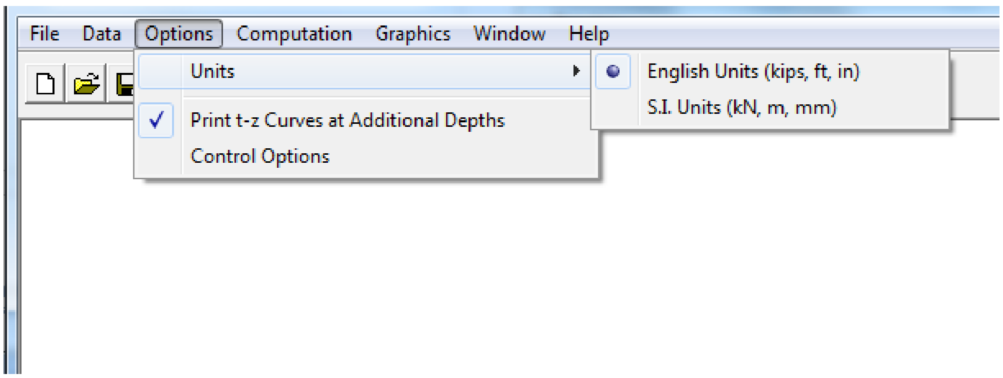


Figure 3.19 Options for units selection

3.3.2 Options > Control Options

This selection allows the user to enter certain control parameters for program performance and output. An illustration of the Options > Control Options dialog box for an example application is shown in Figure 3.22.

Length of each computation increment

This entry represents the length, in ft or m, of each element into which the pile is divided. A default of 1 ft (0.3048 m) is provided by the program. As a general reference, users should not select a length of computation increment that is larger than about half of the smallest soil layer. In some models, large increments may produce noticeable changes in the computational results which should be avoided.

Print increment

The user may select how often results are plotted (outputted) according to the number that is provided in this entry. The length of each "computation increment" is defined in the previous entry. The number used for print increment will not produce any effect in the internal computations of the program.

t-z and Q-w factors

The user may specify any *t* and/or *z* multipliers that is desired to be applied along the length of the modeled pile. The user may also specify any *Q* and/or *w* multiplier that is desired to be applied for the pile tip. This may be useful for certain LRFD-based codes that may suggest the use of a reduction factor (less than one) for load transfers in side resistance (*t* multiplier less than one) and/or in end bearing (*Q* multiplier less than one). The multiplier for associated movements (*z* and *w* multipliers) are normally left as one (unchanged).

Notice that any ‘t’ and ‘Q’ factors specified under this menu are multiplied to any corresponding factors that the user may also specify in the last two columns of the Data > Soil Layers menu for each soil layer if the user selected the ‘Use Reduced Unit Side Friction and Unit Tip Resistance’ radio button under ‘Data > Computational Method > Method for Load Settlement’ (covered in Section 3.2.4.2 of this manual).

Print Internally generated t-z curves

The user can instruct the program to generate *t-z* curves at user-specified depths. The APILE program automatically generates *t-z* curves at the top, middle, and bottom of each soil layer. The user can enter up to 50 other depths for printing of additional *t-z* curves.

Load Settlement Curve

Users may choose to enter specific tip movements by placement of a check mark under Specify Tip Movements and entering the desired movements (from smallest to largest). This can be useful if the user wants to obtain a smoother curve of load-vs-settlement (Graphics > Axial Load vs Settlement).

Depth/Elevation

Many users may prefer to enter the depths of soil layers in elevations and thus visualize the results of load transfers in the same elevation references. To use elevations, the user simply places a check mark under Use Elevations instead of Depth and enters the value of the elevation at the grade level (top of first soil layer).

For a model with a batter pile (Section 3.2.6 and Section 3.2.7), the selection (check mark) of Use Elevations instead of Depth will provide tabular and plot results of load transfers for vertical elevations. When using the default display of depth (no check mark), the tabular and plot results of load transfers are provided for length of pile (length along the pile axis).

The number that the user enters as Elevation at soil surface can be positive or negative and in the same base units (either ft or m) as the one selected for the APILE model. Any previously entered Depth parameters (under Data > Soil Layers) will be converted to the specified elevations. A model can be changed from Elevation to Depth as desired by the user.

Tip Resistance

By default, APILE averages soil properties from 1.5 diameters of pile tip (above and below pile tip). Using the Average Depth to Estimate Tip Resistance drop-down menu, the user may select to change that averaging to 0 D (no averaging), 1.5 D (default averaging) or 3.0 D (three diameters above/below pile tip). This averaging is recommended to prevent piles from punching through to a weaker soil layer. For additional comments, users can read the notes on “Punch Through Commentary on End Bearing” in the separate APILE Technical Manual.

Figure 3.20 Options > Control Options

CHAPTER 4. References for Program Execution and Output Reviews

4.1 Introduction

CHAPTER 4 presents options related to execution of the program and includes methods of addressing run-time errors. This Chapter also includes suggestions for reviewing input, output, and processor text files. The final section of this Chapter includes descriptions about all the output curves that may be observed in graphical form. The commands covered in this chapter are contained in the top menu, under the Computation and the Graphics titles.

4.2 Computation Menu

This menu option is selected to execute the program using the parameters that were saved in the input-data file. Within the options contained under this menu, shown in Figure 4.2, there are commands that facilitate the reviews of the text files produced for storing input data, output results, and processor notes. In addition, the user may select an option to observe a graphical representation of the modeled pile and soil layers. Detailed description of the submenu options contained under the Computation menu are explained in the following topics.

4.2.1 Computation Menu Speed Buttons

Three speed buttons in the button bar (shown in Figure 4.1) provide access to the following commands (from left to right): Computation > Run Analysis, Computation > Edit Output Text, and Computation > 3D View.

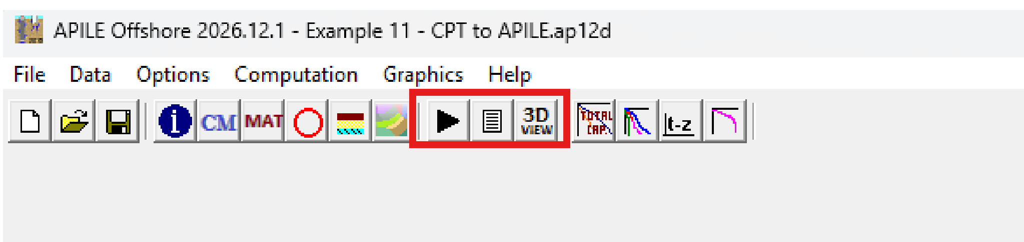
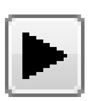


Figure 4.1 Speed Buttons for the Computation Menu (within red rectangle)

4.2.2 Computation > Run Analysis



The input-data file will be first saved to disk after selecting the Computation > Run Analysis submenu option, which executes the computational portion of program APILE.

The user should remember to save the input data under a user-specified name before executing the analytical module. When saving data to disk, APILE will automatically add an extension of the type *.ap12d to the name of the input file.

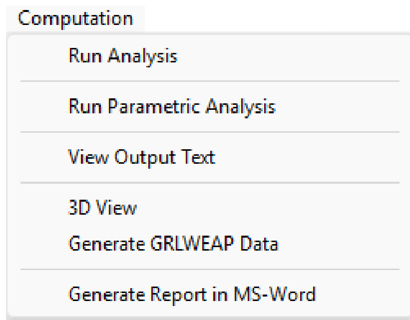


Figure 4.2 Sample Computation menu.

On most current computer systems, the computational runs of APILE are usually completed within a fraction or just a few seconds. After a successful execution, the APILE program will display a screen similar to the one in Figure 4.3, showing the 'Computational Output' of the model.

The Computational Output screen (Figure 4.3) provides the user with two tabs on the left side of the screen: Report and Graphs. The Report tab is explained in Section 4.2.3 of this manual. Features within the Graphs tab are explained in Section 4.3 of this manual.

The Computational Output screen (Figure 4.3), while in the Report tab, also provides the user with two speed-button icons at the bottom of the screen: Print output and Generate MS Word report. The Print output calls the Windows print command. Features within the Graphs tab are explained in Section 4.3 of this manual.

For models with computational errors, APILE will usually display a 'Warning' screen similar to the in Figure 4.4. In these cases, the user should check the output text file for any warning and/or error messages that were produced during computations. Messages would usually be placed at the bottom of the output text and the Computational Output screen is unlikely to display the Graphs tab since there may not be any output results (only an echo printing of the input data).

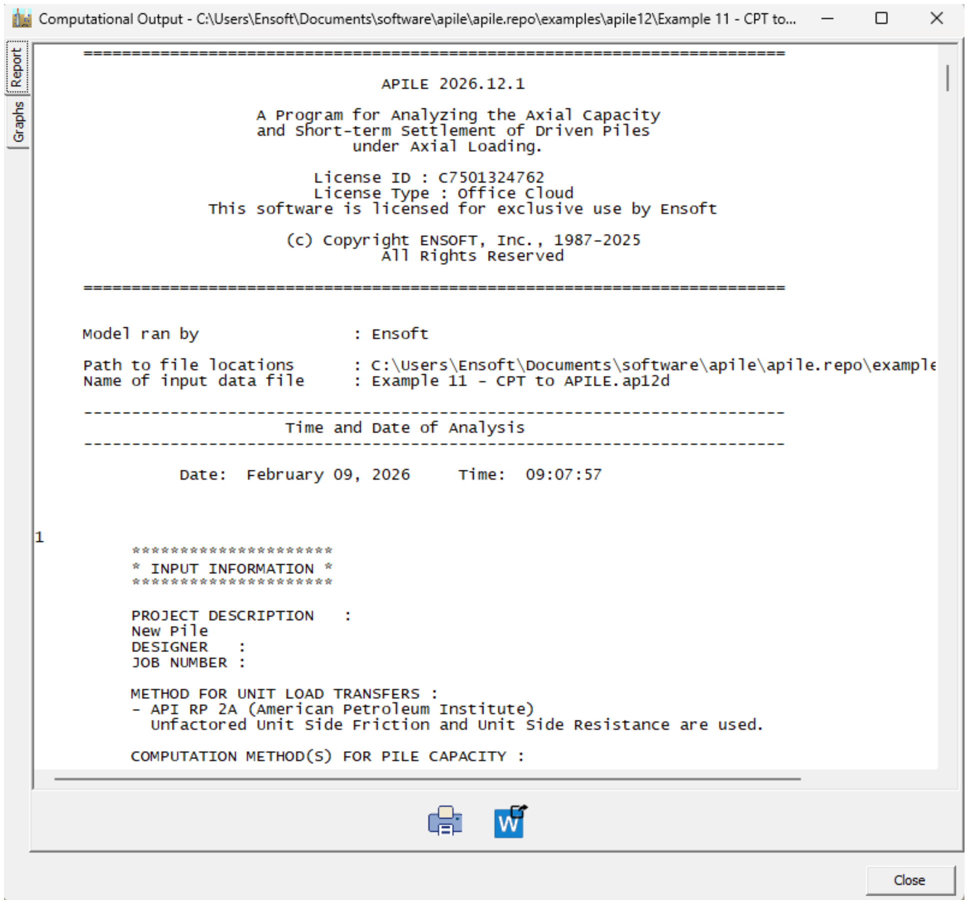


Figure 4.3 Sample Computational output screen.

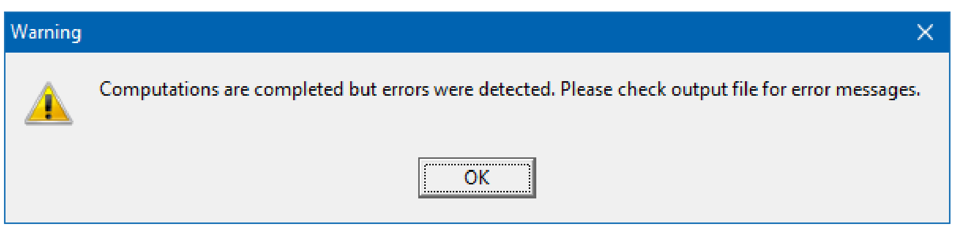


Figure 4.4 Warning screen for computational errors.

4.2.3 Computation > Run Parametric Analysis

APILE allows users to run parametric analyses where one or more properties of either a soil layer or pile properties of the base model is linearly varied between specified starting values and final values.

When Computation > Run Parametric Analysis menu is executed, a dialog window like the one shown in Figure 4.4 will be displayed. Click the green plus button ➕ to select whether you would like to modify properties of a specific soil layer index, or pile properties.

Figure 4.5 Empty Parametric Analysis dialog window

Figure 4.4 shows an example dialog window for specifying parametric variables corresponding to the pile of the base model. Two tabs are displayed:

1. Start Values: modified values of the base model for the first parametric case
2. End Values: modified values of the base model in final parametric case

When executed, APILE will make a fixed number of analyses specified by Increments field. For each increment, the properties of the base model are linearly varied from Start Values to End Values specified in the interface.

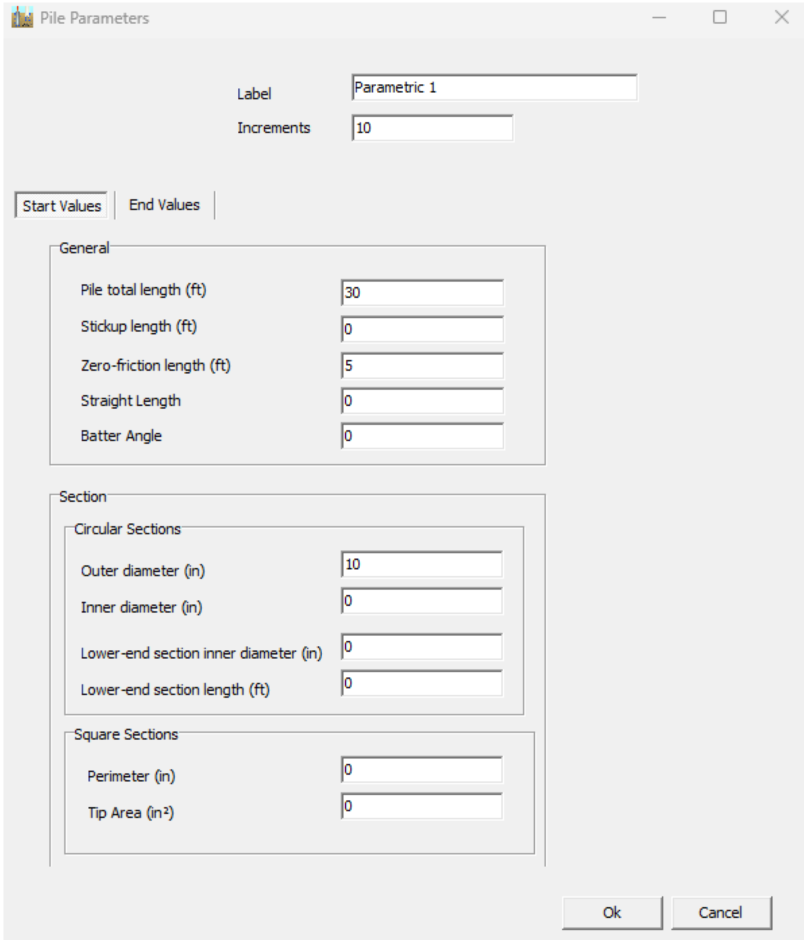


Figure 4.6 Parametric Pile Properties edit dialog

After completion of analyses, results are presented in two modes (see Figure 4.7):

1. Overview: Summary of various pre-defined metrics plotted against the case number
2. Outputs: individual output data, including both report and graphs, corresponding to each analysis number. The number of cases corresponds to the Increment number specified when defining the parametric case.

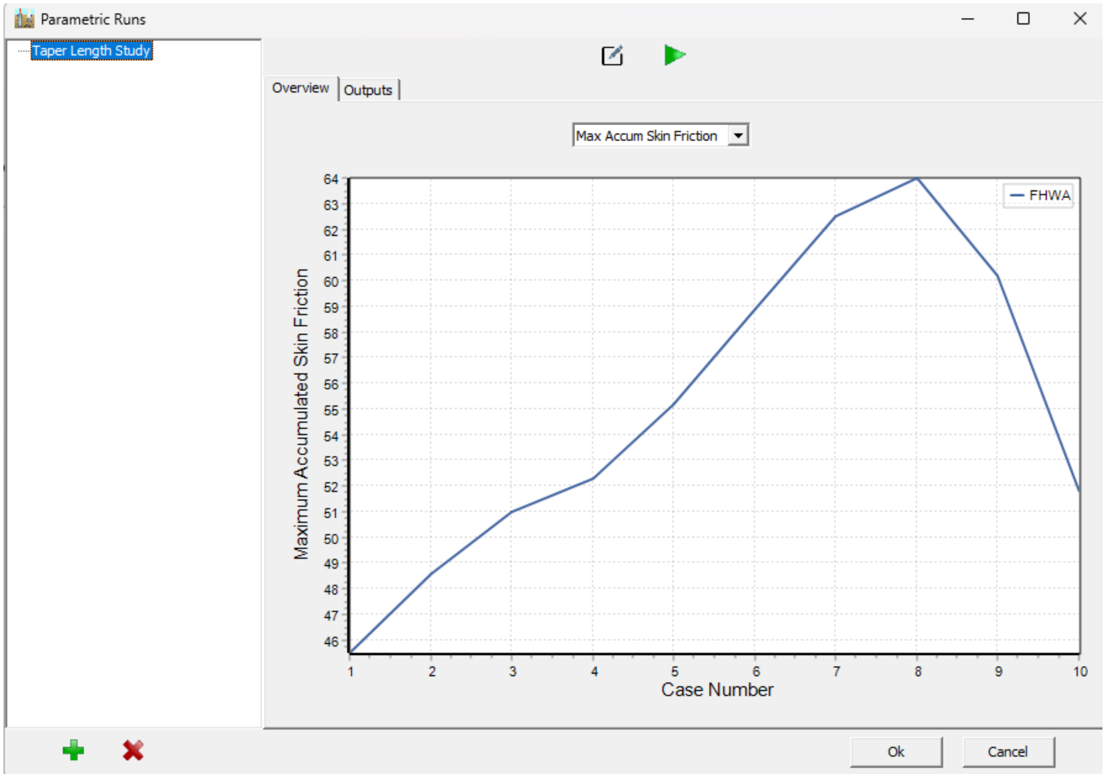


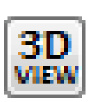
Figure 4.7 Sample Parametric results dialog

Please note that there are limitations when using the graphical interface for running parametric analyses. For example, properties of both pile and a soil layer cannot be modified concurrently between different cases. For more complex workflows where properties from both a soil layer and pile properties need to be varied, see Section 4.4.

4.2.4 Computation > View Output Text

This command is used to view the output report that is generated after each analytical run. This command becomes active after new data files have been saved to disk and successfully executed, or when opening previously-executed data files.

4.2.5 Computation > 3D View



The Computation > 3D View provides a graphical screen that displays a three-dimensional view of the pile and soil layers along with their various depths and other user-selected elements. This command becomes active after data of Pile Properties and Soil Layer Data have been entered under the Data menu, or when opening previously-executed data files. The Show 3D View and new speed buttons provide additional parameters for modifications of the graphical display.

A sample graphics of this command option is shown in Figure 4.5, which also includes the Show 3D View > Combined Plots which may be selected after a successful computational run.

This selection can be useful to quickly visualize the results of pile capacity for skin friction, end bearing and total capacity for various shaft penetrations. The observation can also be helpful to determine the impact of certain soil layers in the contribution to total capacity.

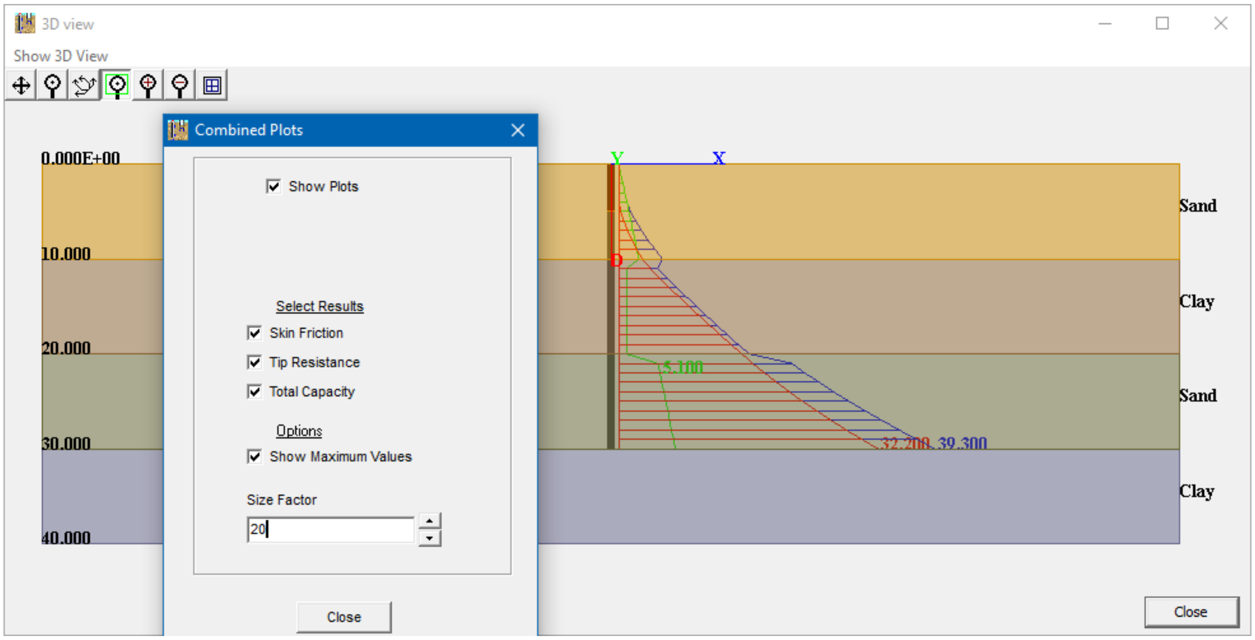


Figure 4.8 Sample Computation > 3D View.

4.2.5.1 3D View Speed Buttons

A group of seven speed buttons provide access to the following commands (from left to right): Panning (to pan click and hold anywhere in 3D graphics plus drag mouse up, down or sideways), Zooming (to zoom click and hold anywhere in 3D graphics plus drag mouse up to enlarge graphics or drag mouse down to reduce graphics), Rotating (to rotate click and hold anywhere in 3D graphics plus drag in any desired direction), Zoom Windows (to zoom into a windows click on top left of desired window to be zoomed in 3D graphics and drag mouse to bottom right), Zoom In (to zoom in click anywhere in 3D graphics), Zoom Out (to zoom out click anywhere in 3D graphics), Restart View (restarts the original 3D graphics before any pan, rotate or zoom operations).

4.2.5.2 Show 3D View Menu

In this menu, users can select to turn on/off the pile image, soil layers and/or the labels for the soil layers. After a successful run, users may also be able to display the Combined Plots (shown in Figure 4.5) with a graphical reorientation of select result charts.

4.2.6 Computation > Generate GRLWEAP Data

APILE has an option to export the soil profile and computed load transfers per pile increment from any model to an external file that can be read by the separate GRLWEAP software for evaluations of pile driving efforts (driveability). The dialog box in Figure 4.6 is provided for reference.

4.2.6.1 Importing into GRLWEAP14

The Generate button in Figure 4.6 prompts the user to save a file of the type '*filename.srp*'. The 'srp' extension is used by GRLWEAP14 to import a 'Soil Resistance File' for Customized Soil Parameters. The following steps are recommended for importing into GRLWEAP14:

1. Create or open a model for Driveability analysis.
2. Select Input > Soil Model.
3. Click Customize Soil Param. Button.
4. Select Import button.
5. Browse and select to Open the 'srp' file that was generated in APILE.
6. Check imported data table to make sure the parameters (see next section for references) are appropriate for the modeled pile system.
7. Click Ok button twice and proceed with interface (other input/features) of the GRLWEAP14 software.

4.2.6.2 APILE's GRLWEAP Output Data

APILE exports the set of parameters listed below to the 'srp' file when generating GRLWEAP14 data. Please note that while some of the values are determined from static axial analysis of piles, others are evaluated solely based on soil parameters and some are set to be constant. Please review the generated values and adjust as needed based on your use case.

Depth: This is the depth, measured from the ground surface downward, used internally by APILE analysis. Maximum number of points accepted by GRLWEAP14 is limited to 100 points.

Unit Shaft Resistance: Unit skin friction obtained by APILE analysis.

Unit Toe Resistance: Tip resistance of pile obtained by APILE analysis, normalized by the pile's end-bearing area. See "end bearing area" further below.

Shaft Quake: Uniformly set to 2.5 mm (please see notes in GRLWEAP manuals: "*Clear relationships between soil type and shaft quake or pile size and shaft quake are unestablished. A 2.5 mm (0.1 in) shaft quake is reasonable and generally accepted. Although shaft quakes are assumed to be the same in all soils, the driveability input allows for variation of those values per soil layer.*").

Toe Quake: The outputted value for toe quake is evaluated based on the table below using solely the soil layer properties (please see notes in GRLWEAP manuals: "*The GRLWEAP toe quake recommendation similarly expresses its magnitude as a function of pile diameter (size). For very dense or hard soils the recommendation is D/120 and for softer materials D/60. Note: Much larger toe quake values have been observed. Toe quakes are often quite different when driving, restriking, or statically loading the same pile. Large toe quakes cause a high rebound and can cause damaging tension stresses in concrete piles even with high resistance values. Further, large toe quakes can produce high blow counts, which makes driving displacement piles difficult.*").

Table 4.1 Toe Quake Reference (GRLWEAP14 Manual)

Clay	Sand		Toe Quake Value
Undrained Shear Strength (kPa)	SPT Blow Count	Friction Angle (degrees)	
$s_u \le 15$	N ≤ 5	$\phi \le 30$	*D*/60
$15 < s_u < 150$	5 < N < 30	$30 < \phi < 41$	Linearly interpolated
$s_u \ge 150$	N ≥ 30	$\phi \ge 41$	*D*/120

.........................In models using non-circular pile sections, APILE computes Toe Quake using an 'effective pile diameter' that is computed based on the user-inputted pile perimeter.

Shaft damping: The value is set to be 0.15 s/m and 0.65 s/m for sand and clay soil types (Standard Smith).

Toe damping: The toe damping is set to a fixed value of 0.5 s/m for all layers (Standard Smith).

Setup factor: User-specified per soil type, with defaults shown in application window (please see notes in GRLWEAP manuals: "*For example, a setup factor of 5 is reasonable in a submerged sand, which is typically 1 or 1.2 for impact driving. This means that only 20% of its long term shaft resistance is present during vibratory driving. On the other hand, for highly plastic cohesive soils, not much resistance is lost. The setup factor may be as low as 1.0 for vibratory driving. Often, it is 2 for impact driving. Alternatively, soft clays or any material that tends to behave in a thixotropic manner may lose as much resistance as for impact driving and should be considered with a higher setup factor.*").

Setup time: Outputted value is the user-inputted value and set to be constant for all data points (please see notes in GRLWEAP manuals: "*A Variable Setup Analysis considers the partial setup that occurs during pile driving caused by driving interruptions. For the Variable Setup Analysis, a set-up time and a limit distance needs considered. The set-up time specifies the time period necessary for the soil to reach the full LTSR. The Limit Distance specifies how far the pile needs driven until it loses all soil set up, or until it reaches the SRD. All soil related static and dynamic resistance parameters, SRD, LTSR, Setup, Friction Fatigue, and Gain/Loss factors and calculations are explained in GW14 Background Report, Part 2.*").

Limit Distance: Outputted value is the user-inputted value and set to be constant for all data points (please see notes above and others in GRLWEAP manuals: "*The limit distance, L_L, is a constant and may be considered a soil property. The user can enter this soil property in the soil resistance profile and has the dimension of length, of m or ft.*"

.... *"There is no point in specifying set-up time if the limit distance is unknown or vice-versa. Entering 1 parameter while not specifying the other leads to curious results"*

.........................*"If no set-up factors are specified, GRLWEAP assumes set-up factors of 1 for all layers. Gain/loss factors then produce uniform capacity gains or losses in all soil layers along the pile*").

Shape factor: Outputted value is the user-inputted value and set to be constant for all data points.

End bearing area: The end bearing area is outputted as follows.

Circular piles:

......Unplugged: $\frac{\pi}{4}(D_o^2 - D_i^2)$

......Plugged: $\frac{\pi}{4}D_o^2$

Non-circular piles:

......Pile-tip cross-sectional area.

In the above D_o and D_i are the outer and inner pile diameters, respectively.

Please see notes in GRLWEAP manuals: "*GRLWEAP users should be aware that modeling plugged (or partially plugged) end bearing requires additional considerations. Most importantly, they should be reminded that for non-displacement piles the soil quake recommendations are 2.5 mm (0.1 in). For displacement piles, the toe quake is GRLWEAP 14 Background Report Part 2 69 recommended to be D/60, where D is the pile diameter or width, for all not very dense or hard soils and D/120 for very dense or hard soils.*".

Users must check and make sure that the generated 'srp' file contains values that are appropriate for their models based on GRLWEAP Technical Manual and/or Technical References.

Any of the exported values can be changed either by editing the outputted 'srp' files with a text editor, or by editing them directly within GRLWEAP14.

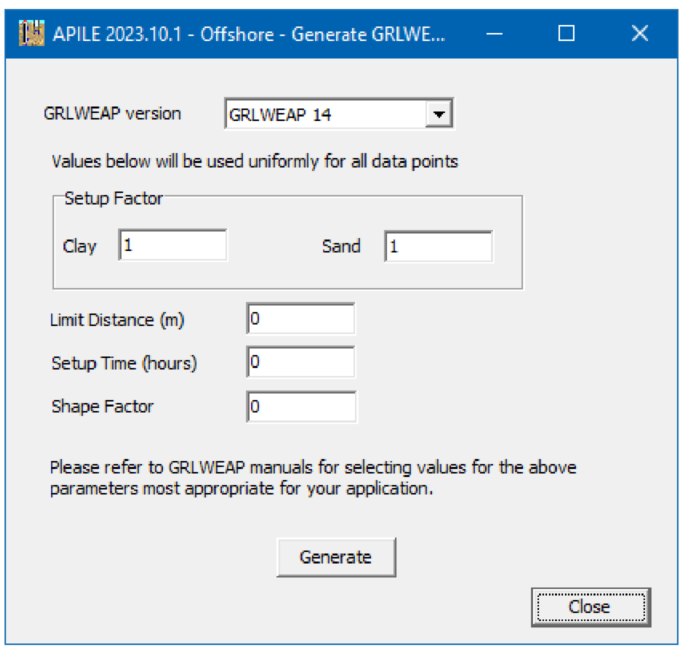


Figure 4.9 Sample Computation > Generate GRLWEAP Data.

4.2.7 Computation > Generate Report in MS-Word

This menu selection allows users to export parameters for the APILE model along with optional data groups (see Figure 4.7) into a pre-formatted Microsoft Word file. Each generated report is provided with the following information:

- Software name, version and update.

- License information (serial number, company name and licensed office site).
- Name and path of input/output data files.
- Date of computational run.
- Echo printing of various model data parameters (computational and unit load transfer methods, type of loading, pile type).

In addition, in the dialog box in Figure 4.7 users can select to include the following optional content:

Input > Model Schematic adds to the Word report a graphical representation of the pile, soil layers (with some mechanical properties) and layer depths (or elevations).

Input > Pile Properties adds a Word table with echo printing of the properties that were entered by the user for the modeled pile.

Input > Soil Properties adds a Word table with echo printing of the soil layers and mechanical properties that were defined by the user. This table also includes any soil properties that were estimated or assumed internally by APILE based on other parameters.

Results > Pile Capacity adds a Word table and/or graphical plots with computational results of Total Skin Friction, Skin Friction (or Self Weight), End Bearing and Ultimate Capacity for each Method of Pile Capacity that were selected by the user.

Results > tz Curves adds a Word table and/or graphical plots with the t-z curves that were internally generated by APILE for top, middle and bottom of each soil layer (and for each optional depth that may have been selected by the user).

Users may copy and paste the contents of any of the tables above from Word to a spreadsheet if they prefer different units or plot format. Keep in mind that the separate Graphics > Export Plots to MS-Excel described in the next section provides a simple method for editing plots.

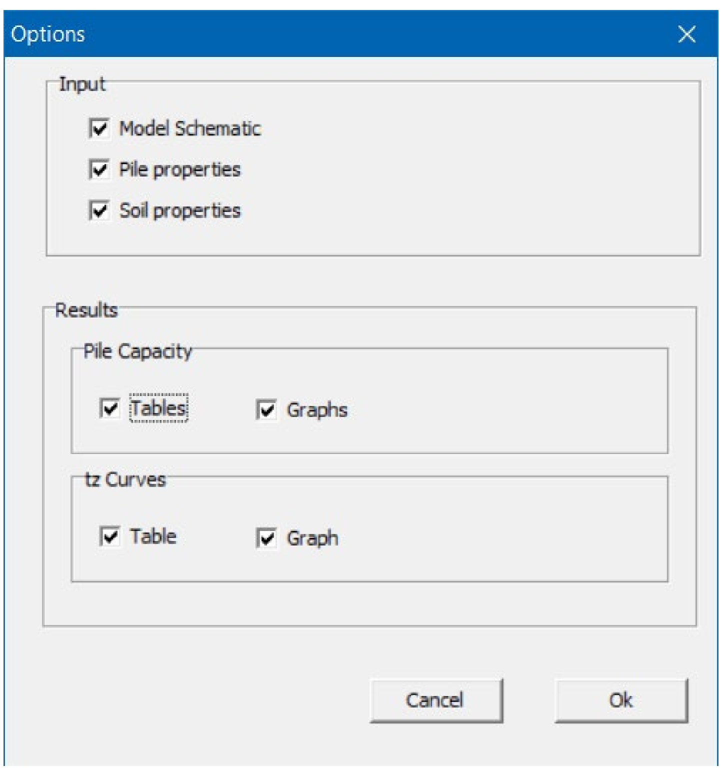


Figure 4.10 Dialog box for Generate Report in MS Word.

4.3 Graphics Menu

This menu is selected to observe the different graphical representations of the program results contained in the output file. Options contained under this menu are shown in Figure 4.8. Not all of the graphics may be enabled for observation, since active curves depend on specifications contained in the input.

Notes Regarding Computation Methods

1. Some graphics and output data will be generated for all four methods of computations, regardless of the internal method that the user selects. Data and plots that will always be generated for all methods of computations (under Data > Computational Method > Method for Pile Capacity) are the following:

    Unit Skin Friction vs. Depth

    Accumulated Skin Friction vs. Depth

    Tip Resistance vs. Depth

    Total Capacity vs. Depth

2. The following graphics will only be generated using the selected method of computation (under Data > Computational Method > Method for Load Settlement):

    Load Distribution

    Combined Plot

    Axial load vs. Settlement

    Internally-Generated t-z Curves

All of the graphical representation of output data that may be produced by the program are contained in the following commands of the Graphics menu:

Unit Skin Friction vs Depth

Accumulated Skin Friction vs Depth

Tip Resistance vs Depth

Total Capacity vs Depth

Load Distribution Curves

Combined Plots vs Depth

Axial Load vs Settlement

Internally Generated t-z Curves

Extra t-z Curves at User Specified Depths

Internally Generated Q-w Curve

The observation of any of the above-listed curves will activate the new graphics mode of APILE. Several changes occur during use of the graphics mode.

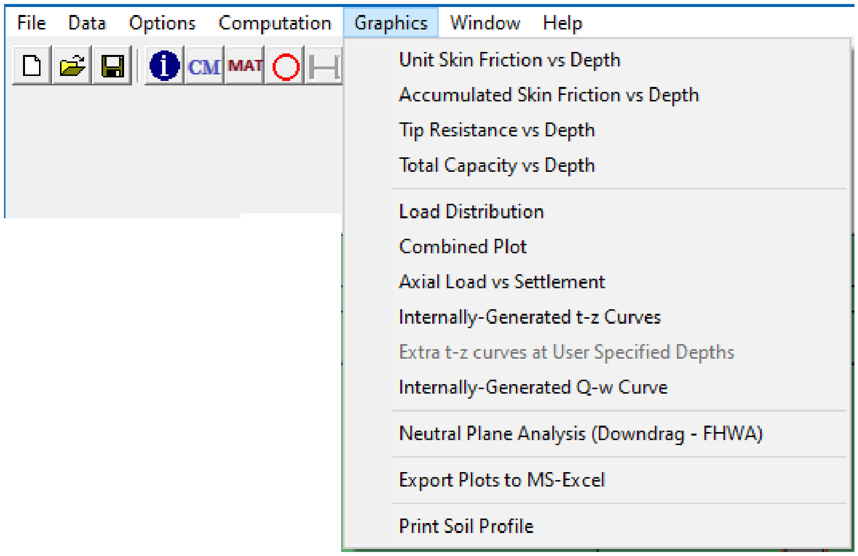


Figure 4.11 Sample Graphics menu.

4.3.1 Mouse Commands in the Graphics Mode

Table 4.2 describes mouse commands that become enabled automatically during all graphical observations of output curves.

Event	Description
Mouse Left Click and Drag	Zooms in to the dragged rectangular region (up to five zoom levels)
Mouse Wheel Scroll	Zoom in and out to current point under the cursor
Mouse Middle Button Double-Click	Fit graph window to graph content
Mouse Middle Click and Drag	Drag and shift plot window
Mouse Right Click	Show context menu on graph
Mouse Double Click on Legend	Turns the selected curve on/off at every click

Table 4.2 Mouse commands in the graphics mode

4.3.2 Plot Options Menu

A sample plot in graphics mode is shown in Figure 4.9. While in graphics mode, users can select the desired plot on the left side of the screen and also some plot options (shown in the middle of Figure 4.9).

The Plot Options menu offers some changes that users can make to the chart settings. Please notice that the changes that are made in this menu are not saved with the model, they are only for visual aid while looking at the results from a model.

Users that need more involved formatting of the plot files are encouraged to select the APILE feature for exporting plot data to a pre-formatted spreadsheet (using the icon at the bottom of Figure 4.9 or the menu described in Section 4.3.14 of this manual). The simple APILE plots are useful for immediate observation of results while the formatting on a spreadsheet allows for a wide variety of presentations in report format. Another option for exporting of plots into a report format was presented in Section 4.2.6 of this manual.

Show Legend

This activates or deactivates the floating legend included in the graphics mode. The legend box can be moved with click-and-drag operations of the mouse to any position in the graphics screen. Despite its location in the screen, the legend is always located at the right-bottom corner on the printouts.

Show Soil Layer

Click this menu-item to activate or deactivate a soil profile plotted at the right side of the graphics. This option is not available in some plots (where not applicable).

Show Markers

This menu provides the option to activate or deactivate the markers for each point of all the curves displayed in the active screen of the graphics mode. By default, the program automatically plots at every foot of penetration, or every 30 cm when using metric units. The user may optionally select to show markers every 1, 2, 3, 5, or 10 increments of unit. The type of markers used in each curve is automatically selected by the program. Once activated, the markers are enabled for all visible curves of the active graphics screen.

Font Size

This menu provides the option to enlarge the default size of fonts used in plots. The user may optionally select to enlarge the font by 1.5, 2, 2.5, 3, or 4 times of the default size.

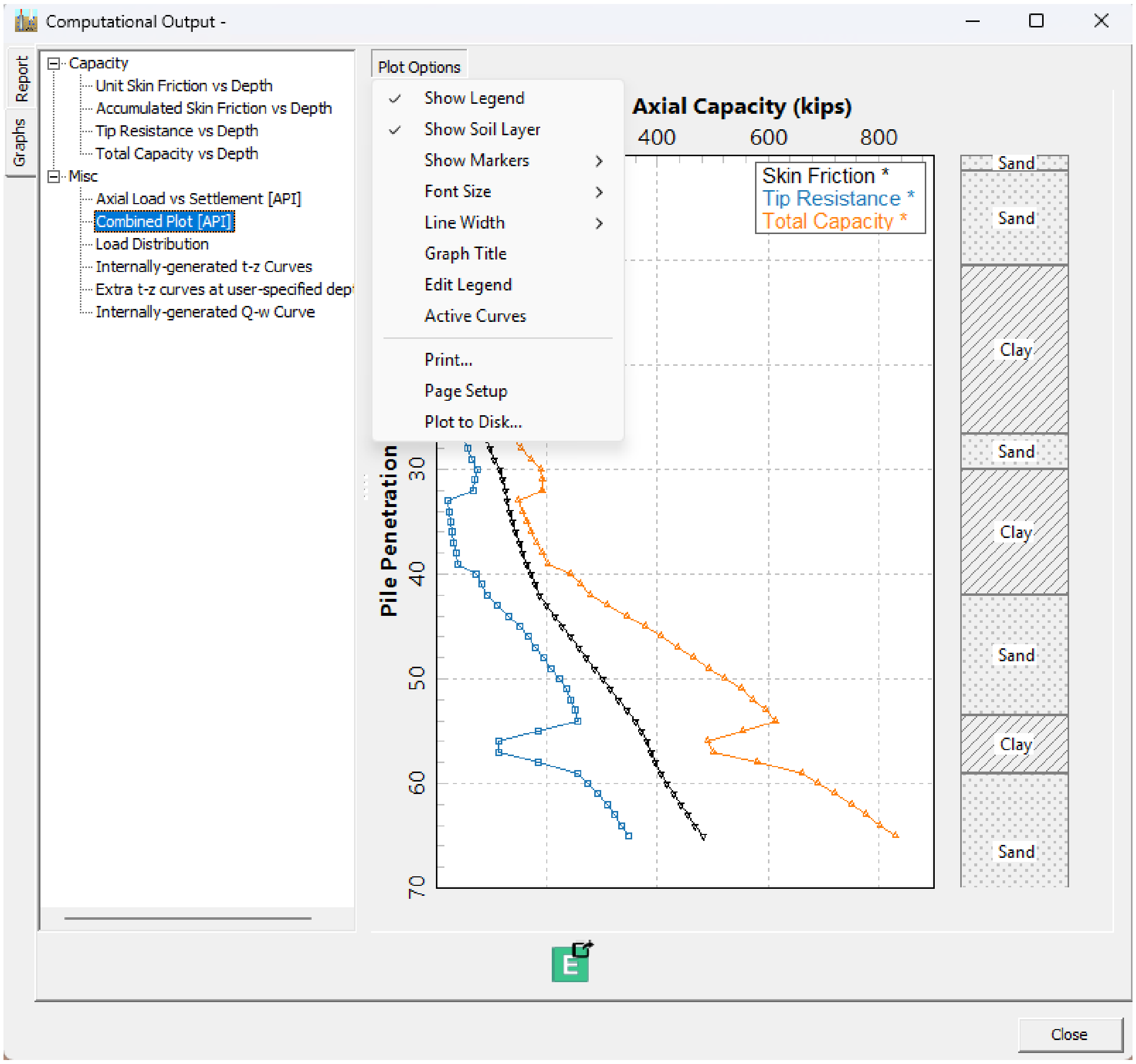


Figure 4.12 Sample Plot and Plot Options Menu in Graphics Mode

Graph Title

The user may optionally add a title to the active graphics using this command. However, the parameters selected here are not saved with the output file and must be changed each time the file is opened.

Edit Legend

The user may change the text of the legend in the active graphics using this command. However, the modified names are not saved with the output file and must be changed each time the file is opened.

Active Curves

This command is used to activate or de-activate the graphs that are displayed on the screen.

Print...

This command is used to produce a hard copy of the active graphics screen. The Print dialog box includes a drop-down menu that allows the user to select any of the installed Windows printers, allows for change of printer properties, and allows the selection of the total number of copies to be printed. The printed graphics is sized according to the margins that the user specifies in the Plot > Page Setup menu.

Page Setup

The user can here specify the printed size of the active-graphics screen. The size of the plot is based on the specified margins and selection of paper orientation. The parameters selected here are not saved with the output file and must be changed each time that the graphics is plotted.

Plot to Disk...

This command is used to save the active-graphics screen to disk. The format of the saved file is as *bmp* graphics (bitmap file), which is the internal-file format used in Microsoft Windows©.

4.3.3 Graphics > Unit Skin Friction vs Depth

This command provides a graphical representation of the unit load transfers in side resistance (skin friction) versus pile length below grade (or versus Elevation) for the modeled pile according to the computational methods that were selected by the user. Unit load transfers in side resistance are presented in units of axial force per area (surface area) of the modeled pile. The data value at each length/depth represents the unit side resistance that was used during internal capacity computations.

For vertical piles (no batter) the vertical axis represents depth or actual pile penetration below ground line (stickup length, if any in the model, is not shown). When the model has batter piles, the vertical axis represents vertical elevation (if check marked in Section 3.3.3) or length of pile below grade along the batter line. If needed, the output text file for models with batter piles also include an extra column with corresponding vertical depth (elevation) below ground.

A sample graphics screen of the Unit Skin Friction vs Depth command option is shown in Figure 4.10. These curves are automatically generated after successful analytical runs of a driven pile.

Notice that the values of unit skin friction represented in these graphics are shown after modifications from the reduction/resistance factors, if any, that were specified by the user (under the Data > Soil Layers menu).

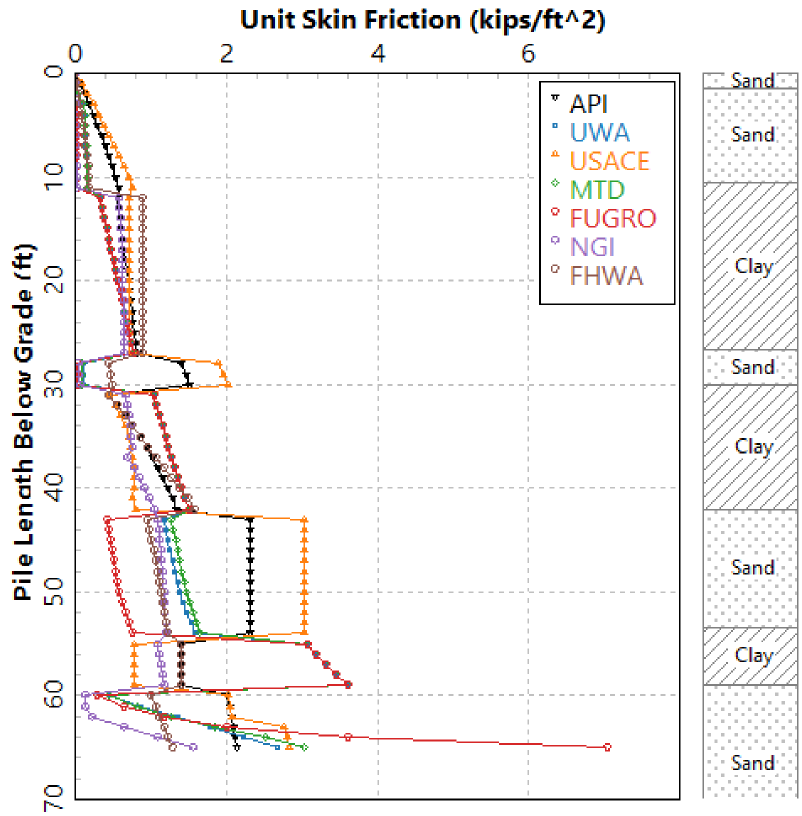


Figure 4.13 Sample Unit Skin Friction vs Depth.

4.3.4 Graphics > Accumulated Skin Friction vs Depth

This command provides a graphical representation of the accumulated load transfers in side resistance (skin friction) versus pile length below grade (or versus Elevation) for the modeled pile according to the computational methods that were selected by the user. Accumulated load transfers in side resistance are presented in units of axial force. The data values represent the total axial load that is transferred to the soil in side resistance at each length/depth.

For vertical piles (no batter) the vertical axis represents depth or actual pile penetration below ground line (stickup length, if any in the model, is not shown). When the model has batter piles, the vertical axis represents vertical elevation (if check marked in Section 3.3.3) or length of pile below grade along the batter line. If needed, the output text file for models with batter piles also include an extra column with corresponding vertical depth (elevation) below ground.

A sample graphics screen of the Accumulated Skin Friction vs Depth command option is shown in Figure 4.11. These curves are automatically generated after successful analytical runs of a driven pile.

Notice that the values of accumulated skin friction represented in these graphics are shown <u>after</u> modifications from the reduction/resistance factors, if any, that were specified by the user (under the Data > Soil Layers menu).

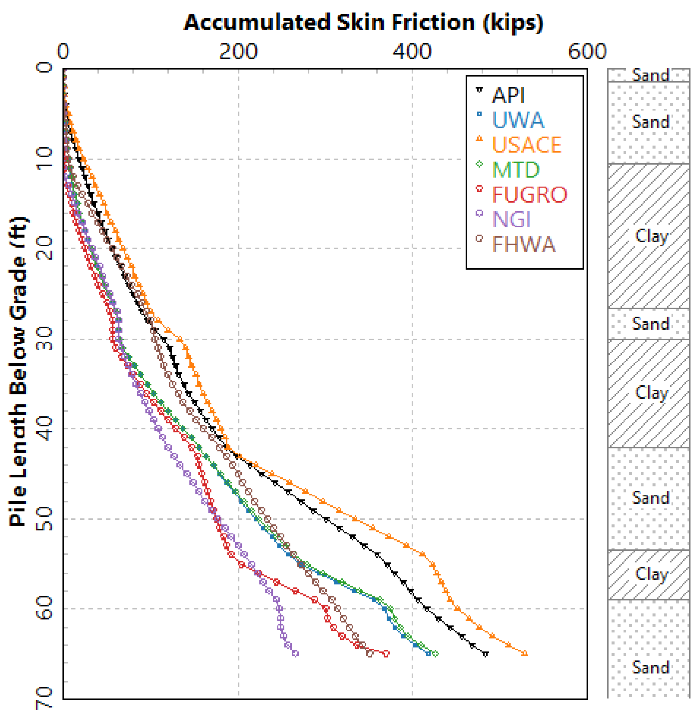


Figure 4.14 Sample Accumulated Skin Friction vs Depth.

4.3.5 Graphics > Tip Resistance vs Depth

This command provides a graphical representation of the tip resistance (end bearing) versus pile length below grade (or versus Elevation) for the modeled pile according to the computational methods that were selected by the user. Tip resistance is presented in units of axial force. The data values represent the total axial load that is transferred to the soil in end bearing for each length/depth (starting from ground surface).

For practical reasons, in open-ended piles with Internal Pile Plus Calculated by Program the internal side friction is added to the end bearing. This is partly because in the APILE program the end bearing plus internal side friction are added together until a plug forms (until it reaches the equivalent end bearing of a close-ended pipe).

For vertical piles (no batter) the vertical axis represents depth or actual pile penetration below ground line (stickup length, if any in the model, is not shown). When the model has batter piles, the vertical axis represents vertical elevation (if check marked in Section 3.3.3) or length of pile below grade along the batter line. If needed, the output text file for models with batter piles also include an extra column with corresponding vertical depth (elevation) below ground.

A sample graphics screen of the Tip Resistance vs Depth command option is shown in Figure 4.12. These curves are automatically generated after successful analytical runs of a driven pile that is subjected to compression loads (under the Data > Computation Method menu). This command option is grayed out for tension loads.

Notice that the values of tip resistance represented in these graphics are shown after modifications from the reduction/resistance factors, if any, that were specified by the user (under the Data > Soil Layers menu).

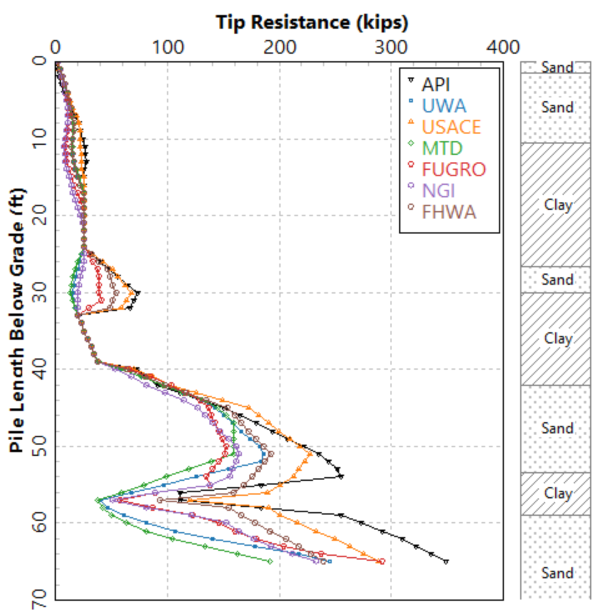


Figure 4.15 Sample Tip Resistance vs Depth.

4.3.6 Graphics > Total Capacity vs Depth

This command provides a graphical representation of the ultimate total capacity versus pile length below grade (or versus Elevation) for the modeled pile according to the computational methods that were selected by the user. Total capacity is presented in units of axial force. The data values represent the total axial load that is transferred to the soil in end bearing plus side resistance for each length/depth (starting from ground surface/grade).

Values of total capacity are equal to skin friction plus tip resistance for compressive loads. Total capacity is equal to skin friction plus self-weight of piles for uplift loads (self-weight is estimated internally according to user selections on Data > Pile Material and Data > Circular-Section Pile or Data > Noncircular-Section Pile).

For vertical piles (no batter) the vertical axis represents depth or actual pile penetration below ground line (stickup length, if any in the model, is not shown). When the model has batter piles, the vertical axis represents vertical elevation (if check marked in Section 3.3.3) or length of pile below grade along the batter line. If needed, the output text file for models with batter piles also include an extra column with corresponding vertical depth (elevation) below ground.

A sample graphics screen of the Total Capacity vs Depth command option is shown in Figure 4.13. These curves are automatically generated after successful analytical runs of a driven pile. Notice that the values of tip resistance represented in these graphics are shown after modifications from the reduction/resistance factors, if any, that were specified by the user (under the Data > Soil Layers menu).

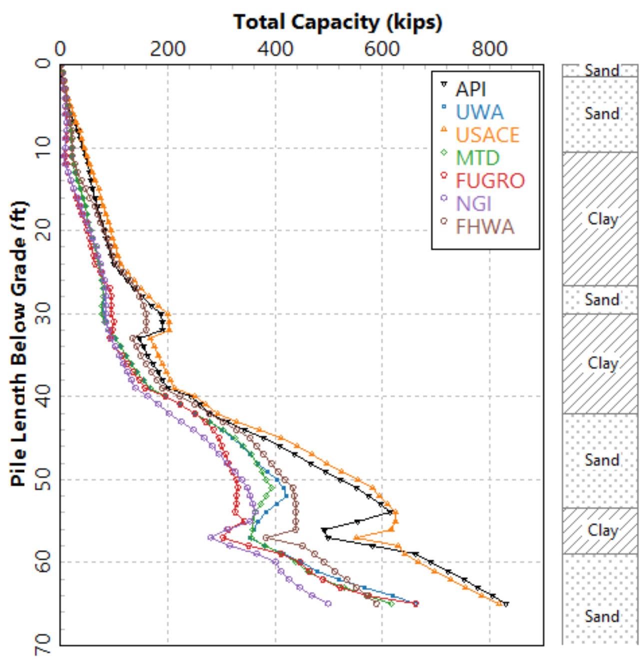
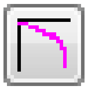


Figure 4.16 Sample Total Capacity vs Depth.

4.3.7 Graphics > Axial Load vs Settlement



This command provides a graphical representation of the curves of axial load versus settlement for the modeled pile based on the *t-z/Q-w* curves generated according to the user-specified computation method (under the Data > Computational Method > Method for Load Settlement menu). For tension loads the settlement curve goes up in the graph to represent pile pullouts.

A sample graphics screen of the Axial Load vs Settlement command option is shown in Figure 4.14. These curves are automatically generated after successful analytical runs of a driven pile.

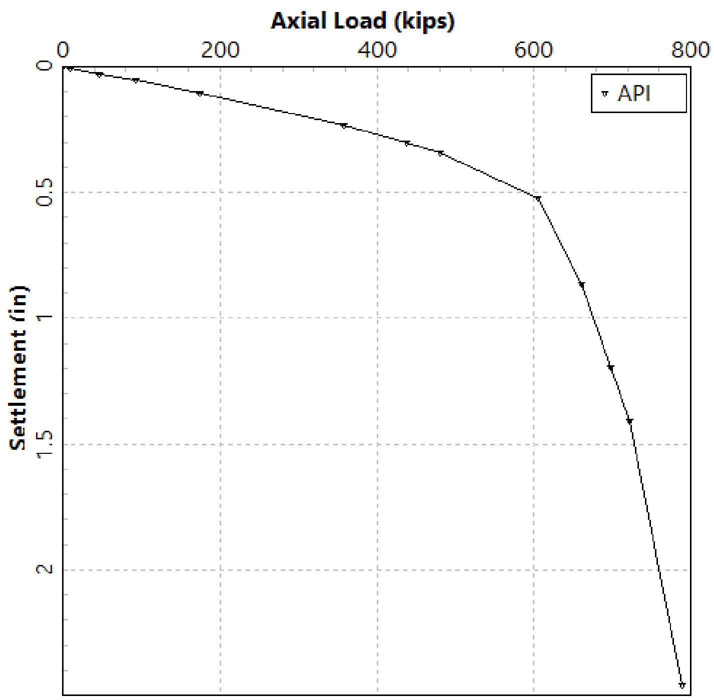
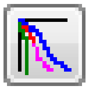


Figure 4.17 Sample Axial Load vs Settlement.

4.3.8 Graphics > Combined Plots vs Depth



This command provides a single graph with the curves of skin friction, tip resistance, and total capacity versus pile length below grade (or versus Elevation) for the modeled pile. The plotted curves of load transfers correspond to the particular criteria selected by the user (under the Data > Computational Method > Method for Load Settlement menu).

For vertical piles (no batter) the vertical axis represents depth or actual pile penetration below ground line (stickup length, if any in the model, is not shown). When the model has batter piles, the vertical axis represents vertical elevation (if check marked in Section 3.3.3) or length of pile below grade along the batter line. If needed, the output text file for models with batter piles also include an extra column with corresponding vertical depth (elevation) below ground.

A sample graphics screen of the Combined Plots vs Depth command option is shown in Figure 4.15. These curves are automatically generated after successful analytical runs of a driven pile. Notice that the values represented in these graphics are shown <u>after</u> modifications from the reduction/resistance factors, if any, that were specified by the user (under the Data > Soil Layers menu).

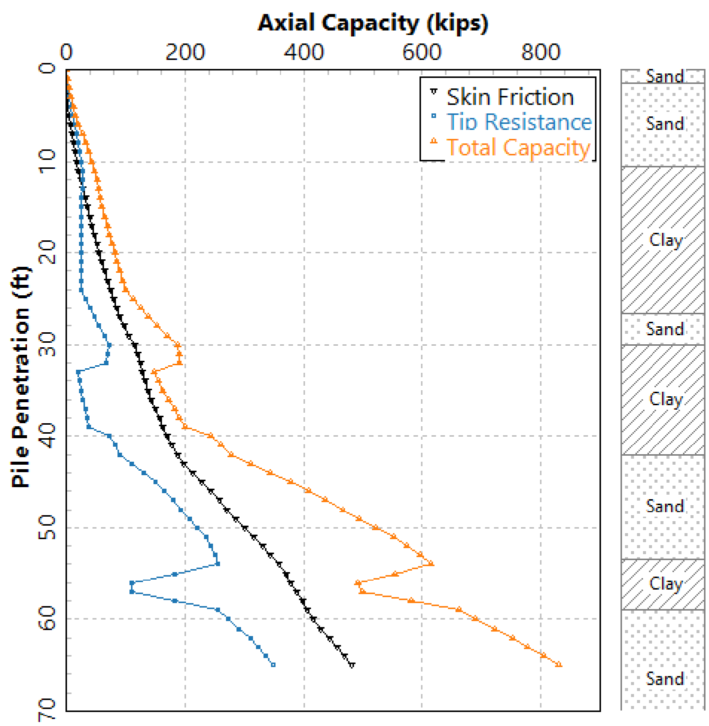


Figure 4.18 Sample Combined Plots vs Depth.

4.3.9 Graphics > Load Distribution

The user may select this command option to observe a graphical representation of distributions of axial loads versus depth for the modeled pile. From this presentation the user can identify the side friction contributed by each soil layer based on the strength parameters. The plotted curves of load distributions correspond to the particular criteria selected by the user (under the Data > Computational Method > Method for Load Settlement menu).

For vertical piles (no batter) the vertical axis represents depth or actual pile penetration below ground line (stickup length, if any in the model, is not shown). When the model has batter piles, the vertical axis represents vertical elevation (if check marked in Section 3.3.3) or length of pile below grade along the batter line. If needed, the output text file for models with batter piles also include an extra column with corresponding vertical depth (elevation) below ground.

A sample graphics screen of the Axial Load vs Load Distribution command option is shown in Figure 4.16. These curves are automatically generated after successful analytical runs of a driven pile.

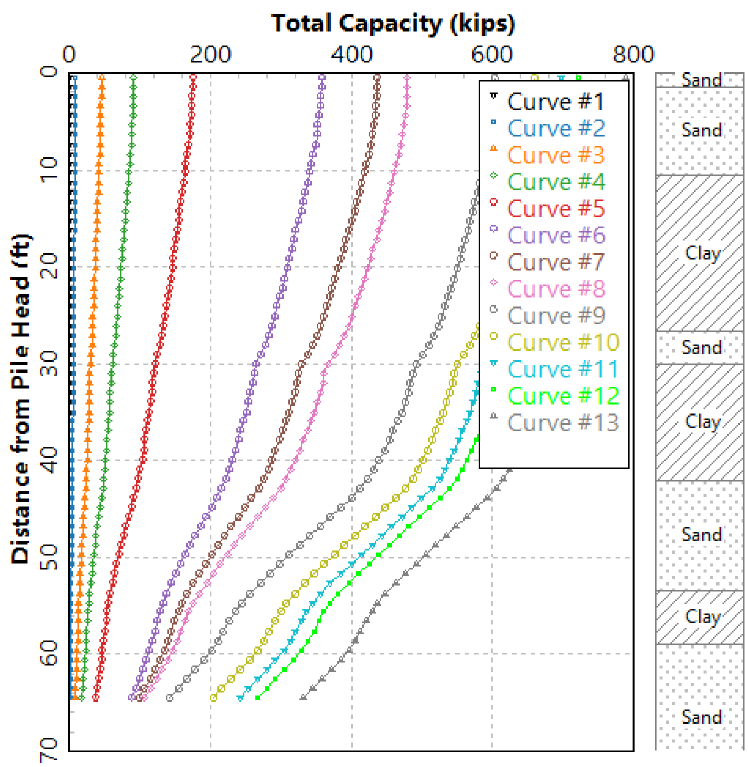
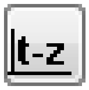


Figure 4.19 Sample Load distribution curves.

4.3.10 Graphics > Internally-Generated t-z Curves



This command provides a graphical representation of the *t-z* curves that were generated internally by APILE based on the user-specified computation method (under the Data > Computational Method > Method for Load Settlement menu). The program automatically generates three *t-z* curves for each soil layer (top, middle, and bottom). The legend for the *t-z* curves indicate depth below grade or elevation (if check marked in Section 3.3.3).

A sample graphics screen of the Internally Generated t-z Curves command option is shown in Figure 4.17. These curves are automatically generated after successful analytical runs of a driven pile.

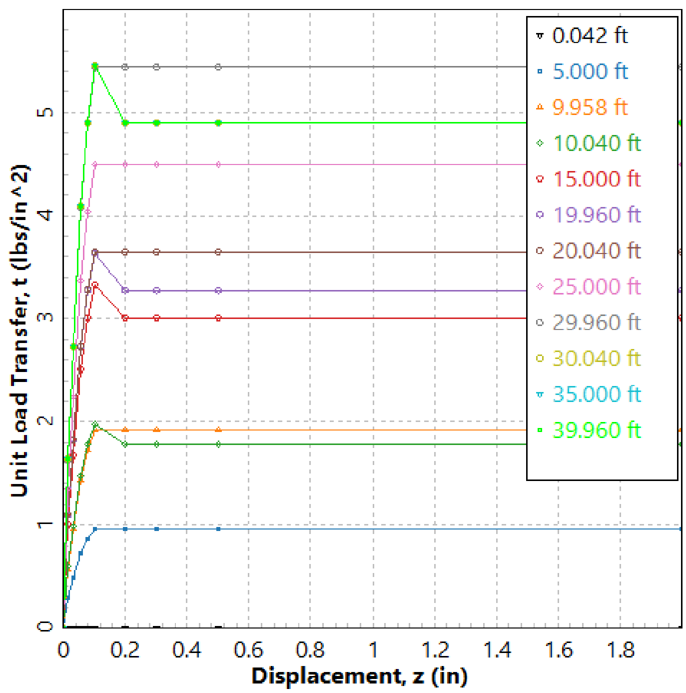


Figure 4.20 Sample of internally-generated t-z curves.

4.3.11 Graphics > Extra t-z Curves at User Specified Depths

This command provides a graphical representation of extra *t-z* curves requested by the user to print out at specific depths (under the Options > Control Options > Print Internally-Generated t-z Curves menu). The *t-z* curves were generated internally by APILE based on the user-specified computation method (under the Data > Computational Method > Method for Load Settlement menu). These curves are in addition to the *t-z* curves that are automatically generated at the top, middle, and bottom of each layer.

This command option is grayed out if the user did not select to the option to print extra *t-z* curves (no check mark under the Options > Control Options > Print Internally-Generated t-z Curves option).

A sample graphics screen of the Extra t-z Curves at User Specified Depths command option is shown in Figure 4.18.

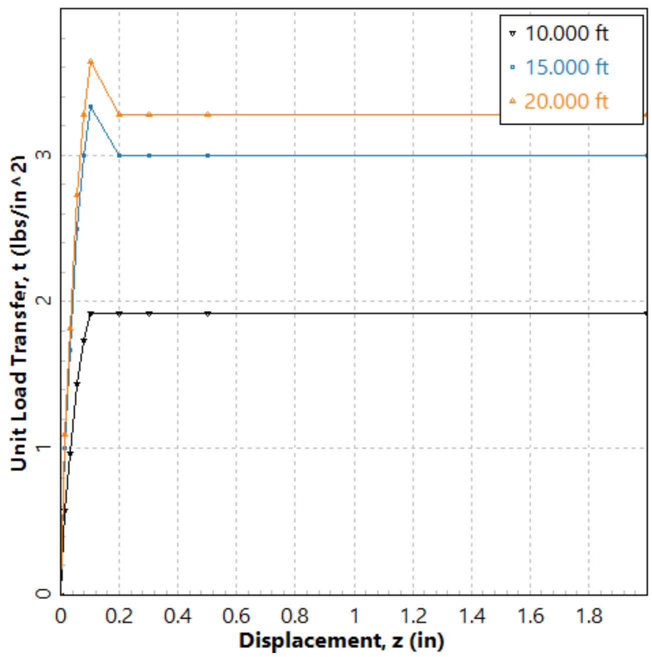


Figure 4.21 Sample of extra t-z curves at user specified depths.

4.3.12 Graphics > Internally-Generated Q-w Curve

This command provides a graphical representation of the *Q-w* curve (tip resistance vs. movement) that was generated based on the user-specified computation method (under the Data > Computational Method/Method for Load Settlement menu). The tip resistance is represented as Q in units of axial force representing total tip resistance at the pile tip, not the unit tip resistance.

This curve is automatically generated after successful analytical runs of a driven pile that is subjected to compression loads (under the Data > Computation Method > Method for Pile Capacity menu). This command option is grayed out for tension loads.

A sample graphics screen of the Internally Generated Q-w Curve command option is shown in Figure 4.19.

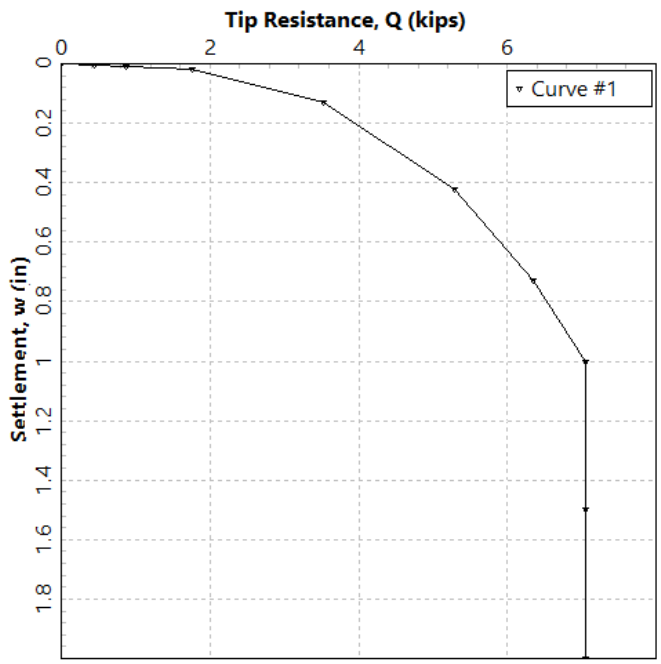


Figure 4.22 Sample of internally-generated Q-w Curve.

4.3.13 Graphics > Neutral Plane Analysis (Downdrag – FHWA)

Models selecting the FHWA Method for pile capacity will provide the curves for Neutral Plane Analysis following FHWA (2016) recommendations. Please see Section 3.5.4 of the APILE Technical Manual for notes and further references on this method.

A sample output of these curves is provided in Figure 4.20. The APILE program allows the users to select the curves of total mobilized resistance based on the shaft resistance plus a mobilized toe resistance of 100%, 50%, and 0% of the nominal toe resistance. Users may change the Pile Penetration at Toe and/or the Permanent Load as desired. Graphics will change according to the values entered by the user. A tabulated display is provided with resulting values of Axial Load and Drag Force.

For ease of reference, the selection (check mark) of the Show Resistance Curves will replace the Neutral Axis curves with the calculated curves (from APILE using FHWA Method) of transfers in side resistance, end bearing and total resistance versus depth.

Any of the charts observed under this display can be printed with the Print Chart button or exported (along with data points) to a pre-formatted excel spreadsheet with the Export Chart to Excel button.

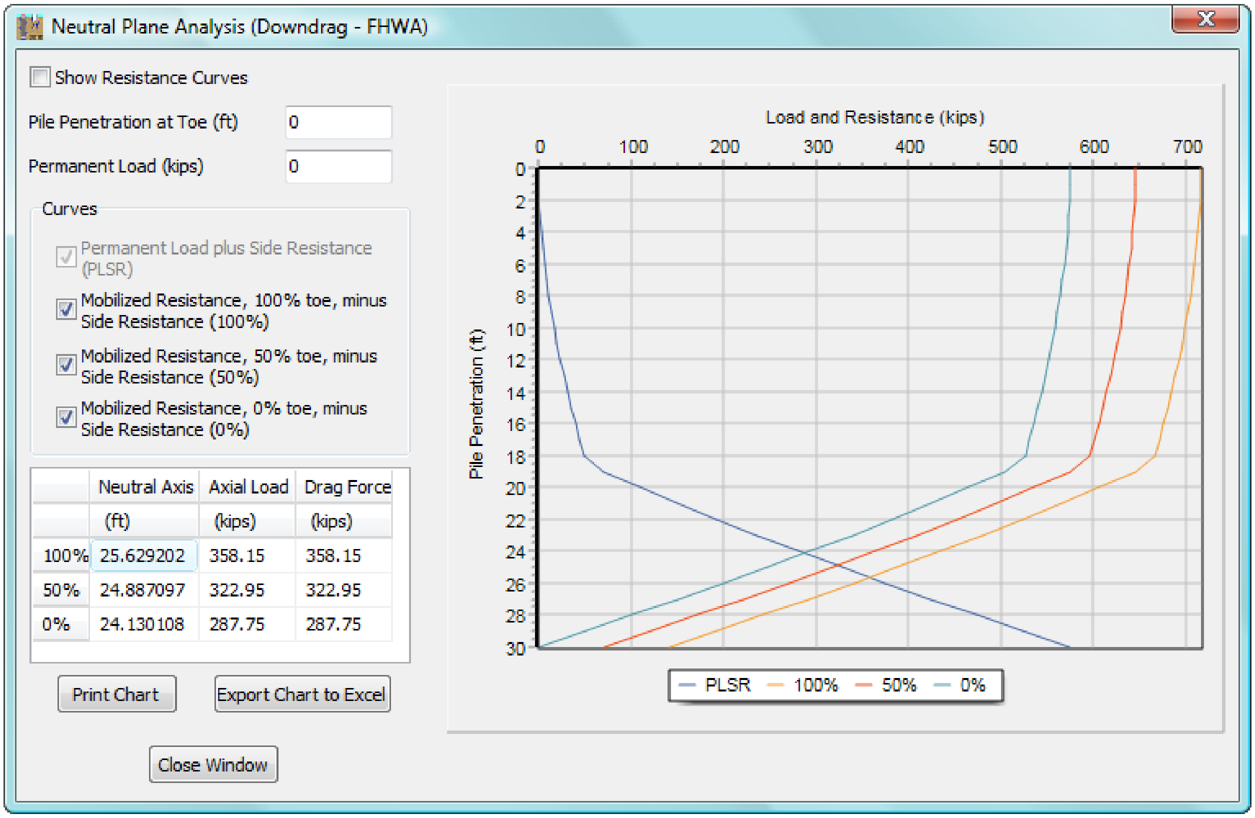


Figure 4.23 Sample Curves of Neutral Plane Analysis.

4.3.14 Graphics > Export Plots to MS-Excel

This command is selected to export some (or all) of the output plots to a pre-formatted spreadsheet file for Microsoft Excel©. Each check-marked plot will be exported to two spreadsheet tabs, one contains the data points and the second the plotted chart. A sample graphics screen of the Graphics > Export Plots to Excel dialog box is shown in Figure 4.21.

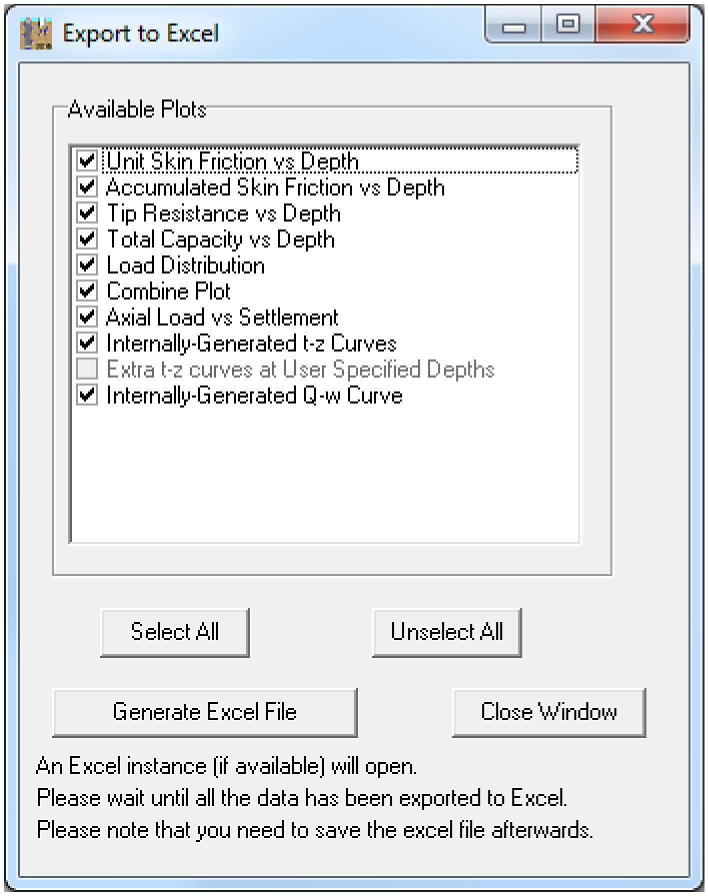


Figure 4.24 Export to Excel Window.

Options contained in this dialog box are explained below.

Select All

Marks all available plots for export to an Excel file.

Unselect All

Unselect all available plots so none will be exported.

Generate Excel File

After clicking this button, the Microsoft Excel software will be started (only if available in the computer in use). The user must wait until all the data has been exported to the file. User must save the generated excel file before closing.

Close Window

Click this button to close the Export to Excel dialog box.

4.4 Command Line Interface

APILE 2026 has a simple command line interface (CLI) for running analyses without opening the application graphical user interface.

This command line is centered around modification of a base input file programmatically. The command line interface use is experimental, subject to change in future, meant to be used only by advanced/power users, and does not perform strict data validation.

Absence of strict data validation means that by using the command line interface one may generate incorrect input files, or modify inactive properties that are not used or editable from the UI application due to user selection. For example, using the command line interface one may set square pile sectional area property when the input file is set to use a circular pile.

When setting values using the CLI, units for all entries are based on existing input file's units (metric or English).

The notation used in this document is as follows:

- Command line arguments enclosed in square brackets are optional arguments. For example, [--length 20.2] means that the user may optionally specify a command line argument --length 20.2. Analogously, command line arguments not enclosed in square brackets are required fields.
- Entries enclosed in angle brackets (e.g. <element>) are placeholders. Reserved placeholders are
  - <number> a numberic value
  - <int> an integer value
  - <str> a string
- Placeholders may also be as follows:
  - <number,number> represents a set of two numbers separated by a comma, e.g. 1.2,3.4
  - <foo|bar|baz> means a choice from an inclusive set with elements {foo, bar, baz}.
  - named placeholder for grouped properties that are defined elsewhere, e.g. <clay-properties>.
- Bash syntax is adopted for splitting long set of chained flags into multiple lines. Namely, the \ character is used to denote line continuation

The application exit code is 0 when the command executes without encountering issues such as missing required parameters, and non-zero otherwise.

4.4.1 Running an existing input file

```
apile.exe --run path_to_input_file.ap12d
```

where

- `path_to_input_file.ap12d` is an absolute path, or a relative path to the current working directory. Enclose the path or filename in quotes if it contains spaces.

4.4.2 Modify a Soil Layer

```
apile.exe --modify layer \
   --input path/to/input_file.ap12d \
   --index <int> \
   [--output <str>] \
   [--depth-const <number>] \
   [--depth-var <number>] \
   [--type <clay|sand|silt>] \
   [--qc <number,number>] \
   [--max-friction <number>] \
   [--max-bearing <number>] \
   [--friction-reduction <number>] \
   [--bearing-reduction <number>] \
   [--zpeak <number,number>] \
   [--unitweight <number,number>] \
   [--user-bearing <number,number>] \
   [--user-friction <number,number>] \
   [<clay-properties>] \
   [<sand-properties>] \
   [<silt-properties>]
```

where

- `--input` is absolute or relative path to an existing APILE input file
- `--index` is the soil layer index, indexed at 0
- `--output` is optional new output file created. If not specified, the input file is overwritten
- `--depth-const` is the new soil layer thickness, keeping all other layers thickness constant

- `--depth-var` is the new soil layer thickness, while modifying the thickness of the layer below targeted layer (if any)
- `--elevation-const` top elevation of the targeted soil layer, while keeping elevation of other layers constant. If this flag is set, depth view is also implicitly changed to elevation view.
- `--type` is the soil layer type. If not specified, assumes unchanged.
- `--unit-weight` is the soil layer unit weight
- `--zpeak` is Z-peak value for t-z curves
- `--qc` is Qc from cone penetration data
- `--max-friction` is maximum side friction
- `--max-bearing` is maximum end bearing
- `--bearing-reduction` is the reduction factor on end bearing
- `--friction-reduction` is the reduction factor on side friction
- `--user-friction` is user-specified skin friction load transfer
- `--user-bearing` is user-specified end-bearing load transfer

Available parameters for <clay-properties> are:

- `--undrained-su <number,number>` is the undrained shear strength
- `--remolded-su <number,number>` is the remolded shear strength
- `--t-residual <number,number>` is the t-residual factors
- `--sensitivity <number,number>` is the soil sensitivity
- `--plastic-index <number,number>` is the plasticity index
- `--initial-side-friction <number,number>` is the initial side friction
- `--yield-stress-ratio <number,number>` is the yield stress ratio

Available parameters for <sand-properties> are:

- `--k0 <number,number>` is the lateral earth pressure
- `--nq <number,number>` is bearing capacity factor
- `--zc <number,number>` is the Zc value for q-w curve

- `--friction-angle <number,number>` is the friction angle
- `--spt <number,number>` is SPT blow count

Available parameters for <silt-properties> are:

- `--k0 <number,number>` is the lateral earth pressure
- `--su <number,number>` is the shear strength
- `--friction-angle <number,number>` is the friction angle
- `--spt <number,number>` is the SPT blow count

Values specified as `<number,number>` refer to the top and bottom values for the specified soil layer.

4.4.2.1 Example

Consider an input file that has 2 sand layers. Now consider the command line arguments:

```
apile.exe --modify layer \
   --input example.ap12d \
   --index 0 \
   --friction-angle 35,38 \
   --undrained-su 10,40
```

The above would result in the following

- The input file would be modified in-place. This is because no --output flag was specified.
- The friction angle of the first layer (index 0) would be modified to be 35 and 38 degrees at the top and bottom, respectively.
- The `--undrained-su` flag would be ignored. This is because the existing layer soil type is sand, and no `--type` flag was specified to overwrite it to clay.

4.4.3 Modify Pile Properties

```
apile.exe --modify pile \
   --input foo.ap12d \
   [--output <str>] \
   [--elastic-modulus <number>] \
   [--const-axial-area <number>] \
   [--squarepile-area] \
   [--circular-od <number>] \
   [--circular-id <number>] \
   [--length <number>] \
   [--stickup <number>] \
   [--batter <number>] \
   [--zero-friction <number>]
```

where

- `--input` is absolute or relative path to an existing APILE input file
- `--output` is optional new output file created. If not specified, the input file is overwritten
- `--elastic-modulus` is pile's elastic modulus
- `--const-axial-area` is used to specify a constant pile cross-sectional area for axial stiffness
- `--square-pile-area` is cross-sectional area for square piles
- `--square-pile-perim` is cross-sectional perimeter for square piles
- `--length` is the pile length
- `--circular-od` is the outer diameter for circular piles
- `--circular-id` is the inner diameter for circular piles
- `--stickup` is the pile stick-up length
- `--batter` is the pile batter angle
- `--zero-friction` is the pile zero friction length

4.4.4 Running Multiple Commands

In cases where you need to run multiple commands, you can experience significant faster results by piping multiple commands to the stdin of the APILE executable. In order to do that, use the flag `` `-` `` which tells APILE to expect input from `stdin`:

For example, in Powershell one may do:

```
echo --run input.ap12d | apile.exe -
```

The content piped to the stdin can be multiple lines. When input is in multiple lines, each line is interpreted to be a separate command.

4.4.4.1 Example

Suppose we have an APILE input files called `input_1.ap12d`, `input_2.ap12d`, `input_3.ap12d`, `input_4.ap12d`.

Create a file called `commands.txt` with the following content

```
--run input_1.ap12d
--run input_2.ap12d
--run input_3.ap12d
--run input_4.ap12d
```

Now, open a Powershell or bash shell (WSL) and navigate to the directory where these files exist. Suppose that our APILE installation directory and the executable are located in

```
c:\Program Files\Ensoft\Apile2026\apile2026.exe
```

Then we can pass the commands specified in the `commands.txt` file to APILE as follows:

Powershell

```
type commands.txt | & 'C:\Program Files\Ensoft\Apile2026\apile2026.exe' -
```

Bash (WSL)

```
cat commands.txt | '/mnt/c/Program Files/Ensoft/Apile2026/apile2026.exe -'
```

Piping commands directly via `cmd` is not supported. Please consult with your shell documentation for piping support.

Content of the file can be any of those specified in previous sections, for example, the contents may specify three separate commands each separated by a new line:

```
--modify pile --input my_file.ap12d --output case1.ap12d --length 20
--modify layer --input case1.pa12d --index 0 --unit-weight 3,3
--run case1.ap12d
```

In above examples, data is piped from file content to APILE via the shell. You can also pipe data from a programming or scripting language. Please refer to documentation of your language for additional help.

4.4.5 Scripting Support

The command line interface can be executed from any language that supports running processes. See Example 12.

CHAPTER 5. Example Problems

5.1 Introduction

This chapter presents several examples that were solved using APILE. In order to assure accuracy from the computer results, some examples have been compared with the results from hand calculations. The step-by-step hand calculations were carried out based on the procedures described in the accompanying APILE Technical Manual. The users can have confidence in their results if limited amounts of hand calculations can be done for comparisons. The studies in this chapter also provide guidance for the analysis of axially loaded piles with APILE.

There are three types of output data provided by the computer. The first type is the output file which contains formatted text that consists of an echo-print of the input data; the distribution of skin friction, end bearing, and total capacity; and the final load-settlement curve. The second type of output presents the data for a graphics file that allows the code to produce plots. All of the data are saved with ASCII format and the user may access the files with any text editor.

Several problems are provided herein as examples of different applications that may be solved using our computer program APILE. Each example focuses on a particular computational feature of the program. Input files for each example are automatically copied to the APILE data directory during installation (*<Root Drive>\Ensoft\APILE2026-Examples*).

Example problems provide the user information on input and output of various cases, and present a quick tutorial for real-world applications. The user is encouraged to study these examples and, with modifications, may even use them to solve similar problems. However, by no means can these limited examples explore the full functions and features provided by APILE.

The main features of each example included with APILE are summarized as follows.

Example Problem 1 – Steel Pipe Pile

- non-uniform soil deposit, two layers of sand and two layers of clay,
- open-ended steel pipe pile,
- example with English units, and
- hand calculations with FHWA, USACE and API methods for verification.

Example Problem 2 – Offshore Steel Pipe Pile in Sand

- sand layers with varying soil parameters,
- open-ended steel pipe pile with internal plug computed within APILE,
- example with S.I. units, and
- hand calculations with API method for verification.

Example Problem 3 – Open-Ended Steel-Pipe Pile in Clay

- clay layers with varying soil parameters,
- open-ended steel pipe pile with internal plug computed within APILE, and
- example with S.I. units.

Example Problem 4 – Prestressed Concrete Pile for Bridge Foundation

- non-uniform soil deposit, one layers of stiff clay and one layer of sand,

- prestressed concrete pile,
- example with S.I. units, and
- hand calculations with API, FHWA, and USACE methods for verification (including accounting for code-specified limiting values).

Example Problem 5 – FHWA Tapered Pile

- sand layers,
- tapered pile for FHWA method (other methods do not account for tapered pile effects),
- example with English units,
- hand calculations with FHWA method for verification (including accounting for code-specified limiting values).

Example Problem 6 – Uplift Pile Capacity

- non-uniform soil layers, and
- study uplift (tension) capacity of pile.

Example Problem 7 – CPT Based Method for Close-Ended Pile

- non-uniform soil layers,
- steel-pipe pile with closed end,
- hand-calculation with NGI and MTD methods for verification, and
- example with S.I. units.

Example Problem 8 – CPT Based Method for Open-Ended Pile

- non-uniform soil layers,
- steel pipe pile with open end,
- hand-calculation with NGI and MTD methods for verification, and
- example with S.I. units.

Example Problem 9 – LRFD Based Method

- non-uniform sand layers,
- steel pipe pile with closed end,
- LRFD load factors and reduction factors, and
- example with S.I. units.

Example Problem 10 – API Method on Battered Pile

- non-uniform clay layers,
- fully plugged, open ended steel pipe pile,
- 1.0H:1.5V pile batter,
- hand-calculation with API method for verification, and

  example with English units.

Example Problem 11 – CPT to APILE

- example for importing and interpreting CPT data into APILE,
- mixed layers of sand and clay,
- extra input of PI and YSR for CPT-based methods (NGI, MTD, Fugro and UWA), and
- example of CPT data imported into APILE with English units.

Example Problem 12 – CLI example

- example for using the command line interface
- mixed layers of sand and clay

5.2 Example Problem 1 – Steel Pipe Pile in Sand and Clay

This example is included to illustrate a common case in which a 10 in. diameter steel pile is subjected to a vertical load. The soil deposit is not uniform, as shown in Figure 5.1. It is assumed that the pile is not plugged.

The computational results from APILE for various methods in this example are compared with approximate hand computations performed using a spreadsheet. Selected graphics outputted by APILE are also presented along with the output file. The user may select to eliminate the printing of capacity for each increment length to shorten the length of the output text (see Section 2.2.4).

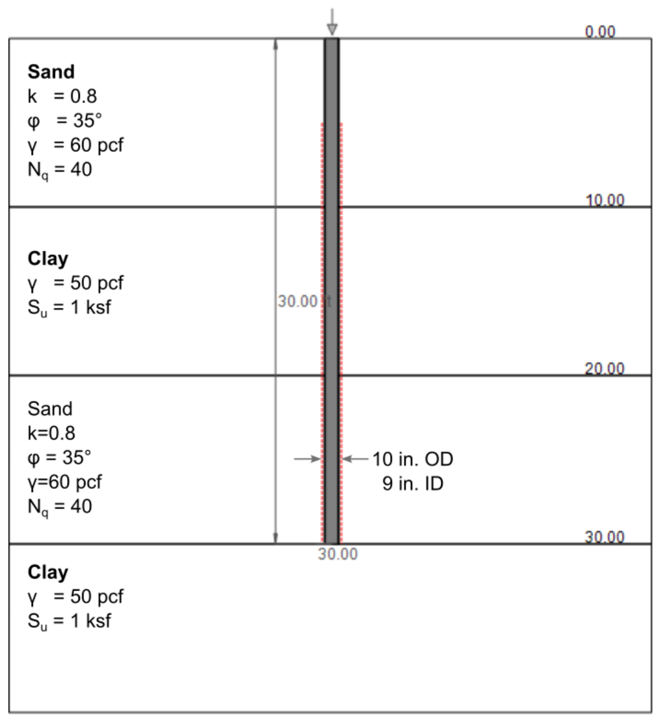


Figure 5.1 General soil description of Example Problem 1.

5.2.1 Comparison of APILE Results with Hand Computations

This section contains some comparisons of the results obtained from hand computations against those from the computer run in APILE for three different methods.

5.2.1.1 FHWA Method

a. Sand layer from 0 to 10 ft

Depth (ft)	Inc. (ft)	Avg. Effect. Stress (psf)	Surface Friction Angle δ (deg)	Coefficient of Lateral Stress (k_δ)	Correction Factor (C_f)	Unit Side Friction (ksf)	Incremental Side Friction (lbs)
2	2	60	11.9	1.15	0.56	7.968	~~41.72~~ 0[1]

4	2	180	11.9	1.15	0.56	23.903	~~125.16~~ 0(1)
6	2	300	11.9	1.15	0.56	39.839	208.60
8	2	420	11.9	1.15	0.56	55.774	292.03
10	2	540	11.9	1.15	0.56	71.710	375.47
						Summation:	**876.1**

(1) APILE model is instructed to ignore top 5 ft

b. Clay layer from 10 to 20 ft

Depth (ft)	Inc. (ft)	Avg Shear Stress (psf)	Length/ Diameter Ratio	Adhesion Coefficient (α)	Unit Side Friction (ksf)	Incremental Side Friction (lbs)
12	2	1000	12	1	1000	5236
14	2	1000	12	1	1000	5236
16	2	1000	12	1	1000	5236
18	2	1000	12	1	1000	5236
20	2	1000	12	1	1000	5236
					Summation:	**26180**

c. Sand layer from 20 to 30 ft

Depth (ft)	Inc. (ft)	Avg. Effect. Stress (psf)	Surface Friction Angle δ (deg)	Coefficient of Lateral Stress (k_δ)	Correction Factor (C_f)	Unit Side Friction (ksf)	Incremental Side Friction (lbs)
22	2	1160	11.9	1.15	0.56	154.043	806.57
24	2	1280	11.9	1.15	0.56	169.979	890.01
26	2	1400	11.9	1.15	0.56	185.914	973.45
28	2	1520	11.9	1.15	0.56	201.850	1056.88
30	2	1640	11.9	1.15	0.56	217.785	1140.32
						Summation:	**4867.23**

d. Summary and Comparison with FHWA Method

Total side friction = 876+26,180+4,867 = 31,923 lbs vs. 32.0 kips (from APILE).

Total tip resistance = $A_p\ \sigma_v\ \alpha\ Nq$ = (0.104) (1700) (0.67) (64) = 7,582 vs. 7.7 kips (from APILE, using Options > Control Options > Average Depth to Estimate Tip Resistance = 0 D for easy comparison with hand calculations, whereas for design purposes it would be more applicable to select an average resistance of +/- 1.5 D from pile tip).

5.2.1.2 USACE Method

a. Sand layer from 0 to 10 ft

Depth (ft)	Inc. (ft)	Avg. Effect. Stress (psf)	Surface Friction Angle δ (deg)	Coefficient of Lateral Stress (k_δ)	Correction Factor (C_f)	Unit Side Friction (ksf)	Incremental Side Friction (lbs)
2	2	60	26.3	1.25	1	37.067	~~194.08~~ 0[(1)]
4	2	180	26.3	1.25	1	99.691	~~521.98~~ 0[(1)]
6	2	300	26.3	1.25	1	166.152	869.97
8	2	420	26.3	1.25	1	232.613	1217.96
10	2	540	26.3	1.25	1	299.074	1565.95
						Summation:	**3653.88**

[(1)] APILE model is instructed to ignore top 5 ft

b. Clay layer from 10 to 20 ft

Depth (ft)	Inc. (ft)	Avg Shear Stress (psf)	Length/ Diameter Ratio	Adhesion Coefficient (α)	Unit Side Friction (ksf)	Incremental Side Friction (lbs)
12	2	1000	12	0.75	750	3927
14	2	1000	12	0.75	750	3927
16	2	1000	12	0.75	750	3927
18	2	1000	12	0.75	750	3927
20	2	1000	12	0.75	750	3927
					Summation:	**19635**

c. Sand layer from 20 to 30 ft

Depth (ft)	Inc. (ft)	Avg. Effect. Stress (psf)	Surface Friction Angle δ (deg)	Coefficient of Lateral Stress (k_δ)	Correction Factor (C_f)	Unit Side Friction (ksf)	Incremental Side Friction (lbs)
22	2	750	26.3	1.25	1	463.343	2426.06
24	2	750	26.3	1.25	1	463.343	2426.06
26	2	750	26.3	1.25	1	463.343	2426.06
28	2	750	26.3	1.25	1	463.343	2426.06
30	2	750	26.3	1.25	1	463.343	2426.06
						Summation:	**12130.31**

d. Summary and Comparison with USACE Method

Total side friction = 3,654+19,635+12,130 = 35,419 lbs vs. 35.1 kips (from APILE)

Total tip resistance = $A_p\ \sigma_v\ Nq$ = (0.104) (750) (47) = 3,666 vs. 3.7 kips (from APILE, using Options > Control Options > Average Depth to Estimate Tip Resistance = 0 D for easy comparison with hand calculations, whereas for design purposes it would be more applicable to select an average tip resistance of +/- 1.5 D from pile tip).

5.2.1.3 API Method

a. Sand layer from 0 to 10 ft

Depth (ft)	Inc. (ft)	Avg. Effect. Stress (psf)	Surface Friction Angle δ (deg)	Coefficient of Lateral Stress (k_δ)	Correction Factor (C_f)	Unit Side Friction (ksf)	Incremental Side Friction (lbs)
2	2	60	30	0.8	1	27.713	~~145.10~~ 0[(1)]
4	2	180	30	0.8	1	72.000	~~376.99~~ 0[(1)]
6	2	300	30	0.8	1	120.000	628.32
8	2	420	30	0.8	1	168.000	879.65
10	2	540	30	0.8	1	216.000	1130.98
						Summation:	**2638.95**

[(1)] APILE model is specified to ignore top 5 ft

b. Clay layer from 10 to 20 ft

Depth (ft)	Inc. (ft)	Avg Shear Stress (psf)	Length/ Diameter Ratio	Adhesion Coefficient (α)	Unit Side Friction (ksf)	Incremental Side Friction (lbs)
12	2	1000	12	0.45	448.95	2350.70
14	2	1000	12	0.47	465.30	2436.32
16	2	1000	12	0.48	480.09	2513.76
18	2	1000	12	0.49	493.63	2584.64
20	2	1000	12	0.51	512.35	2682.65
					Summation:	**12568**

c. Sand layer from 20 to 30 ft

Depth (ft)	Inc. (ft)	Avg. Effect. Stress (psf)	Surface Friction Angle δ (deg)	Coefficient of Lateral Stress (k_δ)	Correction Factor (C_f)	Unit Side Friction (ksf)	Incremental Side Friction (lbs)
22	2	1160	30	0.8	1	535.783	2805.36
24	2	1280	30	0.8	1	591.208	3095.57
26	2	1400	30	0.8	1	646.634	3385.78
28	2	1520	30	0.8	1	702.060	3675.99
30	2	1640	30	0.8	1	757.486	3966.20

Summation:	**16928.88**

d. Summary and Comparison with API Method

Total side friction = 2,639+12,568+16,928 = 32,136 lbs vs. 32.2 kips (from APILE)

Total tip resistance = A_p σ_v Nq = (0.104) (1700) (40) = 7,072 vs. 7.0 kips (from APILE, using Options > Control Options > Average Depth to Estimate Tip Resistance = 0 D for easy comparison with hand calculations, whereas for design purposes it would be more applicable to select an average tip resistance of +/- 1.5 D from pile tip).

5.2.2 Input and Output Data Files for Example 1

Users can read Section 2.1.1 (7) of this manual for reference on the location of placement of the input and output data files for the example files installed with this program. The default installation directory is the following: *(Root Drive) c:\Ensoft\Apile2026-Examples*. The input data files for all examples presented in this manual are installed automatically with the program.

The input-data filename for Example 1 is the following:

Example 1 - Steel Pipe Pile in Sand and Clay.ap12d

The output-data filename for Example 1 is the following:

Example 1 - Steel Pipe Pile in Sand and Clay.ap12o

5.2.3 Graphical Results of Computer Analysis

The resulting plots of unit skin friction, accumulated skin friction, tip resistance, and total capacity versus depth provided by the computer program based on different methods, may be seen in Figure 5.2, Figure 5.3, Figure 5.4 and Figure 5.5 respectively.

Results of combined plots versus depth, shown in Figure 5.6, only contains the curves of skin friction, tip resistance, and total capacity versus depth for the API RP 2A method specified under Data > Computational Method > Load Settlement Method.

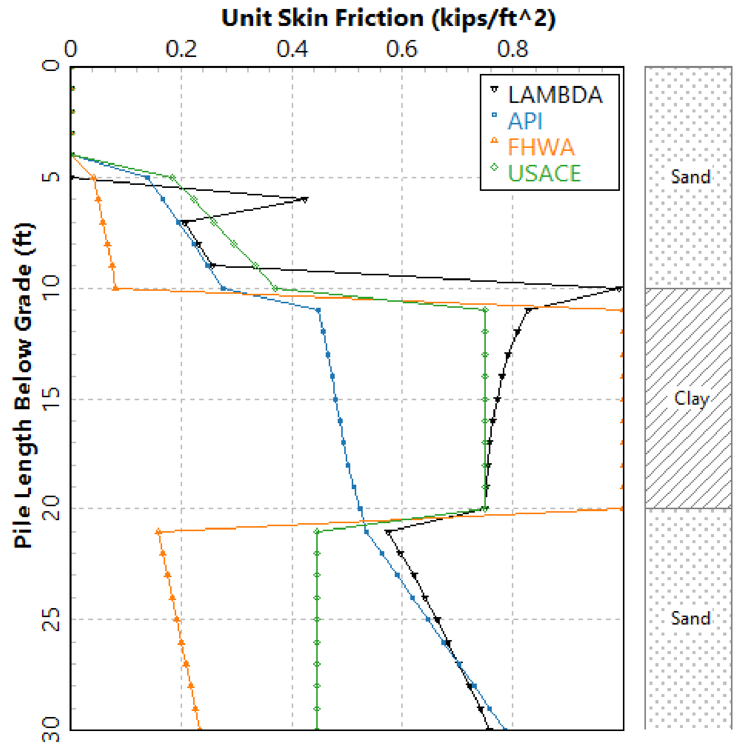


Figure 5.2   Curves of Unit Skin Friction vs Depth for Example Problem 1.

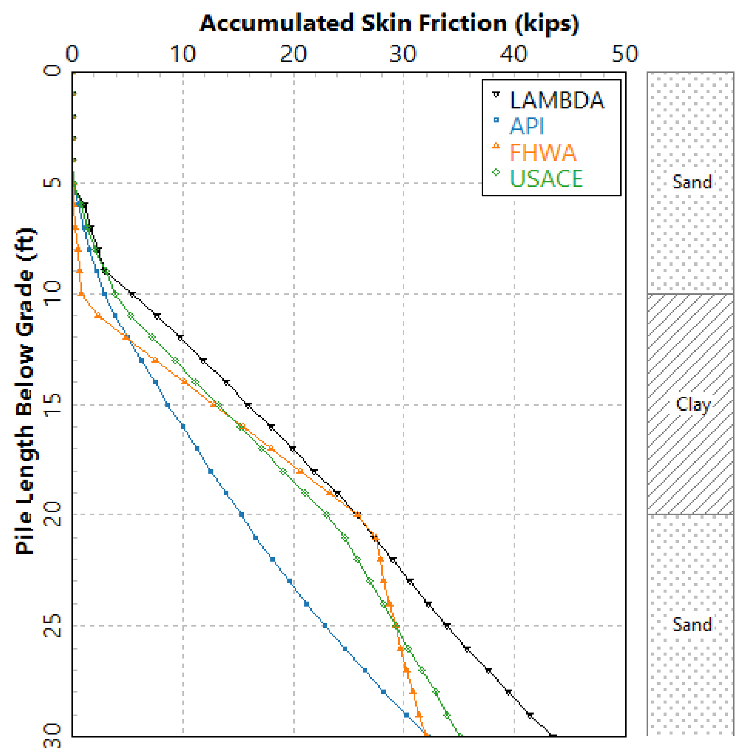


Figure 5.3   Curves of Accumulated Skin Friction vs Depth for Example Problem 1.

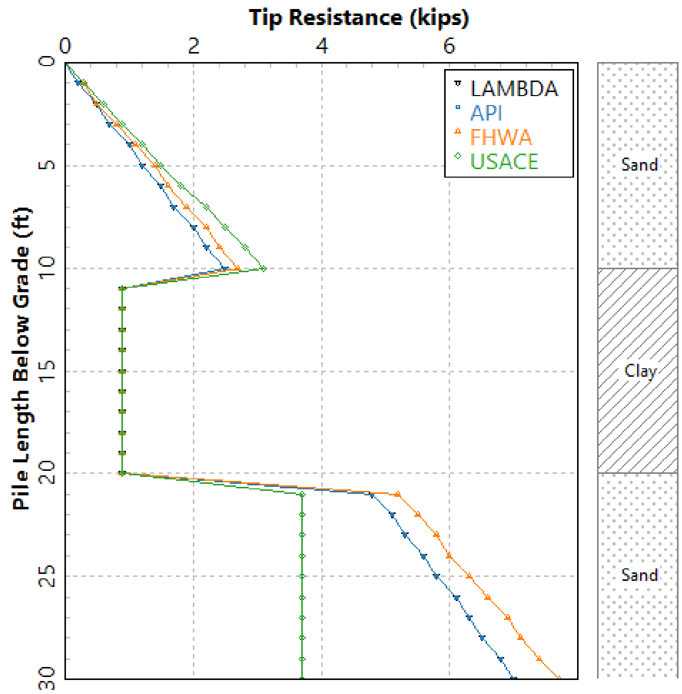


Figure 5.4 Curves of Tip Resistance vs Depth or Example Problem 1.

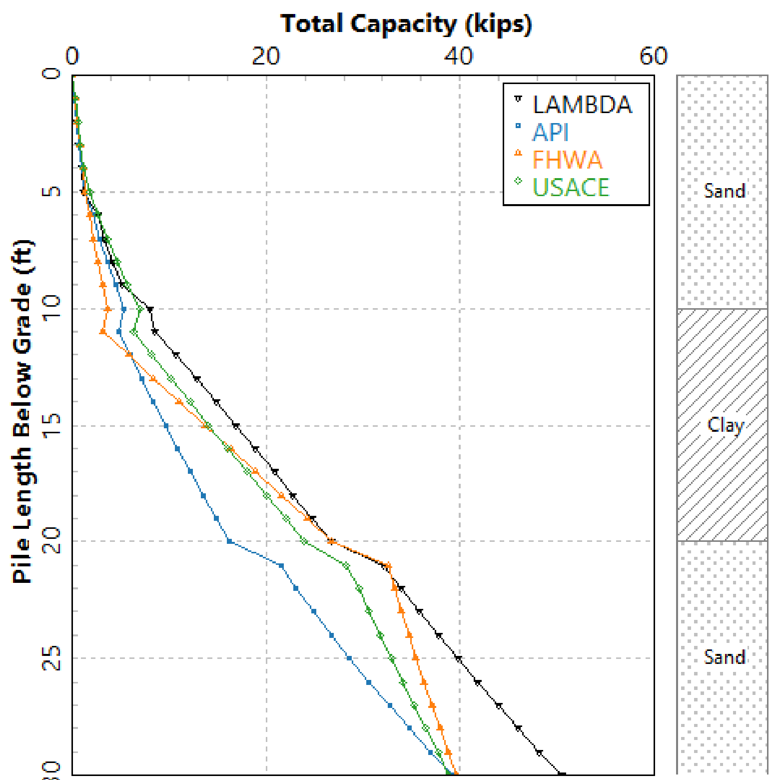


Figure 5.5 Curves of Total Capacity vs Depth or Example Problem 1.

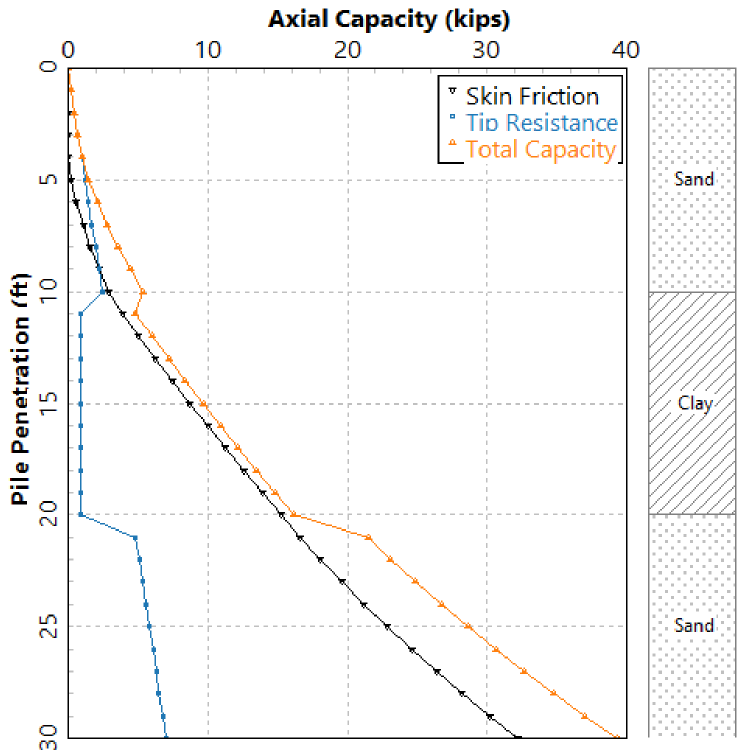


Figure 5.6 Combined Plots vs Depth based on API method for Example Problem 1.

5.3 Example Problem 2 – Offshore Steel-Pipe Pile in Sand

This example is included to illustrate a case of a pile on an offshore structure. The pile is a steel pipe and in this example with on outside diameter of 1000 mm and inside diameter of 860 mm. The subsurface condition mainly consists of cohesionless soils and the pile was driven to a depth of 33.3 meters. The computer program APILE calculated 8,004 kN for the total bearing capacity (API RP-2A), which is similar to the value of 8,187 kN that is obtained from simplified hand calculations. Soil data is provided in Table 5.1.

Layer	Depth (m)	Soil Type	γ' (kN/m^3)	ϕ (Deg.)	K_o	N_q
1	0	sand	18.1	33	0.46	32
	2	sand	19	37.5	0.39	40
2	2	sand	9.2	37.5	0.39	40
	3	sand	10.2	39	0.37	40
3	3	sand	10.2	39	0.37	40
	5	sand	5.7	30	0.5	20
4	5	sand	5.7	30	0.5	20
	25	sand	5.7	30	0.5	20
5	25	sand	5.7	30	0.5	20
	30.5	sand	11.2	40.5	0.35	40
6	30.5	sand	11.2	40.5	0.35	40
	36	sand	11.2	40.5	0.35	40

Table 5.1 Soil Data for Example Problem 2

5.3.1 Hand Computations for API Method

The program output will be compared to the results from the following hand calculations.

5.3.1.1 Skin Friction

The general equation for skin friction is:

$$Q_f = \int_o^L f_x dA_s \tag{5.1}$$

where

Q_f = axial load capacity in skin friction, lb (kN);

L = penetration of pile below ground surface, ft (m);

f_x = unit resistance at depth x, measured from ground surface, lb/ft^2 (kPa); and

A_s = side surface area of pile, ft^2 (m^2).

At each increment,

$$f_x A_s = (k\,(\tan\delta)\,\overline{p}_o)\,A_s$$

$$f_x A_s = k\,(\tan(\phi - 5))(\sum(\gamma h))(\sum \pi Dh)$$

(5.2)

Or,

$$f_x A_s = (Max\ Skin\ Friction)(\sum \pi Dh)$$

(5.3)

where

k = coefficient of lateral earth (ratio of horizontal to vertical normal effective stress), a value of k = 0.8 was recommended for open-ended pipe piles, that are driven unplugged, for loadings in both tension and compression. A value of k = 1.0 was recommended for full displacement piles.

$\overline{p}_o$ = effective overburden pressure at the point in question;

δ = the friction angle between the soil and the pile wall. In the absence of data on δ, APILE computes $\delta = \phi - 5^o$ (in degrees) based on user's inputted value of friction angle (ϕ). The limiting f is interpolated linearly within APILE for intermediate values of δ.

D = outside pile diameter.

Combining Eq. (5.1) and Eq. (5.2):

$$\boldsymbol{Q_f = k(tan(\emptyset - 5)) \sum \gamma h \sum \pi Dh}$$

(5.4)

where k, $\emptyset$ and γ are averaged values.

Using the values from Table 5.1 we can make computations of $\sum \gamma h$ at various sample depths:

at 2m: $\sum \gamma h = \left(\frac{18.1+19}{2}\right) * 2 = 37.1$ kN/m^2

At 3m: $\sum \gamma h = \left[\left(\frac{9.2+10.2}{2}\right) * 1\right] + 37.1 = 46.8\ \text{kN/m}^2$

At 5m: $\sum \gamma h = \left[\left(\frac{10.2+5.7}{2}\right) * 2\right] + 46.8 = 62.7\ \text{kN/m}^2$

Values of unit side resistance (f_x) at various sample depths can be computed as follows:

At 2m, $f_{2m} = \left[\left(\frac{0.46+0.39}{2}\right)\left(tan\left[\frac{33+37.5}{2} - 5\right]\right)(37.1)\right] = 9.20\ \text{kN/m}^2$

At 3m: $f_{3m} = \left[\left(\frac{0.39+0.37}{2}\right)\left(tan\left[\frac{37.5+39}{2} - 5\right]\right)(46.8)\right] = 11.66$ kN/m^2

At 5m: $f_{5m} = \left[\left(\frac{0.37+0.50}{2}\right)\left(tan\left[\frac{39+30}{2} - 5\right]\right)(62.7)\right] = 15.43$ kN/m^2

We can now solve Eq. (5.4) at the various sample depths:

At depth of 2m:

$$Q_{f,2m} = \left[\left(\frac{f_{2m}+f_{0m}}{2}\right) * \pi Dh\right] + Q_{f,0m}$$

$$Q_{f,2m} = \left[\left(\frac{9.20+0}{2}\right)(\pi * 1 * 2)\right] + 0 = 28.89 \text{ kN}$$

At depth of 3m:

$$Q_{f,3m} = \left[\left(\frac{f_{3m}+f_{2m}}{2}\right) * \pi Dh\right] + Q_{f,2m}$$

$$Q_{f,3m} = \left[\left(\frac{11.66+9.20}{2}\right)(\pi * 1 * 1)\right] + 28.89 = 61.65 \text{ kN}$$

At depth of 5m:

$$Q_{f,5m} = \left[\left(\frac{f_{5m}+f_{2m}}{2}\right) * \pi Dh\right] + Q_{f,3m}$$

$$Q_{f,5m} = \left[\left(\frac{15.43+11.66}{2}\right)(\pi * 1 * 2)\right] + 61.65 = 146.76 \text{ kN}$$

Following similar computations methods used in the sample depths above we can now compute values for the remaining depths, with the results included in Table 5.2.

Depth (m)	φ - 5 (deg)	tan (φ-5)	γ(h) (kN/m^2)	Σγ(h) (kN/m^2)	f (kPa)	π(d)(h)	π(d)(h)f	Q_f (kN)
2	30.25	0.58318	37.1	37.10	9.20	6.28	28.89	28.89
3	33.25	0.65563	9.7	46.80	11.66	3.14	32.76	61.65
5	29.5	0.56577	15.9	62.70	15.43	6.28	85.11	146.76
25	25	0.46631	114	176.70	41.20	62.83	1779.07	1925.82
30.5	30.25	0.58318	46.475	223.18	55.31	17.28	833.81	2759.63
33	35.5	0.71329	28	251.18	62.71	7.85	463.47	3223.10

Table 5.2 Hand Computations of Side Resistances for Example Problem 2

- In table above the calculated f values were compared with the limiting values in the Technical Manual. For each depth, the lower of the two values was used.
- For this example, the program has produced output at 0.5-meter increments. Changing the depth increment of the hand calculations to the 0.5-meter increment of depth will produce a more accurate final result (with exact match to the results from the computer program).

5.3.1.2 Base Resistance

The general equation for end bearing in Sands is:

$$Q_p = qA_p \tag{5.5}$$

and

$$q = \overline{p}_o N_q \tag{5.6}$$

Where

Q_p = axial load capacity in end bearing;

q = unit end bearing resistance;

A_p = cross-sectional area of tip of pile.

$\overline{p}_o$ = effective overburden pressure at the pile tip; and

N_q = bearing capacity factor.

To check soil plugging, calculate the average end bearing value from depth *H* to *(H+3D)* as follows:

$$\frac{\int_{H-1.5D}^{H+1.5D} Q_p(x)dx}{3D} \tag{5.7}$$

$$Q_p = (Max.Unit\ End\ Bearing)A_p \tag{5.8}$$

For an open-ended pipe pile for end bearing we must consider both a plugged and unplugged case. The plugged and unplugged values are computed in the following sub sections.

5.3.1.3 Fully Plugged Case

For a fully plugged case the tip area is computed as follows:

$$A_p = full\ bottom\ area\ of\ tip = \frac{\pi * D^2}{4} = 0.785398\ m^2$$

Combining Eq. (5.5) and (5.6):

$$Q_p = q\,A_p = \left(\sum \gamma h\right) N_q A_p \tag{5.9}$$

where γ is an averaged value and the calculated q values are compared with the limiting values in the Technical Manual. For each depth, the lower of the two values is used.

Using the values from Table 5.1 and Eq. (5.9) we calculate the following:

At depth 0m:

$$Q_{p,0m,plug} = 0 \;\; (since\ q = 0)$$

At depth 2m:

$$Q_{p,2m,plug} = \left[\left(\frac{18.1+19}{2}\right) * 2\right] * 40 * 0.785398 = 1165.5\ kN$$

At depth 3m:

$$Q_{p,3m,plug} = \left[37.1 + \left(\frac{19+10.2}{2}\right) * 1\right] * 40 * 0.785398 = 1624.2\ kN$$

At depth 5m:

$$Q_{p,5m,plug} = \left[37.1 + 14.6 + \left(\frac{10.2+5.7}{2}\right) * 2\right] * 20 * 0.785398 = 1061.8\ kN$$

Following similar computations methods used in the sample depths above we can now compute values for the remaining depths, with the results included in Table 5.3.

Depth (m)	γ(h) (kN/m²)	Σγ(h) (kN/m²)	Q_p (plugged (kN)
0	0	0	0
2	37.1	37.1	1165.53
3	14.6	51.7	1624.2
5	15.9	67.6	1061.86
25	114	181.6	2852.57
30.5	46.475	228.075	7165.19
33	28	256.075	7539.82

Table 5.3 Hand Computations of Fully Plugged End Bearing for Example Problem 2

- In table above the calculated q values were compared with the limiting values in the Technical Manual. For each depth, the lower of the two values was used (this is the case at the 33-m depth).
- For this example, the program has produced output at a 0.5-meter increments. Changing the depth increment of the hand calculations to the 0.5-meter increment of depth will produce a more accurate final result (with exact match to the results from the computer program).
- At user's discretion, the APILE program can use averaged values of Q_p over a length of 1.5 pile diameter above and below the pile tip. This is done following Eq. (5.7).

5.3.1.4 Partially Plugged Case

For a fully unplugged case the tip area is computed as follows:

$$A_p = steel\ cross\ sectional\ area = \frac{\pi * (Dout^2 - Din^2)}{4} = 0.204518m^2$$

Adding the effect of side friction from a partial plug in the inner wall of the pile, the previous Eq. (5.10) is now calculated as follows:

$$\boldsymbol{Q_p = q\,A_p = \left(\sum \gamma h\right) N_q A_p + Q_{f,inner\ wall}}$$

(5.10)

where γ is an averaged value and the calculated q values are compared with the limiting values in the Technical Manual. For each depth, the lower of the two values is used.

Using the values from Table 5.1 and Eq. (5.10) we calculate the following:

At depth 0m:

$Q_{p,0m,pplug} = 0\ \ (since\ q = 0)$

At depth 2m:

$Q_{f,inner\ wall} = \pi Dhf = 3.14 * 0.86 * 2 * \frac{0+9.20}{2} = 24.8\ kN$

$Q_{p,2m,pplug} = (37.1 * 40 * 0.204518) + 24.84 = 328.3\ kN$

At depth 3m:

$Q_{f,inner\ wall,3m} = (\pi Dhf) + Q_{f,inner\ wall,2m} = \left(3.14 * 0.86 * 1 * \frac{9.20+12.88}{2}\right) + 24.84 = 54.6\ kN$

$Q_{p,2m,pplug} = (51.7 * 40 * 0.204518) + 54.66 = 477.6\ kN$

At depth 5m:

$$Q_{f,inner\ wall,5m} = (\pi Dhf) + Q_{f,inner\ wall,3m} = \left(3.14 * 0.86 * 1 * \frac{12.88 + 16.64}{2}\right) + 54.6 = 134.4\ kN$$

$Q_{p,2m,pplug} = (67.6 * 20 * 0.204518) + 134.4 = 410.9\ kN$

Following similar computations methods used in the sample depths above we can now compute values for the remaining depths, with the results included in Table 5.5.

Depth (m)	γ(h) (kN/m²)	Σγ(h) (kN/m²)	Q_p (unplugged) (kN)
0	0	0	0
2	37.1	37.1	328.35
3	14.6	51.7	477.61
5	15.9	67.6	410.92
25	114	181.6	2470.67
30.5	46.475	228.075	4328.26
33	28	256.075	4964.14

Table 5.4 Hand Computations of Partially Plugged End Bearing for Example Problem 2

- In table above the calculated q values were compared with the limiting values in the Technical Manual. For each depth, the lower of the two values was used.
- For this example, the program has produced output at 0.5-meter increments. Changing the depth increment of the hand calculations to the 0.5-meter increment of depth will produce a more accurate final result (thus with exact match to the results from the computer program).
- At user's discretion, the APILE program can use averaged values of Q_p over a length of 1.5 pile diameter above and below the pile tip. This is done following Eq. (5.7).

5.3.1.5 Total Resistance

The total bearing capacity of the pile is given in Eq. (5.11). To determine the total bearing capacity of the pile, the smallest value from the skin friction equations in Eq. (5.2) and Eq. (5.3) and the end bearing equations in Eq. (5.7) and Eq. (5.8) must be used in Eq. (5.11).

$$Q_{Total} = Q_f + Q_p \tag{5.11}$$

5.3.2 Comparison of APILE Results with Hand Computations

Table 5.5 contains a comparison of the results obtained from hand computations against those from the computer run in APILE (for API Method).

Since $Q_{p,pplugged} < Q_{p,plugged}$ at all depths then the values in Table 5.4 control the end bearing capacity. Using the computed values from Table 5.2 and Table 5.4 we can find the total resistance displayed in Table 5.5 along with comparisons against the computer run in APILE (API Method).

Depth (m)	Q_f (kN)	Q_p (kN)	Q_T(Hand) (kN)	Q_T(APILE) (kN)
2	28.89	328.35	357.24	349.30
3	61.65	477.61	539.26	497.10
5	146.76	410.92	557.68	561.70
25	1925.82	2470.67	4396.49	4257.70
30.5	2759.63	4328.26	7087.89	6877.90
33	3223.10	4964.14	8187.24	8003.90

Table 5.5 Comparison of Total Resistances for Example Problem 2

- Some discrepancies are noticed between the rough hand calculations and the computed results from APILE. If the user refines the computational depths to match the more accurate 0.5-meter increments used by APILE, the hand computed values should then be much closer to the APILE software calculations.
- APILE model is using Options > Control Options > Average Depth to Estimate Tip Resistance = 0 D for easy comparison with hand calculations, whereas for design purposes it would be more applicable to select an average tip resistance of +/- 1.5 D from pile tip.

5.3.3 Input and Output Data Files for Example 2

Users can read Section 2.1.1 (7) of this manual for reference on the location of placement of the input and output data files for the example files installed with this program. The default installation directory is the following: *(Root Drive) c:\Ensoft\Apile2026-Examples*. The input data files for all examples presented in this manual are installed automatically with the program.

The input-data filename for Example 2 is the following:

Example 2 - Large Steel Pipe Pile in Sand.ap12d

The output-data filename for Example 2 is the following:

Example 2 - Large Steel Pipe Pile in Sand.ap12o

5.3.4 Graphical Results of Computer Analysis

Resulting plots of accumulated skin friction, ultimate tip resistance, and ultimate total capacity versus depth provided by the computer program may b observed in Figure 5.7, Figure 5.8 and Figure 5.9 respectively. Results of axial load versus short-term settlement are included in Figure 5.10.

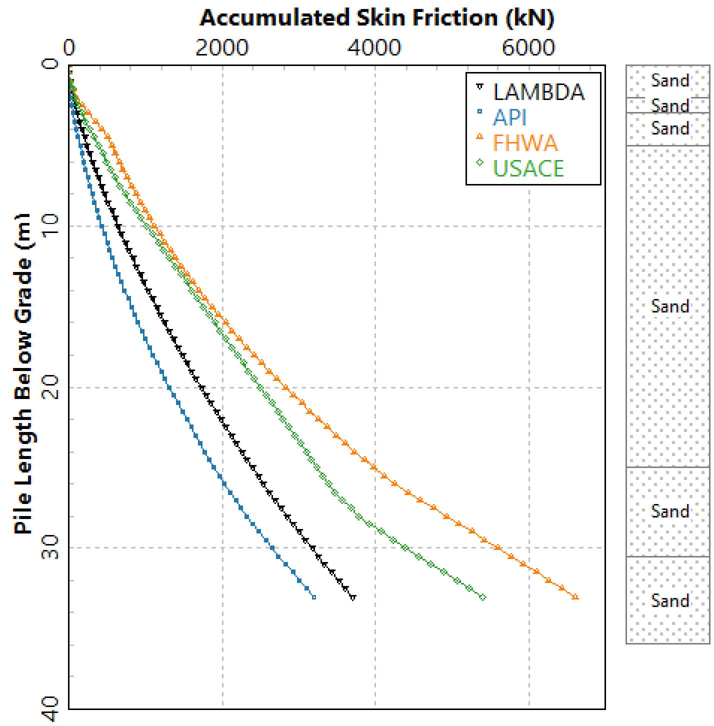


Figure 5.7 Curves of Accumulated Skin Friction vs Depth for Example Problem 2.

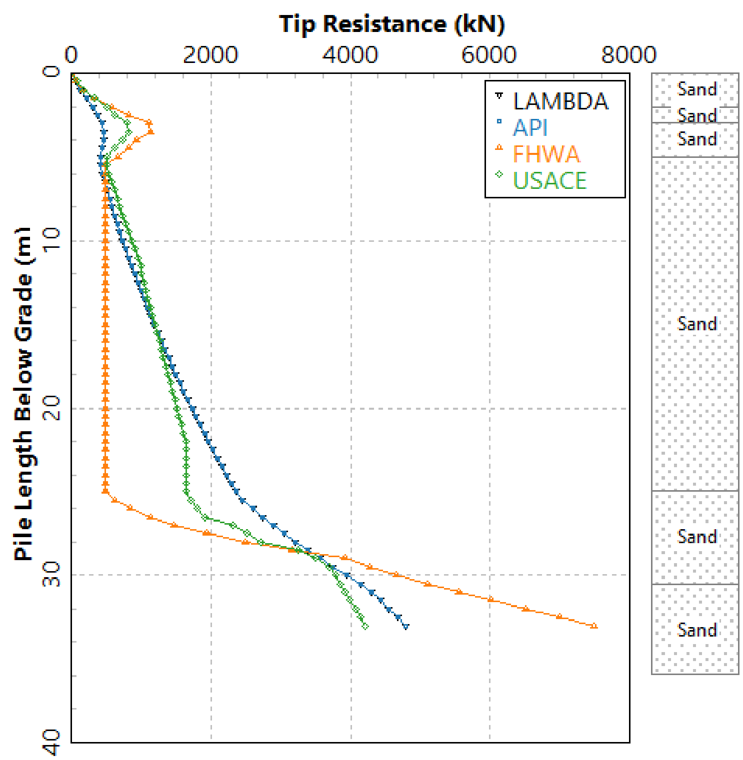


Figure 5.8 Curves of Ultimate Tip Resistance vs Depth for Example Problem 2.

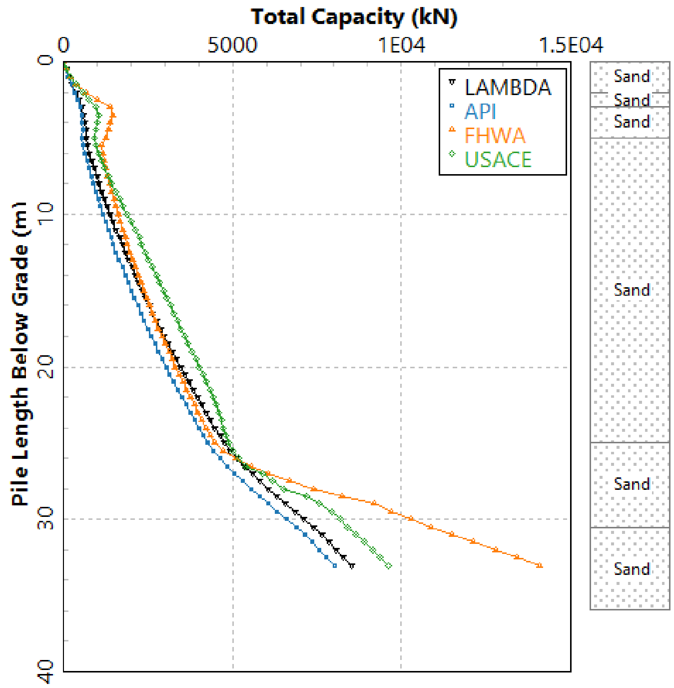


Figure 5.9 Curves of Ultimate Total Capacity vs Depth for Example Problem 2.

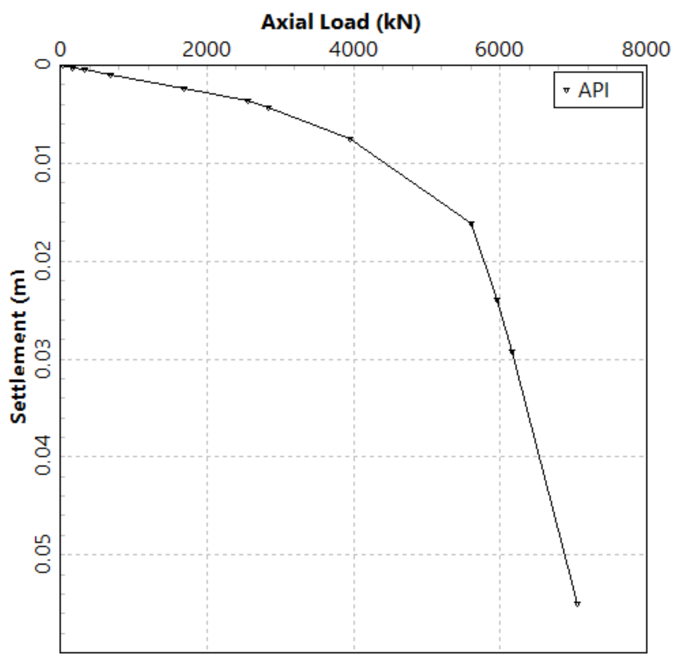


Figure 5.10 Curve of Axial Load vs Settlement for Example Problem 2.

5.4 Example Problem 3 – Steel Pipe Pile in Clay

5.4.1 Description

This example is included to show the response of a steel pile embedded in cohesive soils. The modeled pile is 39 meters long and open-ended steel pipe, with an outer diameter of 500 mm and an inner diameter of 480 mm. The soil data is given in Table 5.6. The bearing capacity was calculated by APILE, using the API RP2A method. Because this pile is open ended, a plug of soil may be forced up the inside of the pile. In this APILE model, the soil resistance from the plug is compared to the resistance from the end-bearing over the full area of the base and the smaller of the two values is used (Data > Pile Section Properties > Plugged/Unplugged Condition > Auto Compute).

Layer	Depth (m)	Soil Type	γ' (kN/m^3)	C (kN/m^2)
1	0	clay	18.6	9.8
	4	clay	18.6	9.8
2	4	clay	8.8	9.8
	10	clay	8.8	9.8
3	10	clay	8.8	19.6
	20	clay	8.8	19.6
4	20	clay	8.8	58.8
	36	clay	8.8	58.8
5	36	clay	9	78.4
	40	clay	9	78.4

Table 5.6 Soil Data for Example Problem 3

5.4.2 Input and Output Data Files for Example 3

Users can read Section 2.1.1 (7) of this manual for reference on the location of placement of the input and output data files for the example files installed with this program. The default installation directory is the following: *(Root Drive) c:\Ensoft\Apile2026-Examples*. The input data files for all examples presented in this manual are installed automatically with the program.

The input-data filename for Example 3 is the following:

Example 3 - Steel Pipe Pile in Clay.ap12d

The output-data filename for Example 3 is the following:

Example 3 - Steel Pipe Pile in Clay.ap12o

5.4.3 Graphical Results of Computer Analysis

The resulting plot of combined ultimate axial capacities versus depth provided by APILE may be observed in Figure 5.11. Results of axial load versus short-term settlement are included in Figure 5.12.

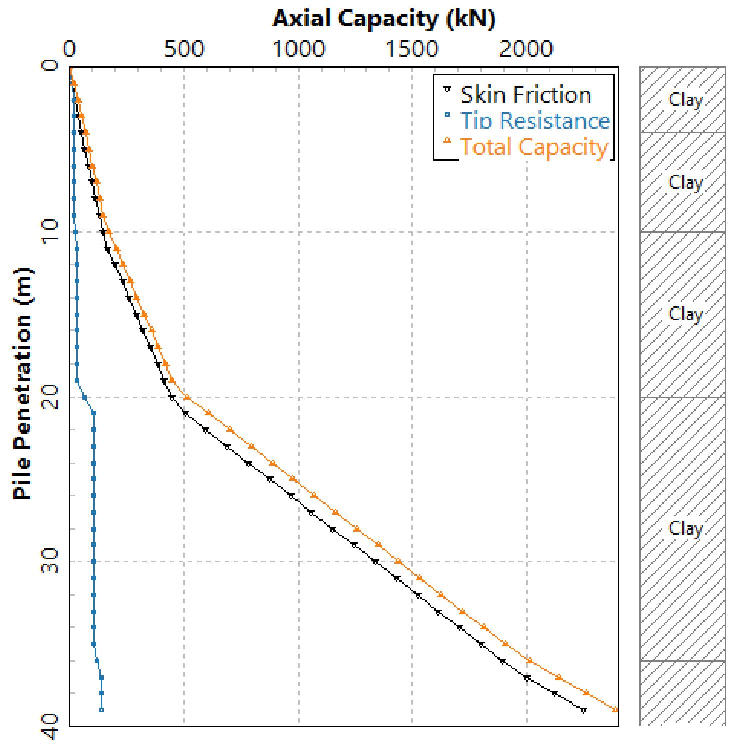


Figure 5.11 Curve of Combined Plots vs Depth (ultimate) for Example Problem 3.

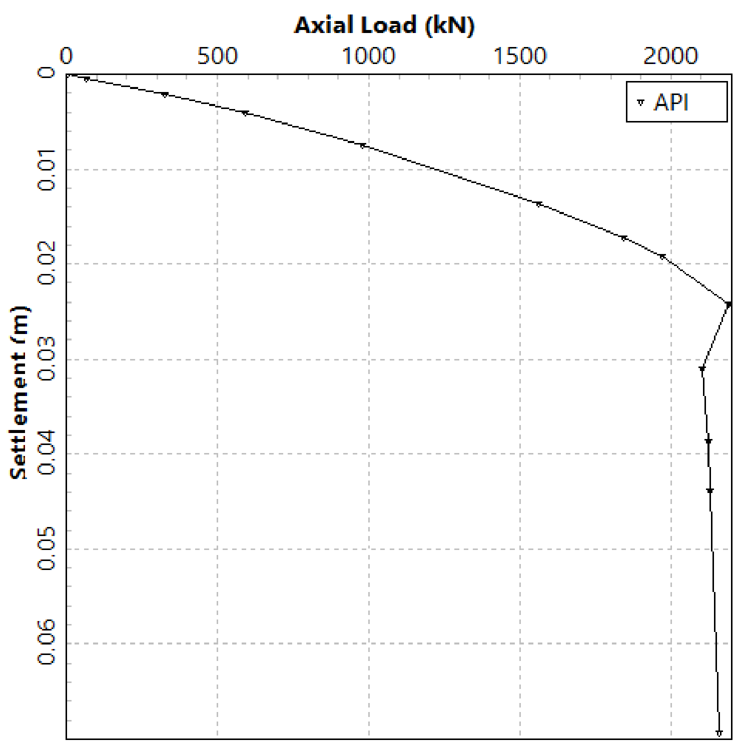


Figure 5.12 Curve of Axial Load vs Settlement for Example Problem 3.

5.5 Example Problem 4 – Prestressed Concrete Pile for Bridge Foundation

This example is included to illustrate a modeling case that may be applicable for a simple bridge foundation. The soil deposit consists of two sublayers as shown in Figure 5.13. The top layer is a 3-meter stiff clay underlain by a medium dense to dense sand layer. One meter of the top clay layer is not considered for axial friction (side resistance) transfers. The proposed pile for these foundations is composed of prestressed concrete piles with 450 mm (18-in.) in outside diameter. The elastic modulus of the prestressed pile is 25,000,000 kN/m^2 (3,626,000 psi). Each pile is required to provide about 2000 kN for a service load.

The APILE output for this example is shown in detail so the user can examine the increase in pile capacity with depth. The user may elect to eliminate the printing of capacity for each increment length to shorten the length of output.

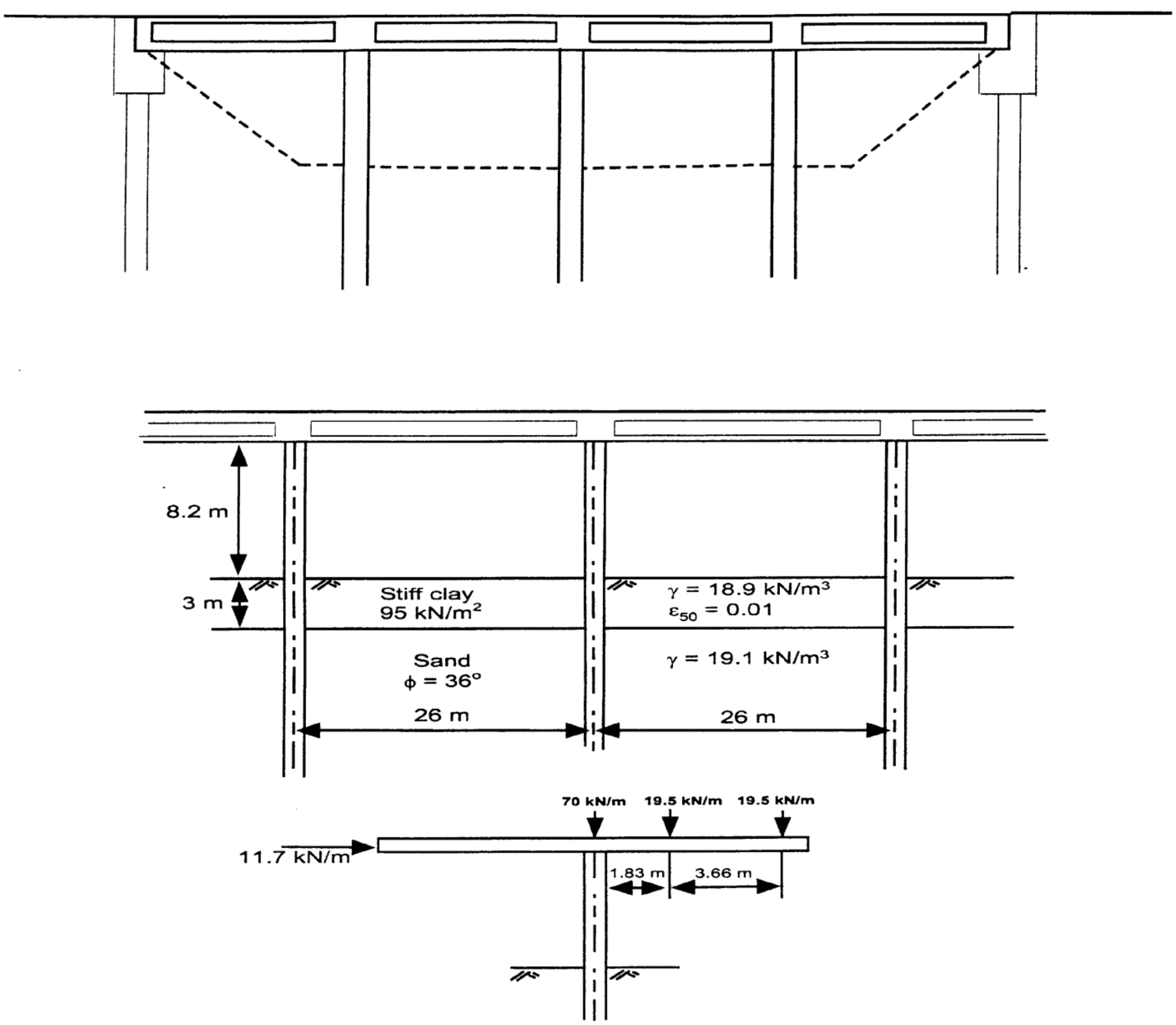


Figure 5.13 Pile layout and soil conditions of Example Problem 4.

5.5.1 Hand Computations and Comparisons with APILE

The program output will be compared to the results from the following hand calculations.

5.5.1.1 API Method – Skin Friction

A. For the top Clay layer (ignoring friction on top 1 meter)

$$fA_S\ (clay) = (\ \alpha\ )\ (\ c\ )*\pi\ *D*\ h \quad (5.12)$$

where

Avg. effective overburden pressure (p) is 18.9 * 1.5 = 28.35 kN/m^2

α = (0.5)(c/p) - 0.25 = (0.5)(95/28.35)-0.25 = 0.37

fA_S (clay) = (0.37) (95)*π *(0.45)* (3-1) = 99 kN

B. For the bottom Sand layer

$$fA_S\ (sand) = k_0*(\Sigma\gamma h)*\tan\ (\phi - 5)*\pi\ *D*\ h \quad (5.13)$$

where

Avg. effective overburden pressure (p) from 0 to 3 m

18.9 * 1.5 = 28.3 kN/m^2

Avg. effective overburden pressure (p) from 3 to 5 m

18.9 * 3 + (9.1) (1) = 65.8 kN/m^2

Avg. effective overburden pressure (p) from 5 to 10 m

18.9 * 3 + (9.1) (2) + (9.1) (2.5) = 97.6 kN/m^2

Avg. effective overburden pressure (p) from 10 to 15 m

18.9 * 3 + (9.1) (7) + (9.1) (2.5) = 143.1 kN/m^2

Avg. effective overburden pressure (p) from 15 to 20 m

18.9 * 3 + (9.1) (12) + (9.1) (2.5) = 188.6 kN/m^2

Avg. effective overburden pressure (p) from 20 to 25 m

18.9 * 3 + (9.1) (17) + (9.1) (2.5) = 234.2 kN/m^2

Computation of skin friction from each sub-layer based on API Method:

(1) Depth interval	(2) Total area (π *D* h)	(3) Avg. effective stress	(4) k_o*tan (ϕ-5) k_o= 1, ϕ = 36	(5) f_S = (3)*(4) < limiting value (99.3)	(6) f_S A = (2)*(5)
3 – 5 m	2.83 m^2	65.8 kN/m^2	0.6	39.5	111.8 kN
5 – 10 m	7.07 m^2	97.6 kN/m^2	0.6	58.6	414.3 kN
10 – 15 m	7.07 m^2	143.1 kN/m^2	0.6	85.9	607.3 kN

15 – 20 m	7.07 m^2	188.6 kN/m^2	0.6	99.3	702.1 kN
20 – 25 m	7.07 m^2	234.2 kN/m^2	0.6	99.3	702.1. kN
				ΣfA_S =	2537.6 kN

5.5.1.2 API Method – End Bearing

The general equation for end bearing is:

$$Q_p = (Nq)\ (\sigma_v)\ (A_p) \tag{5.14}$$

where

A_p (tip area) = (0.45) (0.45) (π./4) = 0.159 m^2,

σ_v (effective stress at tip) = 18.9 *3 + (9.1) (22) = 258 kN/m^2, and

Nq = 40.

Therefore:

Q_p = (40) (258) (0.159) = 1641

Limiting Tip Resistance = 9,600 kPa (see Technical Manual)

Q_p = (9600) (0.159) = 1526.4

5.5.1.3 API Method – Comparisons of APILE Results with Hand Computations

The total transfer in side resistance is provided by adding the results from Eq. (5.12) plus Eq. (5.13):

Q_f = 99 + 2537.6 = 2636.6 kN which compares to 2659.6 kN computed by APILE

(APILE is more accurate since it divides the soil layers into smaller increments)

The transfer in end bearing is provided by the result from Eq. (5.14):

Q_p = 1526.4 kN which compares to 1526.8 kN computed by APILE

5.5.1.4 FHWA Method – Skin Friction

A. For the top Clay layer (ignoring friction on top 1 meter)

$$fA_S\ (clay) = (\ \alpha\ )\ (\ c_u\ ) * \pi * D * h \tag{5.15}$$

= (0.72) (95)*π *(0.45)* (3-1)

= 193 kN

B. For the bottom Sand layer

$$fA_S\ (sand) = k_0 * C_f * (\Sigma\gamma h) * \sin(\delta) * \pi * D * h$$

(5.16)

The average displaced volume per foot is $\pi\ (0.45)^2\ /4 = 0.159\ m^3$.per meter

For a precast concrete pile with $V=1.71\ ft^3$ per ft, $\delta = 0.9\phi$.

Computation of skin friction from each sub-layer based on FHWA Method:

(1) Depth interval	(2) Total area (π *D* h)	(3) Avg. effective stress	(4) k_o *C_f *sin (δ) k_o=2.1,δ =0.9ϕ C_f=0.95.	(5) f_s = (3)*(4) < limiting value (95.5)	(6) f_s A = (2)*(5)
3 – 5 m	$2.83\ m^2$	$65.8\ kN/m^2$	1.07	70.4	199.2 kN
5 – 10 m	$7.07\ m^2$	$97.6\ kN/m^2$	1.07	104.4	738.3 kN
10 – 15 m	$7.07\ m^2$	$143.1\ kN/m^2$	1.07	153.1	1082.5 kN
15 – 20 m	$7.07\ m^2$	$188.6\ kN/m^2$	1.07	201.8	1426.7 kN
20 – 25 m	$7.07\ m^2$	$234.2\ kN/m^2$	1.07	250.6	1771.7 kN
				ΣfA_S =	5218.4 kN

5.5.1.5 FHWA Method – End Bearing

The general equation for end bearing is:

$$Q_p = (\alpha\ )\ (Nq)\ (\sigma_v)\ (A_p)$$

(5.17)

where

A_p (tip area) = (0.45) (0.45) (π./4) = $0.159\ m^2$,

σ_V (effective stress at tip) = 18.9 *3 + (9.1) (22) = $258\ kN/m^2$,

Nq = 60,

α = 0.7, and

The limiting value from Meyerhof (1976) is $7258\ kN/m^2$.

$Q_p = (0.7)\ (60)\ (258) = 9702 > 7258\ kN/m^2$

Therefore the limiting value should be used for the bearing capacity.

$Q_p = (7258)\ (0.159) = 1154$

5.5.1.6 FHWA Method – Comparisons of APILE Results with Hand Computations

The total transfer in side resistance is provided by adding the results from Eq. (5.15) plus Eq. (5.16):

Q_f = 193 + 5218.4 = 5411.4 kN which compares to 5279.9 kN computed by APILE

(APILE is more accurate since it divides the soil layers into smaller increments)

The transfer in end bearing is provided by the result from Eq. (5.17):

Q_p = 1154 kN which compares to 1154.4 kN computed by APILE

5.5.1.7 USACE Method – Skin Friction

A. For the top Clay layer (ignoring friction on top 1 meter)

$$fA_S\ (clay) = (\alpha)\ (c_u)*\pi *D* h \tag{5.18}$$

= (0.5) (95)*π *(0.45)* (3-1)

= 134 kN

B. For the bottom Sand layer

$$fA_S\ (sand) = k_o*(\Sigma\gamma h)*\tan(\delta\square)*\pi *D* h \tag{5.19}$$

The skin friction in sand increases linearly to an assumed critical depth (Dc).

Dc = 20B for dense sand = 20 (0.45 m) = 9 m.

Effective overburden pressure (p) at 9 m

18.9 * 3 + (9.1) (6) = 111.3 kN/m^2

Computation of skin friction from each sub-layer based on USACE Method:

(1) Depth interval	(2) Total area (π *D* h)	(3) Avg. effective stress	(4) k_o*tan (δ) k_o= 1.25, δ = 0.95ϕ	(5) fA_S = (2)*(3)*(4)
3 – 5 m	2.83 m^2	65.8 kN/m^2	0.85	158.3 kN
5 – 9 m	6.65 m^2	84.0 kN/m^2	0.85	403.4 kN
9 – 25 m	22.62 m^2	111.3 kN/ m^2 (critical depth controls)	0.85	2139.9kN
			ΣfA_S =	2701.6 kN

5.5.1.8 USACE Method – End Bearing

The general equation for end bearing is:

$$Q_p = (Nq)\ (\sigma_v)\ (A_p) \tag{5.20}$$

where

A_p (tip area) = (0.45) (0.45) (π/4) = 0.159 m^2,

σ_v (effective stress at Dc) = 18.9 *3 + (9.1) (6) = 111.3 kN/m^2 (assuming Dc=9m but should be computed based on Table in Technical Manual), and

Nq = 55 (approximate, from Figure in Technical Manual), so

Q_p = (55) (111.3) (0.159) = 973 kN.

5.5.1.9 USACE Method – Comparisons of APILE Results with Hand Computations

The total transfer in side resistance is provided by adding the results from Eq. (5.18) plus Eq. (5.19):

Q_f = 134 + 2701.6 = 2835.6 kN which compares to 2894.8 kN computed by APILE

(APILE is more accurate since it divides the soil layers into smaller increments)

The transfer in end bearing is provided by the result from Eq. (5.20):

Q_p = 973 kN as compared to 991.3 kN computed by APILE

(APILE uses a better approximation than the hand computations for the critical depth Dc and for the bearing capacity factor Nq for the USACE method)

5.5.2 Input and Output Data Files for Example 4

Users can read Section 2.1.1 (7) of this manual for reference on the location of placement of the input and output data files for the example files installed with this program. The default installation directory is the following: *(Root Drive) c:\Ensoft\Apile2026-Examples*. The input data files for all examples presented in this manual are installed automatically with the program.

The input-data filename for Example 4 is the following:

Example 4 - Prestressed Concrete Pile.ap12d

The output-data filename for Example 4 is the following:

Example 4 - Prestressed Concrete Pile.ap12o

5.5.3 Graphical Results of Computer Analysis

The resulting plots of ultimate accumulated skin friction and ultimate tip resistance versus depth provided by the APILE computer program may be observed in Figure 5.14 and Figure 5.15, respectively.

Note that the load-transfer curve of skin friction versus depth in Figure 5.14 starts from about the 1-m depth (actually from the previous finite increment in some methods). This is because the program was instructed to ignore skin friction at the top 1 meter.

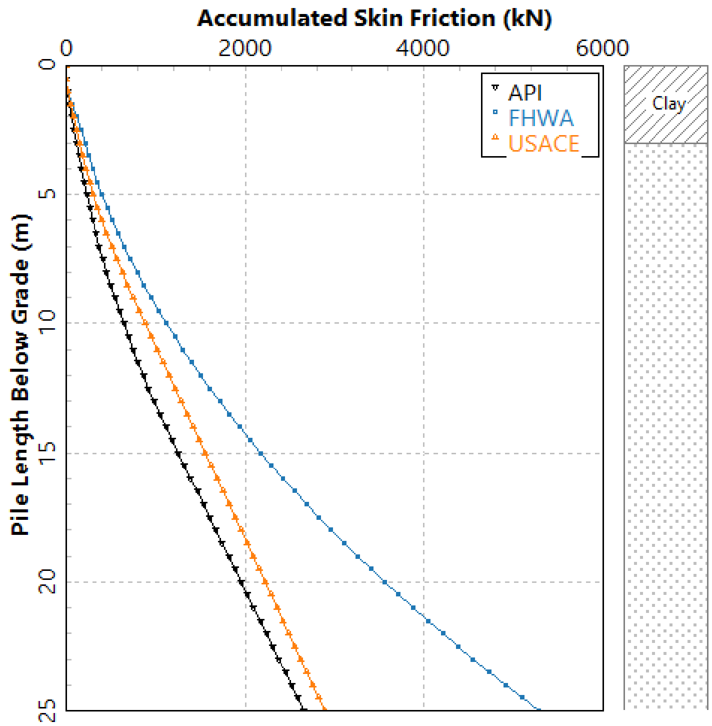


Figure 5.14 Curve of Ultimate Skin Friction vs Depth for Example Problem 4.

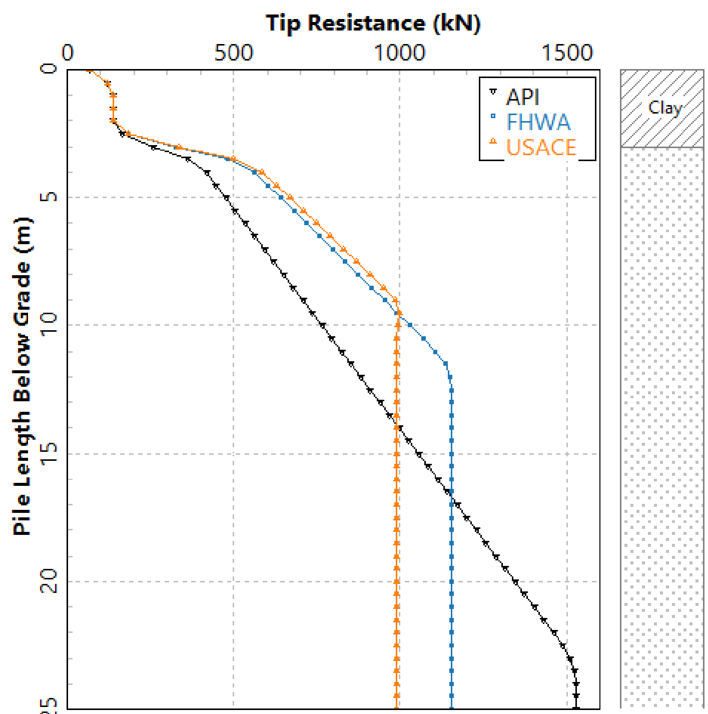


Figure 5.15 Curve of Ultimate Tip Resistance vs Depth for Example Problem 4.

5.6 Example Problem 5 – Tapered Pile Capacity

Driven piles with a depth-variable circumference or perimeter over all of their length are called tapered piles. They are usually installed using some type of impact hammer and have long been recognized as the most cost effective driven pile alternative to use in applications calling for “friction piles”, especially in coarse-grain soil condition (Peck 1958).

This example is included to illustrate an application in which a Raymond Uniform Tapered Pile (made of steel) was considered for the deep foundation. The tapered pile has a diameter of 12 inches at the pile tip and the taper angle is 0.5 degrees extending from the pile tip to the pile head. The length of the proposed pile is 30 feet, which results in a diameter of 18.28 inches at the pile head.

The soil deposit consists of two sublayers as shown in Figure 5.16. The top layer is 18-ft loose sand with the internal friction angle of 30 deg., underlain by a very dense sand layer with the internal friction angle of 40 deg. The theory for extra load transfer from the angle of pile taper in sand layers is only applicable by the FHWA method, which adopts the recommendations by Nordlund (1963, 1970).

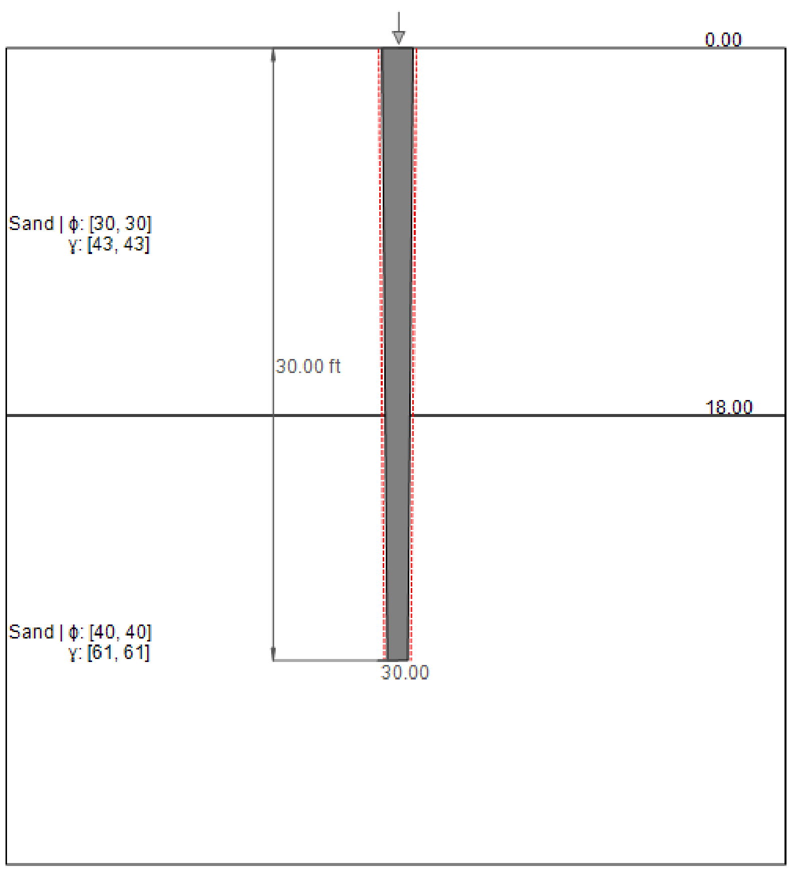


Figure 5.16 Pile layout and soil conditions of Example Problem 5.

5.6.1 Hand Computations and Comparisons with APILE

The program output will be compared to the results from the following hand calculations.

Step 1. Compute effective stresses in the middle of soil layers:

Layer 1: $\bar{\sigma}_{v0} = P_D = 383.4\, psf$

Layer 2: $\bar{\sigma}_{v0} = P_D = 1130.4\, psf$

Step 2. Compute $\delta/_{\phi}$ for each one of the layers (pile segments):

Layer 1. Compute volume:

The depth of pile at middle of first layer is equal to 9 ft + 18 ft/2 = 21 ft

The increase of radius at 21 ft above the pile tip:

$tgw = \frac{x}{h} => x = h \cdot \tan\omega$

$x = 21\, ft \tan(0.5) => 0.1832642\, ft$

Diameter of pile at middle of first layer in inches

D_1 = 12 + 2 * 12 * x = 12 + 2 * 12 * 0.1832642 = 16.398341

$Volume = \frac{\pi \bar{D}_1^2}{4} = \frac{\pi * 16.398341^2}{4*144} = 1.4666524 \frac{ft^3}{ft}$

Compute $\delta/_{\phi}$ for layer 1 (interpolate linearly):

V = 1.4 $\delta/_{\phi} = 1.159$

V = 1.5 $\delta/_{\phi} = 1.184$

$$\left(\delta/_{\phi} - 1.159\right) = \frac{1.184 - 1.159}{1.5 - 1.4}(1.4666524 - 1.4)$$

$$(\delta/_{\phi})_{layer\ \#1} = 1.1756631$$

Layer 2. Compute volume:

The increase of radius at 6 ft above the pile tip

$x = h \cdot \tan(w) = 6 * \tan(0.5) => 0.0523612\, ft$

Diameter of pile at middle of second layer:

$D_2 = 12" + 2 * 12 * 0.0523612 = 13.256669"$

$$Volume = \frac{\pi \bar{D}_2^2}{4} = \frac{\pi 13.256669^2}{4 * 144} = 0.958509\, ft^3/ft$$

Compute $\delta/_{\phi}$ for layer 2 (interpolate linearly):

V = 0.9 $\delta/_{\phi} = 1.025$

V = 1.0 $\delta/_{\phi} = 1.053$

$$\left({}^{\delta}/_{\phi} - 1.025\right) = \frac{1.053 - 1.025}{1.0 - 0.9}(0.958509 - 0.9)$$

$$({}^{\delta}/_{\phi})_{layer\ \#2} = 1.0413825$$

Step 3. Compute values of K_δ for both layers:

Layer 1: $Volume = 1.4666524\, ft^3/ft$

$\phi = 30°$

Interpolate linearly for $w = 0.5°$:

V = 1 $K_\delta = 2.928$

V = 10 $K_\delta = 3.180$

$$(K_\delta - 2.928) = \frac{3.18 - 2.928}{\log(10) - \log(1)}[\log(1.4666524) - \log(1)]$$

$$K_{\delta_{layer\ 1}} = 2.9699145$$

Layer 2: $Volume = 0.958509\, ft^3/ft$

$$\phi = 40°$$

For w = 0.5° and any volume between 0.1 and 10 ft^3/ft the value of $K_\delta = 17.28$.

$$K_{\delta_{layer\ 2}} = 17.28$$

Step 4. Compute the correction factor (use same digitized curves as computer program):

Layer 1: ${}^{\delta}/_{\phi} = 1.1756631;\ \phi = 30°$

${}^{\delta}/_{\phi} = 1$ CF = 1.0

${}^{\delta}/_{\phi} = 1.2$ CF = 1.03

$$(CF - 1) = \frac{1.03 - 1}{1.2 - 1}(1.1756631 - 1)$$

$$CF_{layer\ 1} = 1.0263495$$

Layer 2: ${}^{\delta}/_{\phi} = 1.0413825;\ \phi = 40°$

For $\phi = 38°$

${}^{\delta}/_{\phi} = 1$ CF = 1.0

${}^{\delta}/_{\phi} = 1.2$ CF = 1.07

$$(CF - 1) = \frac{1.07 - 1}{1.2 - 1}(1.0413825 - 1)$$

$$CF_{\phi=38} = 1.0144839$$

For $\phi = 42°$

$$\delta/_{\phi} = 1 \qquad \text{CF} = 1.0$$

$$\delta/_{\phi} = 1.2 \qquad \text{CF} = 1.09$$

$$(CF - 1) = \frac{1.09 - 1}{1.2 - 1}(1.0413825 - 1)$$

$$CF_{\phi=38} = 1.0186221$$

Interpolate linearly for $\Phi = 40°$

$$CF_{\Phi=40°\,layer\,2} = 1.016553$$

Step 5. Compute values of δ:

Layer 1: $\delta_{layer\,1} = 1.1756631 * 30° = 35.269893°$

Layer 2: $\delta_{layer} = 1.0413825 * 40° = 41.6553°$

Step 6. Compute friction contribution for each layer:

$$Q_s = K_\delta * CF * P_D * \left[\frac{\sin(\delta + w)}{\cos w}\right] * C_d * \Delta d$$

Layer 1

$$Q_{S_1} = 2.9699145 * 1.0263495 * 383.4 * \frac{\sin(35.269893 + 0.5)}{\cos(0.5)} * 3.1415927 * 16.398341 * 18$$

$$Q_{S_1} = 52790.621\ [pounds]$$

Layer 2

$$Q_{S_2} = 17.28 * 1.016553 * 1130.4 * \frac{\sin(41.6553 + 0.5)}{\cos(0.5)} * 3.1415927 * \frac{13.25669}{12} * 12$$

$$Q_{S_2} = 555037.24\ [pounds]$$

Compute total frictional resistance:

$$Q_s = Q_{S_1} + Q_{S_2} = 52.79[kips] + 555.04[kips] = 607.83[kips]$$

which compares to 575.5 kips computed by APILE

Step 7. Compute tip resistance contribution from FHWA method:

$$Q_p = A_p\,\bar{q}\,\alpha_t\,N_q' \tag{5.21}$$

where

A_p is the pile tip bearing area,

q is the vertical stress at pile base level,

N_q' = bearing capacity factor (see figure in Technical Manual), and

α_t = dimensionless factor dependent on the depth-width relationship of the pile (see figure in Technical Manual).

$A_p = \pi D_p^2 / 4 = 3.14 (12)^2 / 4 = 113.1 \text{ in}^2 = 0.785 \text{ ft}^2$

$q = 42.6 \text{ lb/ft}^3 \times 18 \text{ ft} + 60.6 \text{ lb/ft}^3 \times 12 \text{ ft} = 1494 \text{ lb/ft}^2$

$N'_q = 160$

$\alpha_t = 0.75$

Q_p = 140.7 kips which compares well to 140.8 kips computed by APILE

Step 8. Compute limiting tip resistance:

Q_L = 327.98 kips which is higher so not controlling

Step 9. Total static pile capacity is then

$Q_T = 607.83[kips] + 140.81[kips] => 748.64\ kips$, which compares well to the 716.3 kips obtained from the APILE model.

(APILE is more accurate since it divides the pile sections into smaller increments)

5.6.2 Input and Output Data Files for Example 5

Users can read Section 2.1.1 (7) of this manual for reference on the location of placement of the input and output data files for the example files installed with this program. The default installation directory is the following: *(Root Drive) c:\Ensoft\Apile2026-Examples*. The input data files for all examples presented in this manual are installed automatically with the program.

The input-data filename for Example 5 is the following:

Example 5 - FHWA Tapered Pile.ap12d

The output-data filename for Example 5 is the following:

Example 5 - FHWA Tapered Pile.ap12o

5.6.3 Graphical Results of Computer Analysis

The resulting plots of ultimate total capacity versus depth provided by the computer program may be observed in Figure 5.17. Figure 5.18 includes a plot of axial load versus settlement.

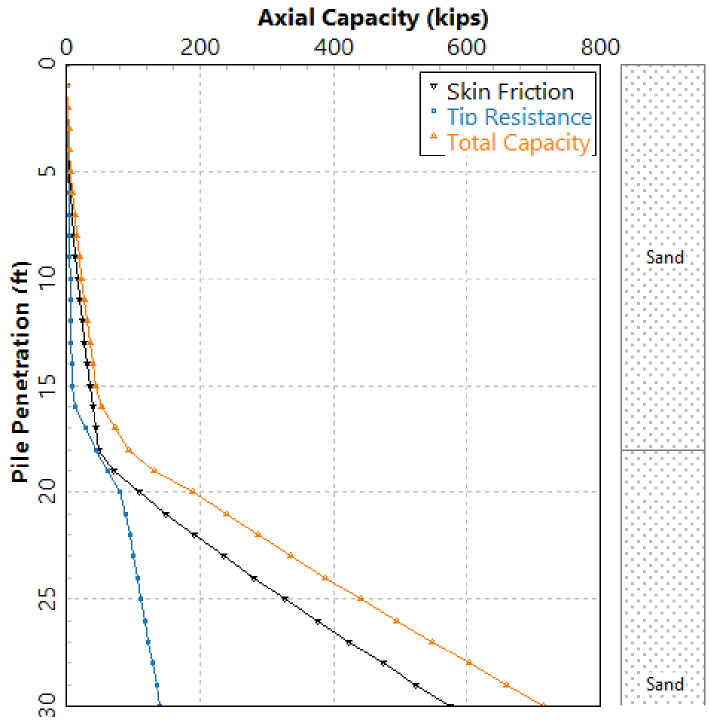


Figure 5.17 Curve of Combined Plots (Ultimate Total Capacity) vs Depth for Example Problem 5.

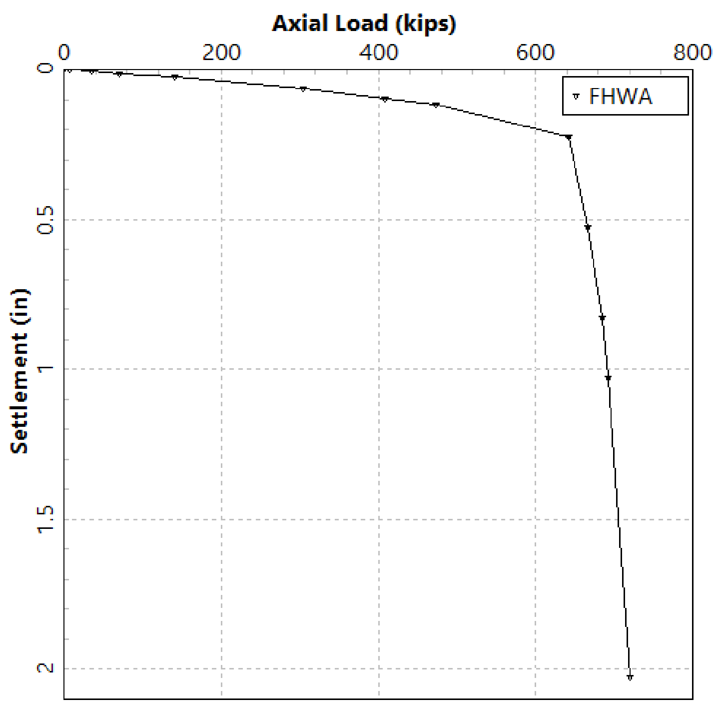


Figure 5.18 Axial Load vs Settlement for Example Problem 5.

5.7 Example Problem 6 – Uplift Pile Capacity

5.7.1 Description

Piles may be subjected to loads in tension instead of compression. The tension capacity of piles differs from the compression capacity of piles in both the side friction and end bearing. For piles under tension the soil resistance is from the side friction only.

Some research recommends applying a reduction factor to the side friction when the pile moves upward based on field experimental studies. This may be caused by less confining pressure from the soil around the pile under tension. This example includes an arbitrary reduction factor of 0.8 for tension capacity (under Data > Computational Method > Loading Type > Tension).

A different reduction in side friction may be specified primarily to cover a distance near the shallow depth. This example includes an arbitrary 4-meter exclusion of friction in the top soil layer (under Data > Pile Section Properties > Zero-Friction Length).

The tension capacity of piles should also include the self-weight of piles. This is automatically accounted within APILE according to the pile type/material selected by the user. The values computed by APILE are included in a column in the output text file.

This example illustrates a common case for study of the tension capacity of a pipe pile. The soil deposit consists of six sub-layers as shown in Table 5.7. The pile is a 60-m long, open-ended steel pipe, with an outer diameter of 1000 mm and an inner diameter of 936 mm.

The output is shown in detail so the user can examine the increase in pile capacity with depth. The user may elect to eliminate the printing of capacity for each increment length to shorten the length of output.

Layer	Depth (m)	Soil Type	γ' (kN/m^3)	C_u (kN/m^2)	ϕ (Deg.)	K_o	N_q
1	0 10	Clay	4	0.1 20	---	---	---
2	10 20	Sand	9	---	34	0.6	20
3	20 30	Clay	6	200 200	---	---	---
4	30 40	Sand	9	---	36	0.6	30
5	40 50	Clay	9	350 350	---	---	---
6	50 100	Sand	9	---	38	0.6	30

Table 5.7 Soil data for Example Problem 6

5.7.2 Input and Output Data Files for Example 6

Users can read Section 2.1.1 (7) of this manual for reference on the location of placement of the input and output data files for the example files installed with this program. The default installation directory is the following: *(Root Drive) c:\Ensoft\Apile2026-Examples*. The input data files for all examples presented in this manual are installed automatically with the program.

The input-data filename is the following:

Example 6 - Uplift Pile Capacity.ap12d

The output-data filename is the following:

Example 6 - Uplift Pile Capacity.ap12o

5.7.3 Graphical Results of Computer Analysis

The resulting plots of ultimate total capacity versus depth provided by the computer program may be observed in Figure 5.19. The self-weight of the pile is included in the total capacity for the uplift (tensile) capacity. Figure 5.20 includes a plot of uplift load versus uplift movement.

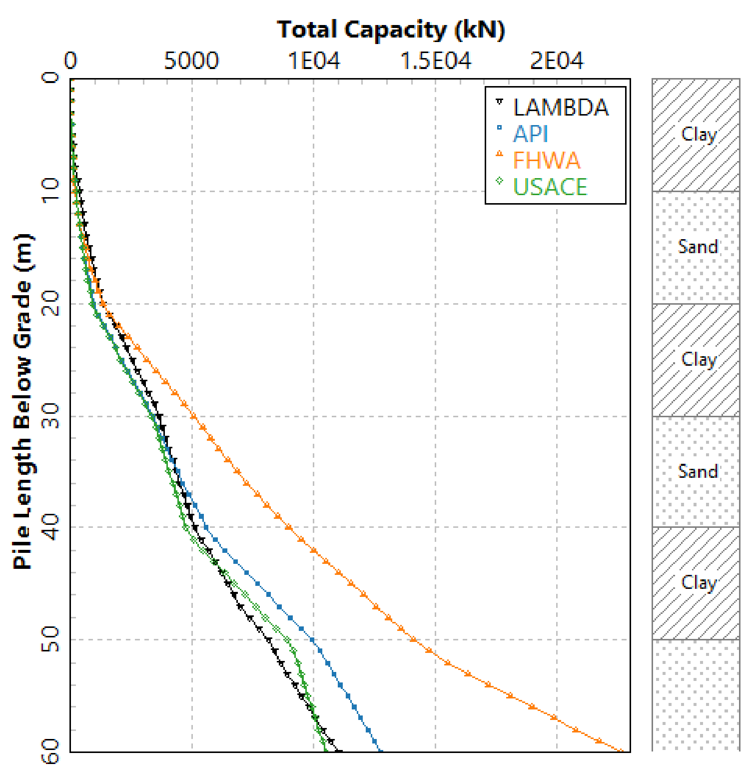


Figure 5.19 Curve of Ultimate Total Capacity vs Depth for Example Problem 6.

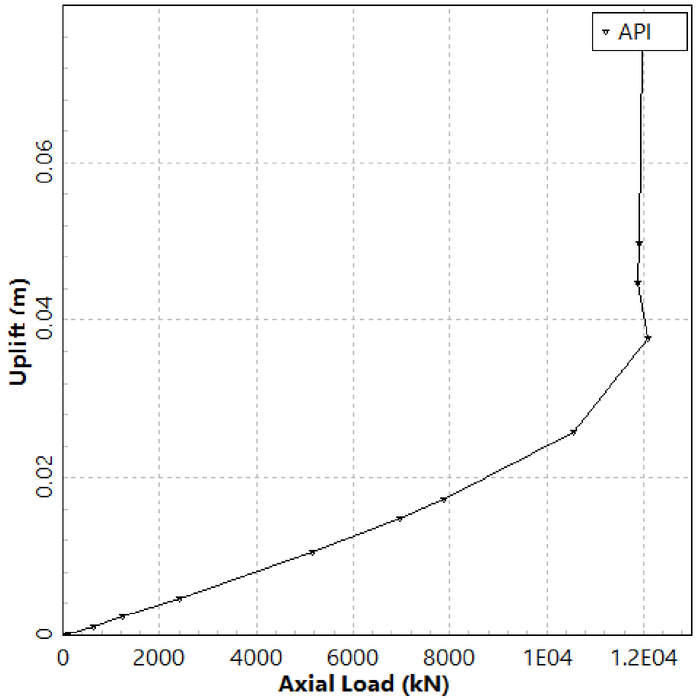


Figure 5.20 Curve of Axial Load vs Movement for Example Problem 6.

5.8 Example Problem 7 (Offshore Version) – CPT Based Methods for Close-Ended Pile

Many of the existing semi-empirical methods for predicting the axial capacity of driven piles were developed approximately two decades ago on the basis of an extended database of static-loading tests. The soil properties and subsurface conditions were obtained primarily by conventional sampling methods and testing equipment, including the Standard Penetration Test (SPT), field-vane test, and triaxial-undrained (UU) tests using undisturbed soil samples, taken by the use of Shelby tubes.

Recently, the cone penetration test (CPT) has been widely used in subsurface exploration worldwide, especially in the offshore industry. The American Petroleum Institute (API) conducted a review of CPT-based methods for assessment of the axial capacity of driven piles. Two CPT-based methods have been studied and adopted by API as alternate design methods. Those two CPT-based methods that were selected by API are: the NGI-99 method developed by the Norwegian Geotechnical Institute and the MTD method developed by Imperial College in London (Richard Jardine et al, 2005).

The example included here are for the customers who purchased the offshore-version of APILE. This example is for an offshore application and will focus on the axial capacity of closed-ended piles predicted by different semi-empirical methods. Computed results from four CPT-based methods are included for comparison. The pile is a 60-m long pipe with a closed end and with an outer diameter of 2134 mm and an inner diameter of 2044 mm. The soil deposit consists of six sub-layers and the soil properties, including those from CPT tests, are shown in Table 5.8.

Layer	Depth (m)	Soil Type	γ' (kN/m^3)	C_u (kN/m^2)	ϕ (Deg.)	K_o	N_q	Q_c	PI	YSR
1	0 10	Clay	4	0.1 20	---	---	---	1 200	50	2
2	10 20	Sand	9	---	34	0.6	20	10,500 20,000	---	---
3	20 30	Clay	6	200 200	---	---	---	2,000 2,000	20	3
4	30 40	Sand	9	---	36	0.6	30	30,500 39,500	---	---
5	40 50	Clay	9	350 350	---	---	---	5,000 5,000	15	3
6	50 100	Sand	9	---	38	0.6	30	50,000 50,000	---	---

Table 5.8 Soil data for Example Problem 7

5.8.1 Comparison of APILE Results with Hand Computations

Table 5.9 and Table 5.10 contains various comparisons of the results obtained from approximate hand computations (spreadsheet) against those from the computer run in APILE for two different offshore methods.

NGI METHOD				
Layer	Depth (m)	Soil Type	Total Skin Friction (kN)	
			Hand Calc	Computer
1	0 10	Clay	516	537
2	10 20	Sand	3,504	3,571
3	20 30	Clay	6,280	6,251
4	30 40	Sand	14,859	14,780
5	40 50	Clay	12,014	11,844
6	50 60	Sand	30,033	28,619

Table 5.9 Comparison of results for NGI Method in Example Problem 7

MTD METHOD				
Layer	Depth (m)	Soil Type	Total Skin Friction (kN)	
			Hand Calc	Computer
1	0 10	Clay	295	268
2	10 20	Sand	4,048	3,783
3	20 30	Clay	5,767	5,313
4	30 40	Sand	12,360	13,503
5	40 50	Clay	17,572	15,206
6	50 60	Sand	30,114	33,711

Table 5.10 Comparison of results for MTD Method in Example Problem 7

5.8.2 Input and Output Data Files for Example 7

Users can read Section 2.1.1 (7) of this manual for reference on the location of placement of the input and output data files for the example files installed with this program. The default installation directory is the following: *(Root Drive) c:\Ensoft\Apile2026-Examples*. The input data files for all examples presented in this manual are installed automatically with the program.

The input-data filename is the following:

Example 7 - CPT Methods on Close Ended Pile.ap12d

The output-data filename is the following:

Example 7 - CPT Methods on Close Ended Pile.ap12o

5.8.3 Graphical Results of Computer Analysis

The resulting plots of total capacity from different empirical methods and axial load versus settlement computed based on MTD method may be observed in Figure 5.21 and Figure 5.22.

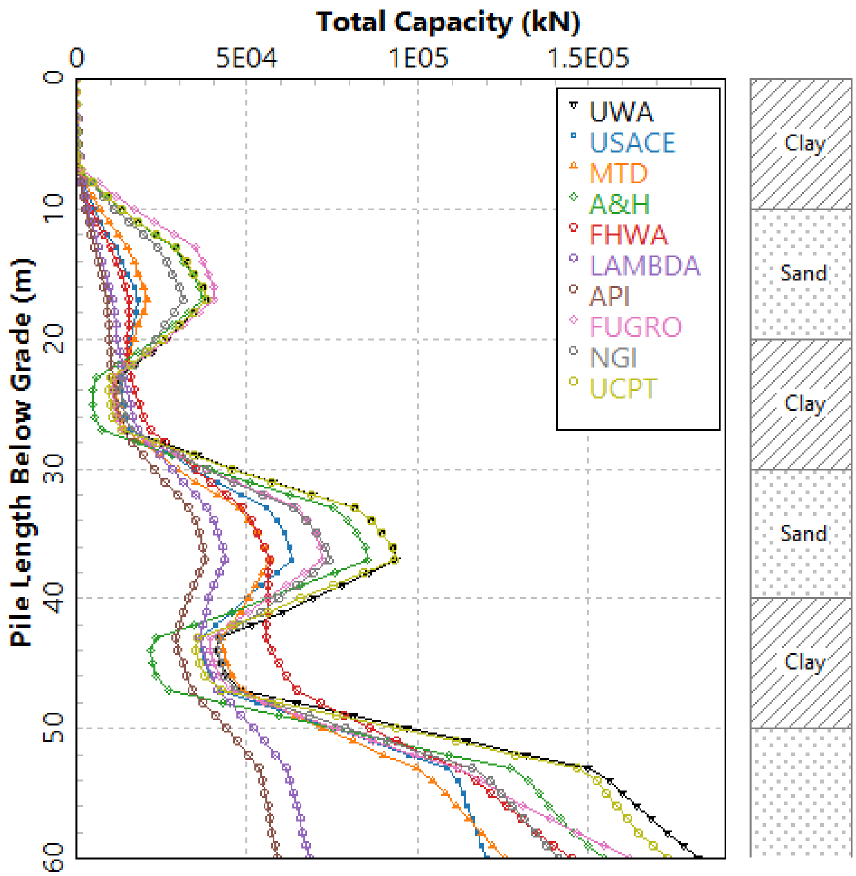


Figure 5.21 Curves of Ultimate Total Capacity vs Depth for Example Problem 7.

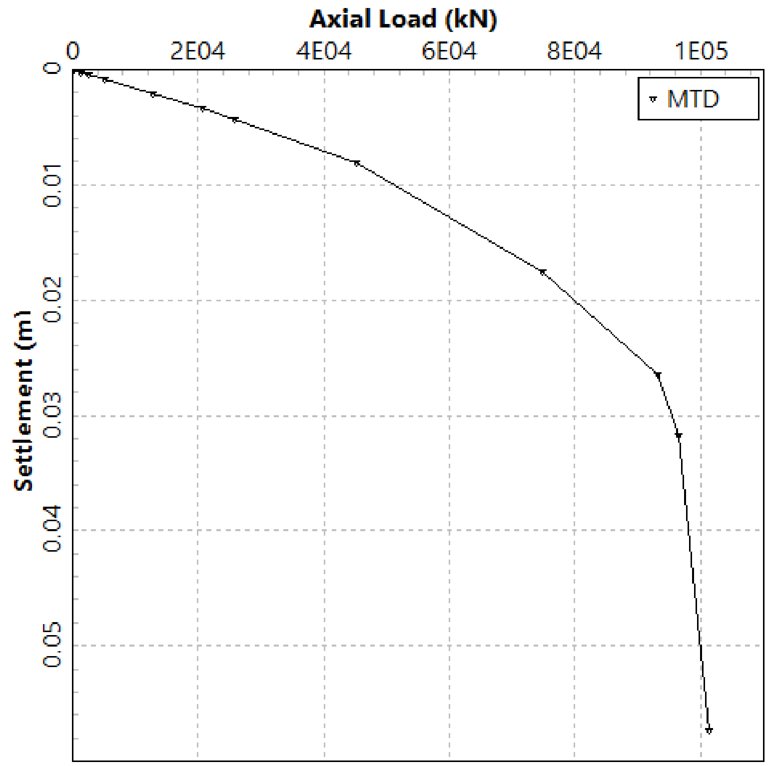


Figure 5.22 Curve of Axial Load vs Settlement for Example Problem 7.

5.9 Example Problem 8 (Offshore Version) – CPT Based Methods for Open-Ended Pile

Many large offshore piles are driven with an open-ended tip. It is obvious that soil will be pushed into the pile through the pile tip during pile driving, forming a soil plug inside the pipe pile. If the soil plug develops excessive side friction on the inner wall at a certain depth, the soil plug may not be pushed further into the pipe pile by driving. This condition is typically referenced as a fully plugged pile. On the other hand, the soil plug may be pushed up continuously during pile driving because the friction developed on the inner wall is not strong. In this case the pile tip is not fully plugged and it is usually referenced as an unplugged pile.

The determination if the pile acts as a fully plugged pile or as an unplugged pile is a very complicated task. One simple approach is described in the APILE Technical Manual. For unplugged conditions, the total soil resistance at the tip is the sum of the side friction along the inner surface of the pile and the end bearing from the metal area at the pile tip. If the pile is fully plugged, the soil resistance at the pile tip is derived from end bearing over the full area of the base. Comparing the soil resistance at the tip, based on the above two different conditions, the user may take the results from APILE with the smaller one for the recommended tip resistance.

The total length of soil plug formed inside the pipe pile depends on the soil properties in each sub-layer. In many cases the length of the soil plug may be less than 50% of the total pile penetration. The MTD method (as well as other offshore methods) directly asks the user to determine the plug condition as one of the required input parameters.

This example is included for the customers who purchased the offshore-version of APILE. This example will focus on the axial capacity of open-ended, unplugged piles predicted by four CPT-based semi-empirical methods (NGI, MTD, Fugro, and UWA methods) for an offshore application. The pile is a 60-m-long pipe with an outer diameter of 2134 mm and an inner diameter of 2044 mm. The soil deposit consists of six sub-layers and the soil properties, including Q_C from the CPT tests, are shown in Table 5.11.

Notice that from the output text file from APILE, a pile plug fully develops (no asterisk in output table) after 34 meters of pile penetration using the NGI Method and after 29 meters of pile penetration for the MTD Method.

Layer	Depth (m)	Soil Type	γ' (kN/m^3)	C_u (kN/m^2)	ϕ (Deg.)	K_o	N_q	Q_c	PI	YSR
1	0 10	Clay	4	0.1 20	---	---	---	1 200	50	2
2	10 20	Sand	9	---	34	0.6	20	10,500 20,000	---	---
3	20 30	Clay	6	200 200	---	---	---	2,000 2,000	20	3
4	30 40	Sand	9	---	36	0.6	30	30,500 39,500	---	---
5	40 50	Clay	9	350 350	---	---	---	5,000 5,000	15	3
6	50 100	Sand	9	---	38	0.6	30	50,000 50,000	---	---

Table 5.11 Soil data for Example Problem 8

5.9.1 Comparison of APILE Results with Hand Computations

Table 5.12 and Table 5.13 contains various comparisons of the results obtained from approximate hand computations (spreadsheet) against those from the computer run in APILE for two different offshore methods.

NGI METHOD				
Layer	Depth (m)	Soil Type	Total Skin Friction (kN)	
			Hand Calc	Computer
1	0 10	Clay	516	537
2	10 20	Sand	2,513	2,253
3	20 30	Clay	6,280	6,145
4	30 40	Sand	9,288	9,361
5	40 50	Clay	12,014	11,498
6	50 60	Sand	18,771	18,111

Table 5.12 Comparison of results for NGI Method in Example Problem 8

MTD METHOD				
Layer	Depth (m)	Soil Type	Total Skin Friction (kN)	
			Hand Calc	Computer
1	0 10	Clay	230	209
2	10 20	Sand	2,563	2,399
3	20 30	Clay	4,495	4,099
4	30 40	Sand	7,771	8,535
5	40 50	Clay	13,697	11,720
6	50 60	Sand	24,032	26,010

Table 5.13 Comparison of results for MTD Method in Example Problem 8

5.9.2 Input and Output Data Files for Example 8

Users can read Section 2.1.1 (7) of this manual for reference on the location of placement of the input and output data files for the example files installed with this program. The default installation directory is the following: *(Root Drive) c:\Ensoft\Apile2026-Examples*. The input data files for all examples presented in this manual are installed automatically with the program.

The input-data filename is the following:

Example 8 - CPT Methods on Open Ended Pile.ap12d

The output-data filename is the following:

Example 8 - CPT Methods on Open Ended Pile.ap12o

5.9.3 Graphical Results of Computer Analysis

The resulting plots of the total capacity predicted by different methods and the axial load versus settlement based on the NGI method may be observed in Figure 5.23 and Figure 5.24, respectively.

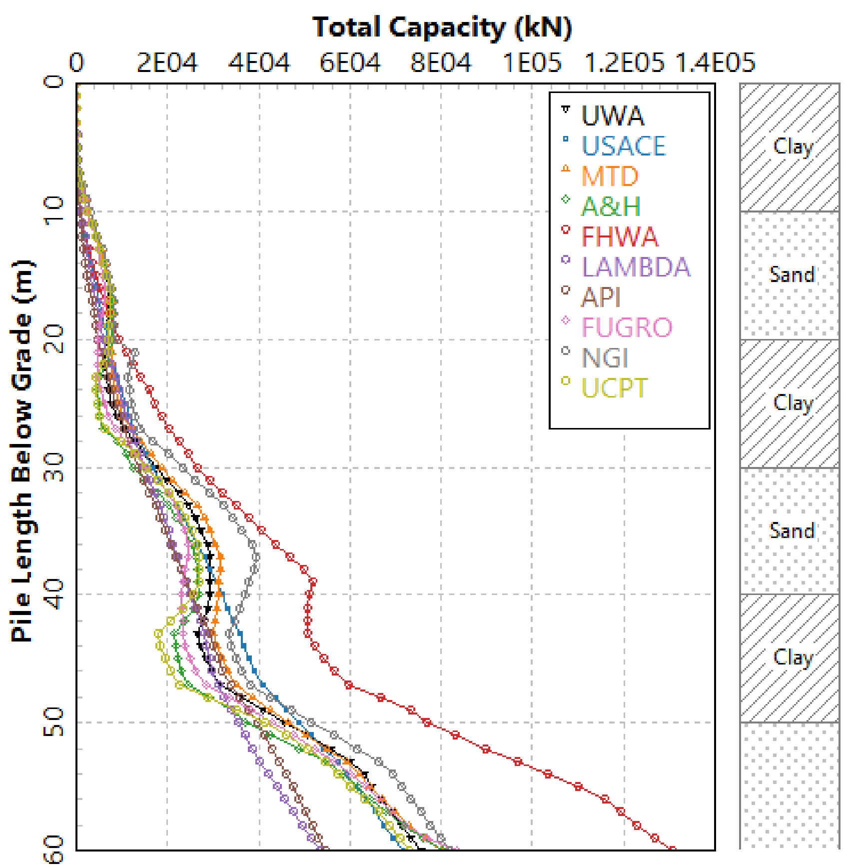


Figure 5.23 Curves of Ultimate Total Capacity vs Depth for Example Problem 8.

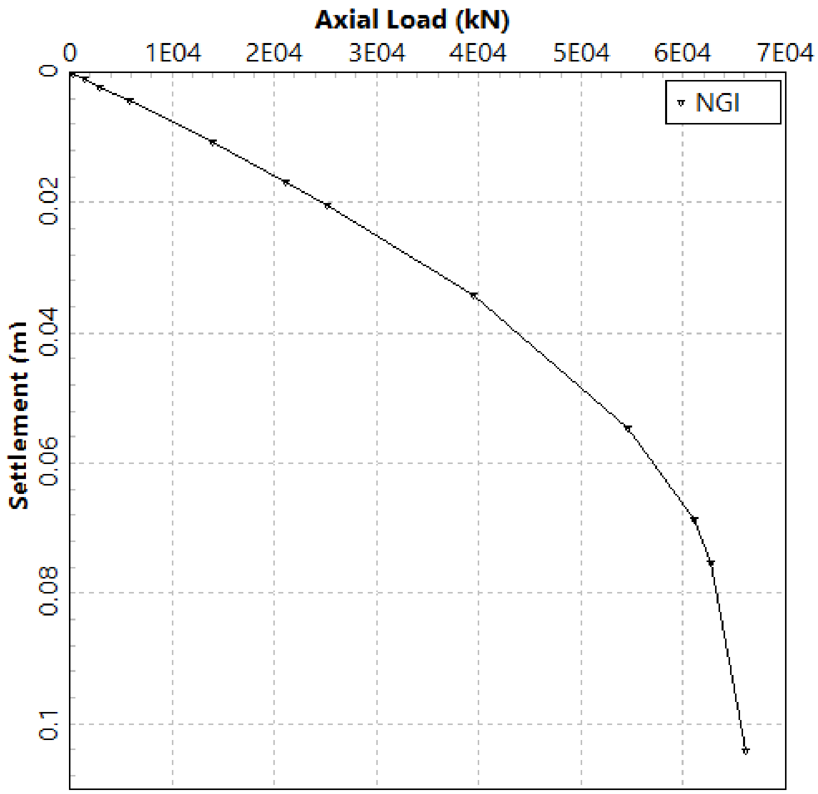


Figure 5.24 Curve of Axial Load vs Settlement for Example Problem 8.

5.10 Example Problem 9 – LRFD Method on Closed Pipe Pile

An example is presented from the National Highway Institute's publication titled "Load and Resistance Factor Design (LRFD) for Highway Bridge Substructures" (NHI, 2001) to illustrate a simple example of driven piles as foundations based on the LRFD method. This example is included to demonstrate the convenience of using APILE in the design of driven piles under axial loads based on the new LRFD design procedures.

The proposed driven pile is a close-ended steel pipe pile with an outside diameter of 460 mm. The wall thickness is 12.7 mm. The total length (penetration) below the original grade (without scouring) is 12 meters. The configuration and loading of the proposed bridge substructures are shown in Figure 5.25.

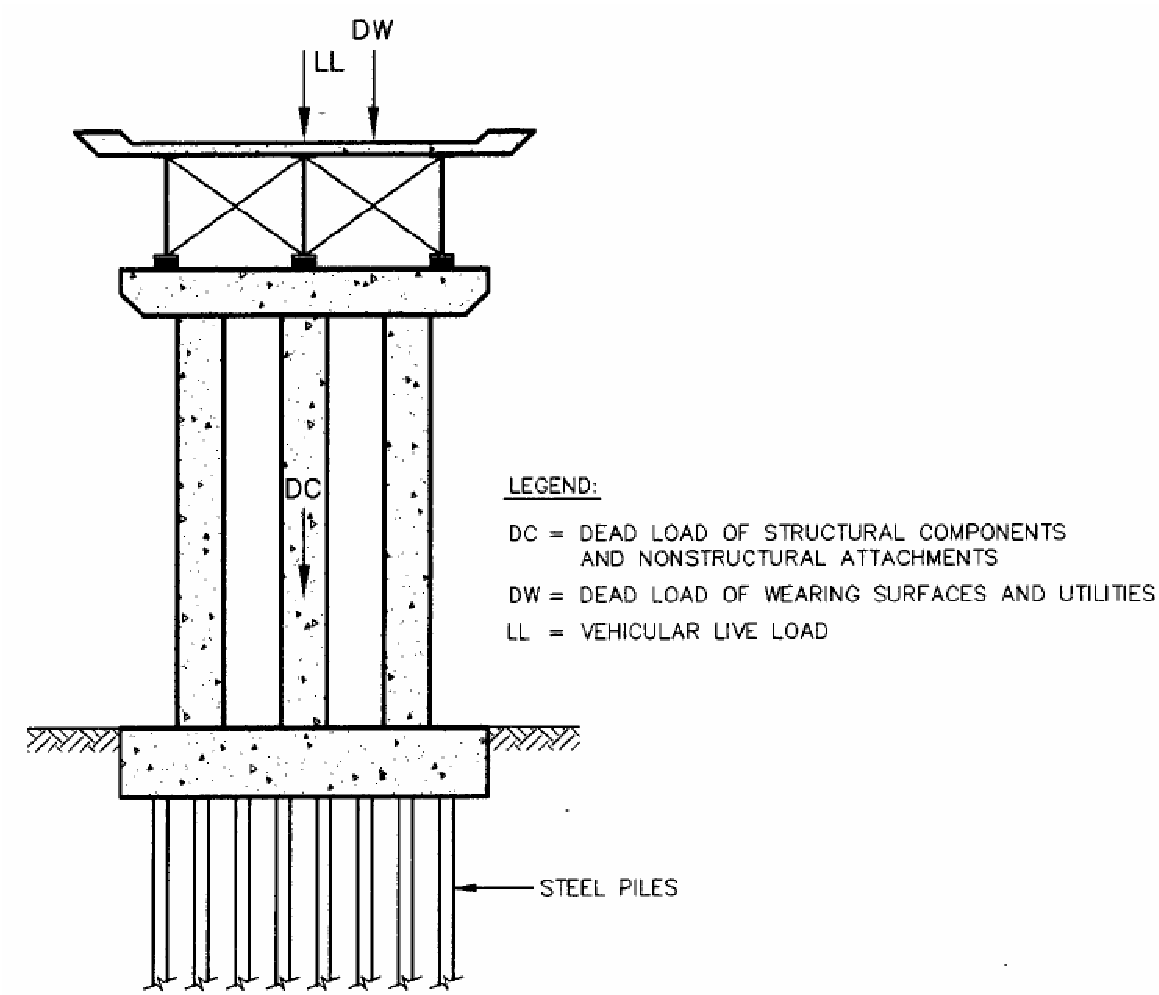


Figure 5.25 Bridge substructures configuration and loading for Example Problem 9.

5.10.1 Soil Profile and Properties

A generalized subsurface profile along the alignment of the bridge is shown in Figure 5.26. The subsurface soils are predominated by fine sand and medium dense to dense sand. The soil density and strength increase with depth.

The water table is at the 2 m below the existing ground surface. Soil properties for use in analysis includes unit weight and the penetration resistance (SPT blow counts).

5.10.2 Loading Computations

The unfactored vertical loads on the pile group (substructure) shown in Figure 5.25 include:

DC (Dead load of structural components and non-structural attachments) = 4600 kN.

DW (Dead load of wearing surfaces and utilities) = 3900 kN.

LL (Vertical live load) = 3450 kN.

The total unfactored load (Q) is:

Q = DC + DW + LL

= 4600 kN + 3900 kN + 3450 kN

= 11950 kN

For the Strength I and Service I Limit States, the factor load is expressed as

$$\sum \eta_i \gamma_i Q_i$$

Assume a typical structure such that $\eta_i = 1.0$. The load factors for Limit States of Strength I and Service I are listed in Table 5.14.

Limit State	γ_{DC}	γ_{DW}	γ_{LL}
Strength I	1.25	1.25	1.75
Service I	1.00	1.00	1.00

Table 5.14 Summary of factored loads for Example Problem 9

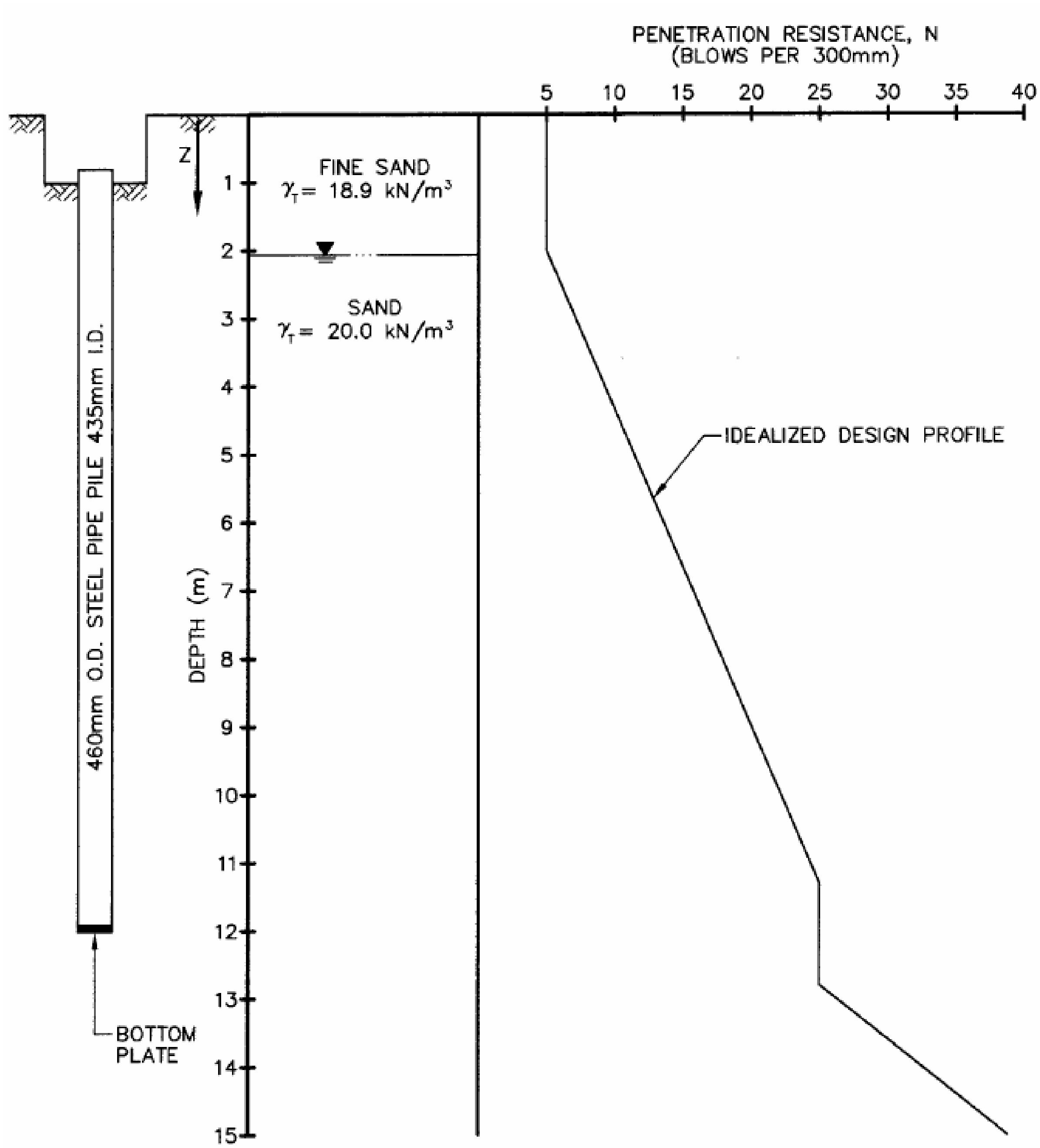


Figure 5.26 General soil description of Example Problem 9

The total factored load effects are then calculated as follows.

For the Strength I Limit State:

$$\sum \eta_i \gamma_i Q_i = \eta_i [\, \gamma_{DC}\, DC + \gamma_{DW}\, DW + \gamma_{LL}\, LL \,]$$

$$= (1.0)\,[\,(1.25)\,(4600\text{ kN}) + (1.50)\,(3900\text{ kN}) + (1.75)\,(3450\text{ kN})\,]$$

$$= 17638\text{ kN}$$

For the Service I Limit State:

$$\sum \eta_i \gamma_i Q_i = \eta_i [\, \gamma_{DC}\, DC + \gamma_{DW}\, DW + \gamma_{LL}\, LL \,]$$

$$= (1.0)\,[\,(1.0)\,(4600\text{ kN}) + (1.0)\,(3900\text{ kN}) + (1.0)\,(3450\text{ kN})\,]$$

$$= 11950\text{ kN}$$

5.10.3 APILE Estimated Axial Capacity of Single Pile from N_{60} SPT

Calculations of nominal side and base resistance were carried out in APILE (filename "*Example 9 - LRFD Method on Closed Pipe Pile - Initial.ap12d*"). Table 5.15 shows the calculated ultimate side friction and ultimate tip resistance for various methods and the values provided by the referenced publication (NHI, 2001). The NHI manual uses Meyerhof (1976) which provides low estimate of side friction rom SPT values. The NHI manual also references the Field Tests from Vesic (1970) done on a test pile at the same site. The FHWA results from APILE are close to those from the Vesic, 1970, field tests.

Methods	Side Friction, kN	Tip Resistance, kN	Total Ultimate Capacity, kN
NHI 2001 (Meyerhof, 1976)	445	1460	1905
FHWA method	1028	1267	2295
US ARMY method	730	1047	1777
API method	759	802	1561
Field Test (Vesic, 1970)	1180	1900	3080

Table 5.15 Initial calculations of ultimate axial compressive capacity for Example 9

The factored axial resistance of a single pile is:

$$Q_R = \phi\, Q_{ult} = \phi_{qp}\, Q_p + \phi_{qs}\, Q_s$$

The reduction factors for the computation methods based on SPTs are:

$$\phi_{qp} = 0.45$$

$$\phi_{qs} = 0.45$$

The reduction factors for the axial capacity of a driven pile based on a full-scale loading test are:

$$\phi_{qp} = 0.8$$

$$\phi_{qs} = 0.8$$

The factored side friction and tip resistance for the methods above (filename "*Example 9 - LRFD Method on Closed Pipe Pile - Final.ap12d*") and the result from the full-scale loading test are presented in Table 5.16. Based on Strength I Limit State, the total factored load is 17638 kN. If the designer selects the factored pile capacity based on FHWA method (Total Factored Capacity of 1033 kN), the substructure pile group will need 17 piles. On the other hand, having a local site test (Vesic, Total Factored Capacity of 2464 kN) can reduce the pile group to 7 or 8 piles.

Methods	Side Friction, kN	Tip Resistance, kN	Total Factored Capacity, kN
NHI 2001 (Meyerhof, 1976)	200	657	857
FHWA method	463	570	1033
US ARMY method	329	471	800
API method	341	361	702
Field Test (Vesic, 1970)	944	1520	2464

Table 5.16 Final calculations of factored axial compressive capacity for Example 9

5.10.4 Input and Output Data Files for Example 9

Users can read Section 2.1.1 (7) of this manual for reference on the location of placement of the input and output data files for the example files installed with this program. The default installation directory is the following: *(Root Drive) c:\Ensoft\Apile2026-Examples*. The input data files for all examples presented in this manual are installed automatically with the program.

The input-data filenames are the following:

Example 9 - LRFD Method on Closed Pipe Pile - Initial.ap12d

Example 9 - LRFD Method on Closed Pipe Pile - Final.ap12d

The output-data filenames are the following:

Example 9 - LRFD Method on Closed Pipe Pile - Initial.ap12o

Example 9 - LRFD Method on Closed Pipe Pile - Final.ap12o

5.10.5 Graphical Results of Computer Analysis

The results of factored side friction, tip resistance, and total capacity versus depth provided by the computer program for FHWA method were plotted together in Figure 5.27 and Figure 5.28 includes a plot of axial load versus settlement. Based on Service I Limit States, the total factored load is 11950 kN on a total of 17 piles. Therefore, each pile will take 703 kN, which will have an approximate settlement of 0.003 m as indicated in Figure 5.28.

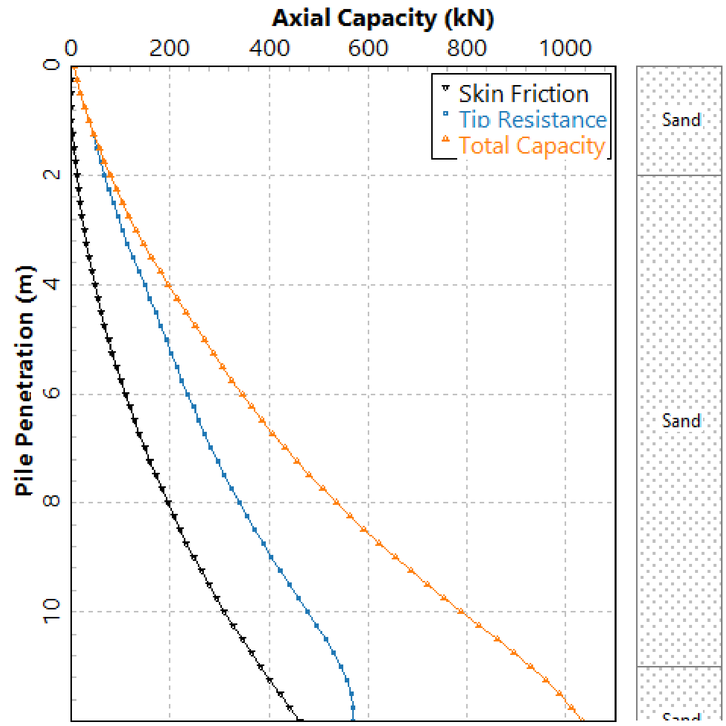


Figure 5.27 Curve of LRFD Geotechnical Capacity (Factored Capacity) vs Depth for Example Problem 9 (FHWA Method).

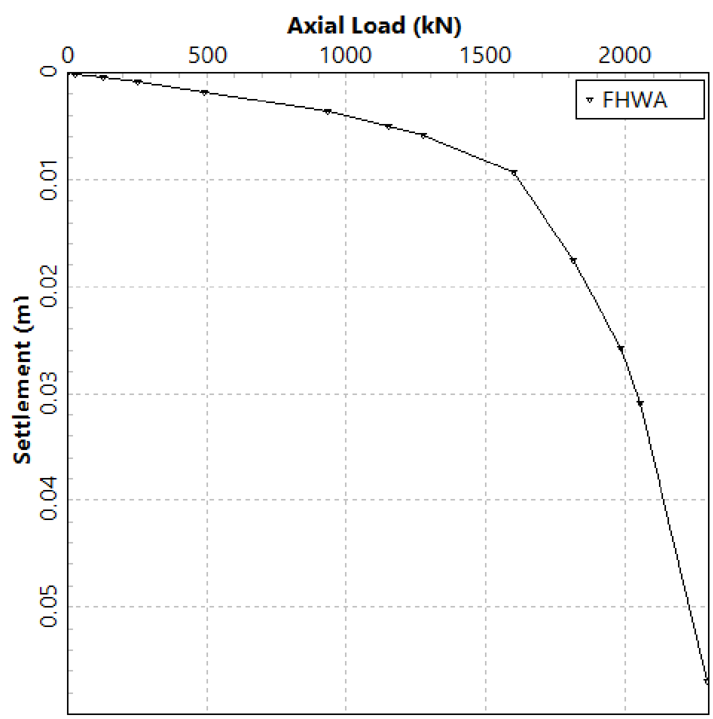


Figure 5.28 Curve of Axial Load vs Settlement for Example Problem 9.

5.11 Example Problem 10 – Battered Pile

Battered piles are used to resist large lateral loads when there is a large unsupported pile length or in weak soils where there is little lateral support. Many offshore or marine structures are subjected to overturning moments due to wind load, wave pressure, and ship impacts. Also, retaining walls are subjected to horizontal forces and bending moments due to earth pressure. For foundations in such structures, designers often evaluate the use of combinations of vertical and batter piles.

The ability to install driven piles on an angle, or batter, gives such piles a distinct advantage with respect to their ability to carry lateral loads. Batter piles carry lateral loads primarily in axial compression and/or tension while vertical deep foundations carry lateral loads in shear and bending. When subjected to lateral loading, batter piles will therefore generally have a greater capacity and be subject to smaller deformations than vertical piles of the same dimensions and material.

A pile driven on an angle is usually expressed as a batter ratio (horizontal to vertical). Example of 1:6 batter ratio is a 1-foot horizontal to 6-feet vertical, and sometimes the batter ratio is also expressed as a batter angle between the pile axis and the vertical.

5.11.1 Soil Profile and Pile Properties

A generalized subsurface profile along the alignment of the bridge is shown in Figure 5.29. The subsurface soils are predominantly soft to medium stiff and stiff normal consolidated clay nearby a coastal area. The soil density and strength increase with the increase of soil depth. The water table is at the existing ground surface. Soil properties for use in analysis include effective unit weight (γ') and undrained shear strength (c), which are presented in the soil profile.

Steel pipe piles with 24-in OD and wall thickness of 0.5 inches are considered for this application. The pile will be installed with 1 to 1.5 batter ratio degrees (1.0H:1.5V), which represents a batter angle of approximately 33.7 degrees (input into APILE). The total embedded pile length is 144 ft, which will penetrate approximately 6 ft into the bottom stiff clay layer. The pile will be driven based on the specified batter ratio with a close-ended pile tip. The API method is used for prediction of the axial compressive capacity of the battered pile for this application. The total side resistance can also be considered as pull-out capacity (under tension). Some applications may apply a reduction factor on the side friction for the uplift (pull-out) capacity if the pile has short embedded length.

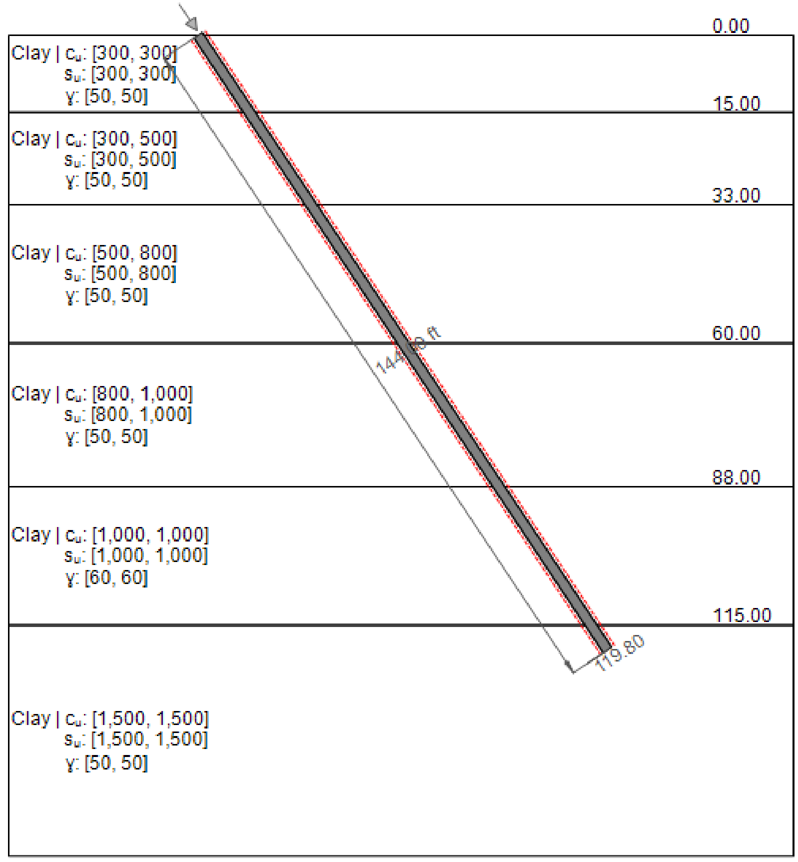


Figure 5.29 General soil description of Example Problem 10

5.11.2 Hand Computations and Comparisons with APILE

The program output will be compared to the results from the following hand calculations.

5.11.2.1 API Method – Skin Friction

Computations of side resistance were performed using a spreadsheet, with the following results:

Layer #	Depth below mudline, ft	Pile embed. ft	batter pile segment,ft L/cosθ	Adjusted layer, ft APILE	Effective unit WT pcf	Undrained c (Su) psf	Average c (Su) α	Average effective stress, psf	c/p	alpha α	Unit friction psf	Friction of each layer lbs	Accumulated Friction lbs
1	0-15	15	18.03	18.03	49.6	300	300	372	0.806	0.557	167.03	18922.36	18922.4
2	15-33	18	21.64	39.67	49.6	300 - 500	400	1190.4	0.336	0.863	345.02	46903.03	65825.4
3	33-60	27	32.45	72.12	49.6	500 - 800	650	2306.4	0.282	0.942	612.20	124835.95	190661.3
4	60-88	28	33.66	105.78	49.6	800 - 1000	900	3670.4	0.245	1.000	900.00	190319.13	380980.5
5	88-115	27	32.45	138.23	59.6	1000	1000	5169.4	0.193	1.000	1000.00	203913.35	584893.8
6	115-120	5	6.01	144.24	59.6	1500	1500	6123	0.245	1.000	1500.00	56642.60	641536.4

The total side friction from the table above is approximately 641 kips vs. 633 kips from APILE.

5.11.2.2 API Method – End Bearing

The tip area (closed ended tip) = 3.14 ft2

The unit tip resistance = 9 (1500 psf) = 13,500 lbs/ft2 = 13.5 k/ft2

The total tip resistance = 13.5 (3.14) =42.4 kips vs. 42.4 kips from APILE.

5.11.2.3 API Method – Total Capacity

The total compressive capacity is approximately 683 kips using approximate hand computations and 675 kips from APILE. The total pull-out capacity, without applying a reduction factor, is 641kips for the battered pile (based on approximate hand computations, 633 kips based on APILE results). For comparison, if the pile is driven vertically without the batter to the same tip elevation (the pile tip at 6 ft into the bottom clay layer), the compressive capacity will be only 582 kips.

5.11.3 Input and Output Data Files for Example 10

Users can read Section 2.1.1 (7) of this manual for reference on the location of placement of the input and output data files for the example files installed with this program. The default installation directory is the following: *(Root Drive) c:\Ensoft\Apile2026-Examples*. The input data files for all examples presented in this manual are installed automatically with the program.

The input-data filename is the following:

Example 10 - API Method on Battered Pile.ap12d

The output-data filename is the following:

Example 10 - API Method on Battered Pile.ap12o

5.11.4 Graphical Results of Computer Analysis

The APILE results of factored side friction, tip resistance, and total capacity versus length along the battered pile for the API method are plotted together in Figure 5.30. Axial load versus settlement is in Figure 5.31.

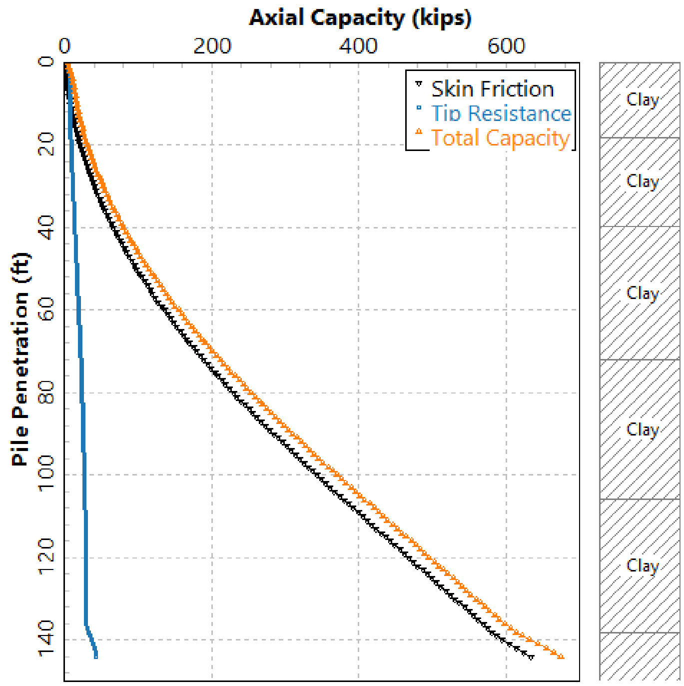


Figure 5.30 Curve of Combined Plots (Ultimate Total Capacity) vs Battered Length for Example Problem 10.

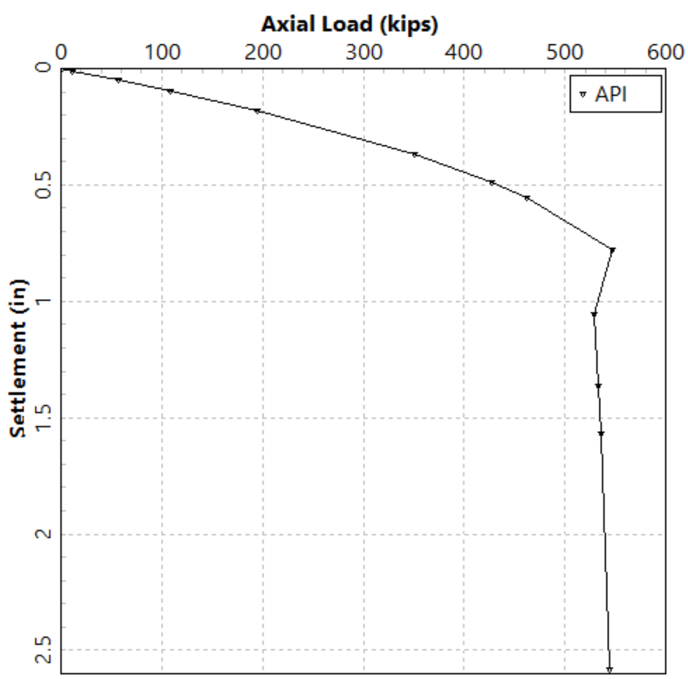


Figure 5.31 Axial Load vs Settlement for Example Problem 10.

5.12 Example Problem 11 – CPT to APILE

This example is used to demonstrate various features for importing and processing of data files obtained from cone penetration tests (CPT) into soil layers for APILE. Users may start with a new data file (File > New) and select to import CPT data (Data > Import CPT Data) or users may open an existing APILE model that needs to be modified with a new soil profile generated from imported CPT data. This example describes importing into a new data file, but the process is similar for importing into an existing file/APILE model.

5.12.1 Sample CPT Data

A soil testing agency that was contracted for the CPT test at a site provides the user with a CPT data file and the information in Table 5.17. This is the only required information for importing and interpreting the CPT data into APILE. The sample CPT data file '*Example 11 - CPT-01 - Ensoft Site.cpd*' in included within the files for this APILE example.

CPT File Name:	Example 11 - CPT-01 - Ensoft Site.cpd	Column 1:	Depth (m)
		Column 2:	Qc (tsf)
		Column 3:	Fs (tsf)
		Column 4:	Pore Pressure (psi)
		Column 5:	Inclinometer (degrees)*
Cone:	15 cm with Net Area Ratio = 0.80		
Ground Water:	15.8 ft during testing		

* This value/parameter is not currently used or necessary for importing or interpretation

Table 5.17 Summary of Sample CPT Data from Testing Agency

5.12.2 Importing & Interpreting CPT Data

Selection of Data > Import CPT Data for the sample CPT data file (*Example 11 - CPT-01 - Ensoft Site.cpd*) using parameters from Table 5.17 above are displayed in Figure 5.32. Selecting the Import button (lower right in Figure 5.32) provides a new screen similar to Figure 5.33.

Notice that the units in the screen are now consistent English units (Depth in feet and Q_{tip} in psf), since the new APILE data file was started with English units. If the user desires to have metric/SI units then start the process again with a new APILE file and select SI Units (Options > Units > S.I. Units).

The user has to enter new soil layers (using the green + button), select soil types, select layer depths, and enter the mechanical properties for the top and bottom of each soil layer. After close evaluations of the different interpreted parameters from the CPT file, the user may reach similar modeling decisions as those partially shown in Figure 5.34. The full set of parameters can be found by opening Example 11 (*Example 11 - CPT to APILE.ap10d*) and selecting Data > Soil Layers > Edit Soil Layers with CPT.

5.12.3 Pile Properties & Computation Methods

The pile data is not consequential for this example, but the model assumes a steel pipe pile with 24-in OD and wall thickness of 0.5 inches with a length/penetration of 65 ft. The FHWA, USACE and API methods are used for prediction of the axial compressive capacity, while the API method is used for the load-settlement curves.

In addition, this model also selects the NGI, MTD, Fugro and UWA methods (for the APILE Offshore Version) since those are better associated to CPT-based parameters. For side resistance in cohesive soils, these CPT methods also use two other variables (Plasticity Index in NGI and Yield Stress Ratio in the other methods) which need to be provided by the soil investigation or computed by the user outside APILE. This example uses the values shown in Table 5.18, but the user should read the applicable sections in Chapter 3 of the APILE Technical Manual for notes regarding these variables.

In particular, the following reference is provided for the Yield Stress Ratio:

> *Yield Stress Ratio* (*YSR*) is defined as the vertical effective yield stress (σ'_{vy}) to the vertical in situ effective stress (σ'_{vo}). *OCR* (over-consolidation ratio) is defined as the vertical maximum pre-consolidation effective stress (σ'_{vc}) to the vertical in situ effective stress (σ'_{vo}). *YSR* is also named as apparent *OCR* in some literature, but generally *YSR* is greater than *OCR*.

Layer	Depths (ft)	Plasticity Index (%)	Yield Stress Ratio
Clay	10.5 26.6	30 30	2.0 2.0
Clay	30.0 42.0	25 25	2.0 2.0
Clay	53.5 59.0	20 20	3.0 3.0

Table 5.18 PI and YSR for Example 11.

5.12.4 Input and Output Data Files for Example 10

Users can read Section 2.1.1 (7) of this manual for reference on the location of placement of the input and output data files for the example files installed with this program. The default installation directory is the following: *(Root Drive) c:\Ensoft\Apile2026-Examples*. The input data files for all examples presented in this manual are installed automatically with the program.

The input-data filename is the following:

Example 11 - CPT to APILE.ap12d

The output-data filename is the following:

Example 11 - CPT to APILE.ap12o

5.12.5 Graphical Results of Computer Analysis

APILE results of unfactored total capacity versus length for the various computational methods are plotted together in Figure 5.35. Axial load versus settlement is in Figure 5.36.

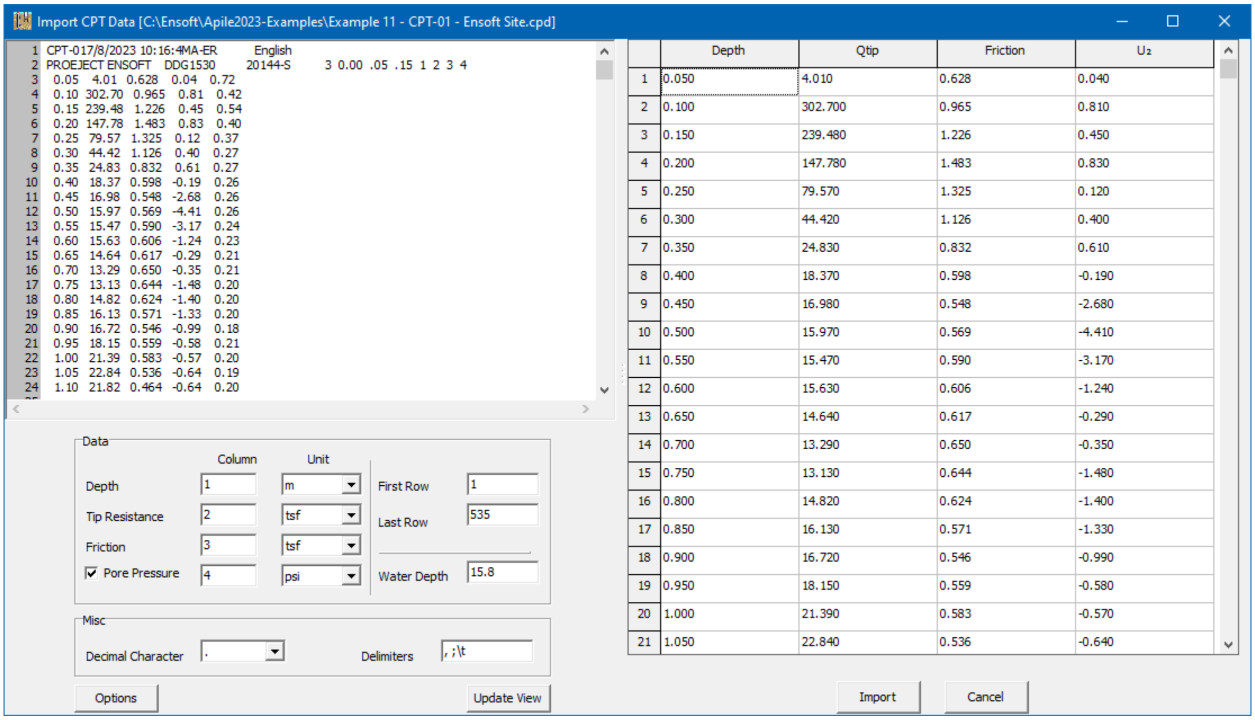


Figure 5.32 CPT Data Import Parameters for Example 11

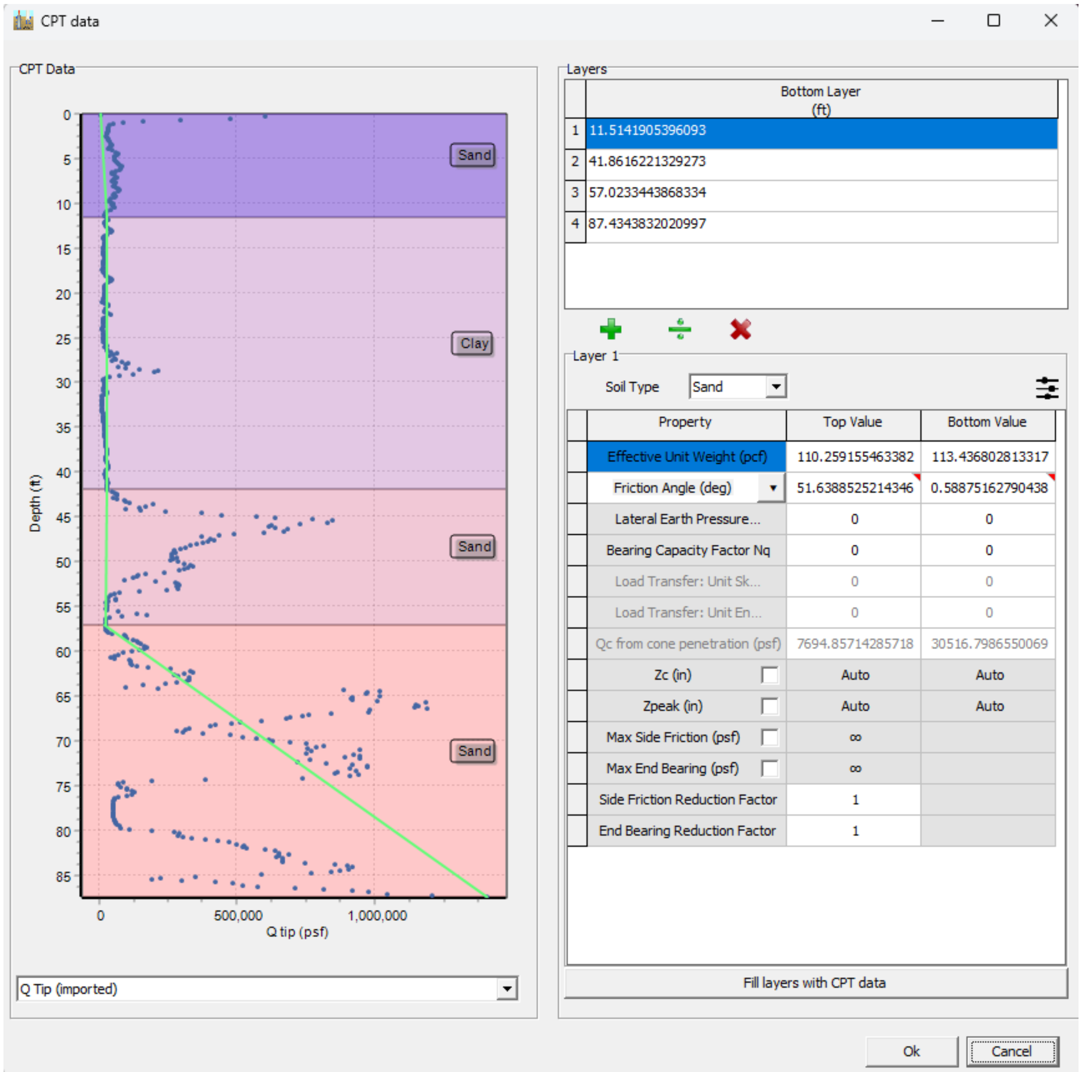


Figure 5.33 Initial populated Soil Data from Newly Imported CPT Data

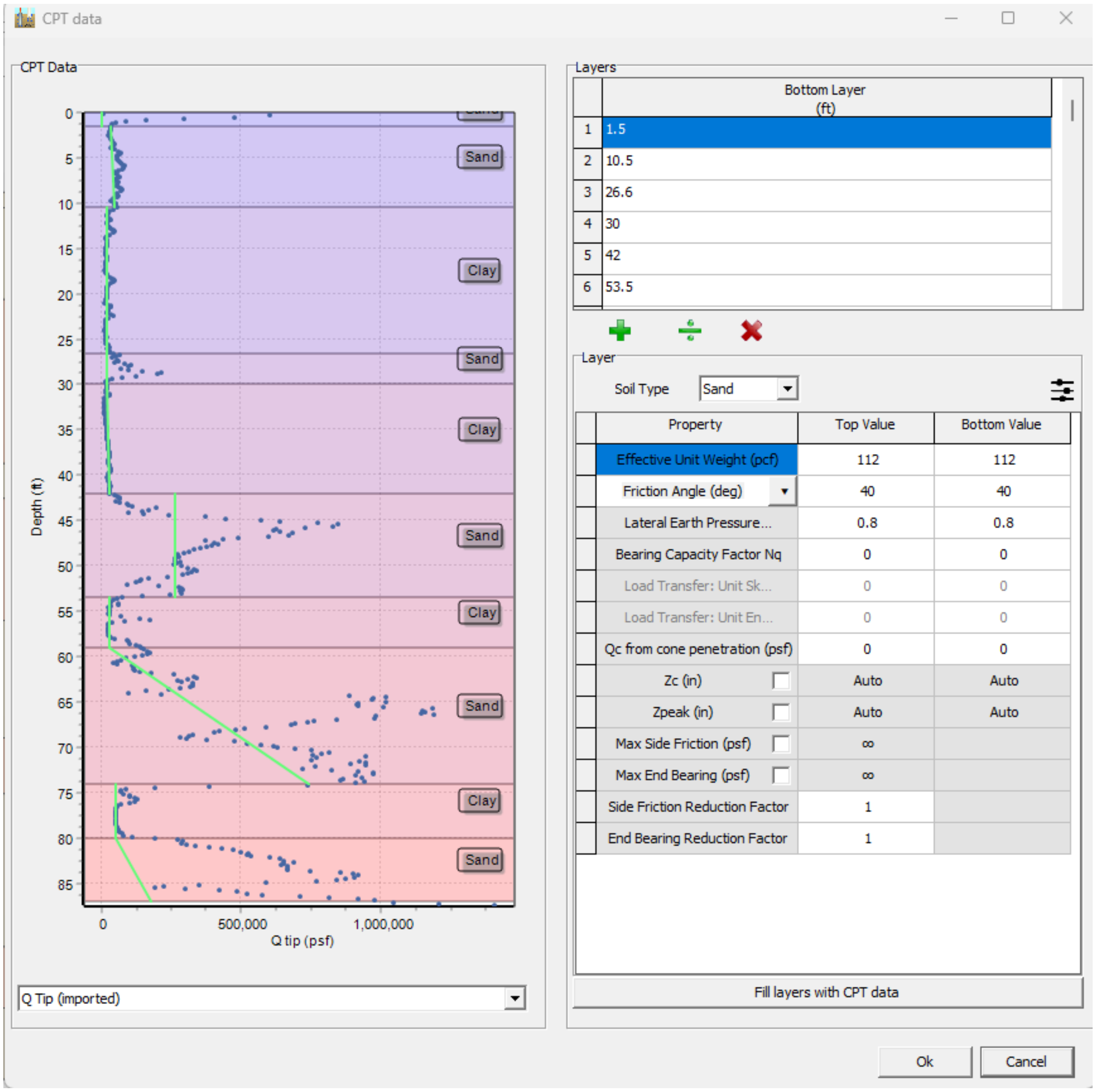


Figure 5.34 Sample Soil Data from Imported CPT for Example 11

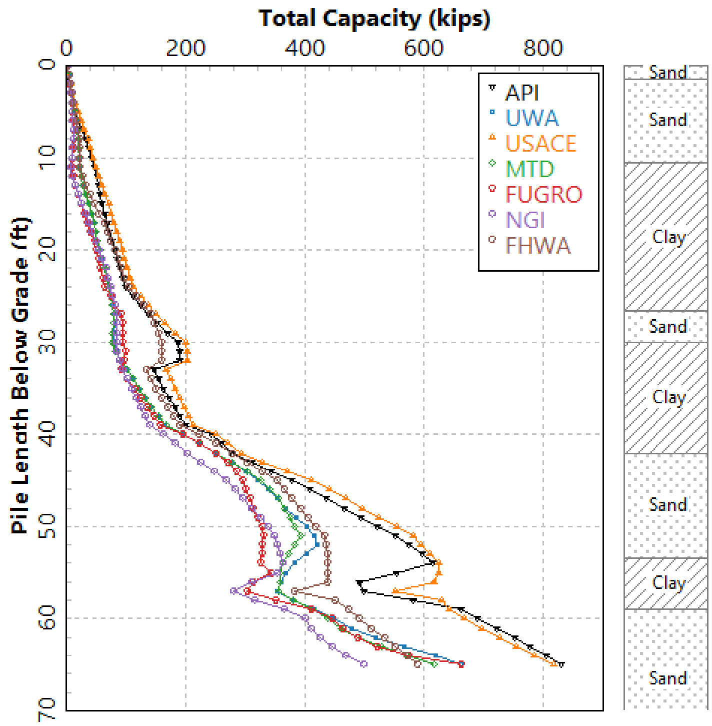


Figure 5.35 Ultimate Total Capacity vs Pile Length for Example Problem 11.

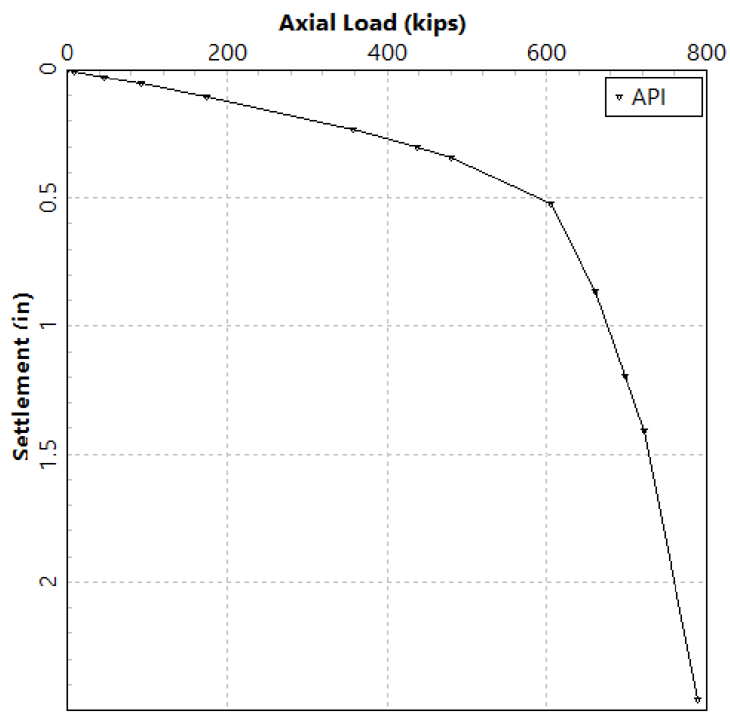


Figure 5.36 Axial Load vs Settlement for Example Problem 11.

5.13 Example Problem 12 – CLI example

In this example, we utilize the command line interface (CLI) to quickly analyze the load-settlement behavior of multiple piles in a stratum of soil layers where the soil surface and pile positions vary. There are a total of 18 piles, which will be labeled as Case F, Case E, etc. See Figure 5.36 for reference. The variable parameters are:

- Soil surface elevation
- Pile tip position
- Pile length

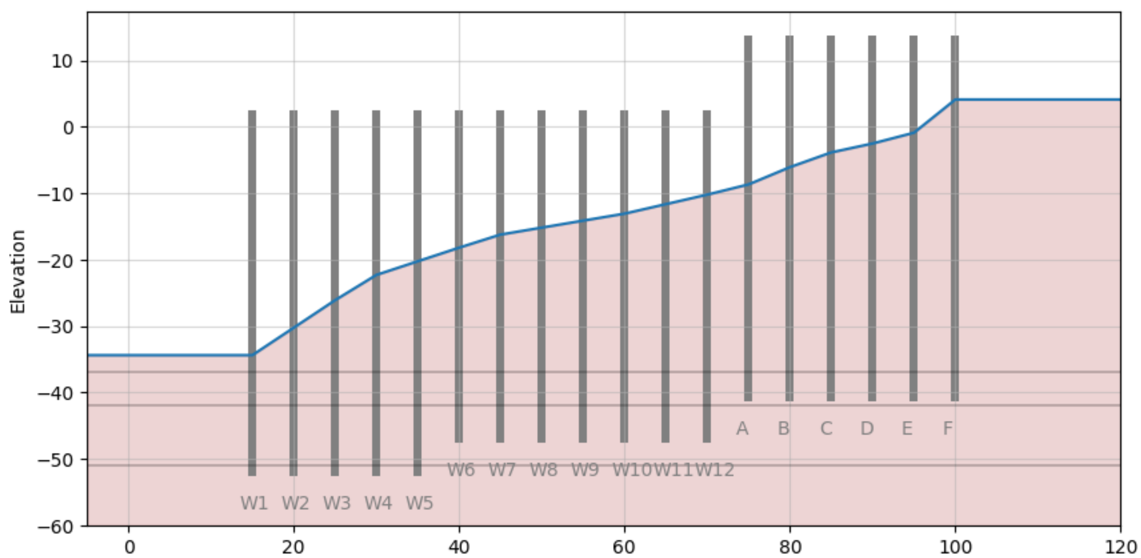


Figure 5.37 Soil stratum and pile layouts in Example 12.

The CLI for APILE is centered around input file modification. We will therefore generate the model for Case F (pile located on the far right) and use it as our base model. This base model will be called `Example12-base-model.ap12d`. All other cases will be ran by modifying the base model.

To modify and run one case, we will need to run the following set of CLI flags sequentially:

1. Modify pile properties (Section 4.4.3) and create a new input file

```
apile.exe --modify pile --length {length} --stickup {stickup} --input Exam-
ple12-base-model.ap12d --output case_{case_id}.ap12d
```

2. Modify and overwrite the newly created input file by modifying layer properties (Section 4.4.2)

```
apile.exe --modify layer --index 0 --elevation-const {elev} --input
case_{case_id}.ap12d
```

3. Run the analysis and export the data (Section 4.4.1)

```
apile.exe --run case_{case_id} --export output/case_{case_id}.json
```

In above steps, `{length}`, `{stickup}`, `{elev}`, and `{case_id}` are place holders for the appropriate attribute for each case.

While you can invoke each command individually as a separate and sequential process, piping all commands simultaneous to APILE instead of running them one-by-one will significantly increase execution time.

To automate this process for all the cases we will therefore use the following overall approach:

1. Compile a list of all parameters including case identifier, pile length, and surface elevation
2. Generate the commands listed above for each case, and store them in memory
3. Finally, execute APILE and tell it to expect input from stdin, and pipe all generated commands to it (See Section 4.4.4):
   ```
   {command_list} | apile.exe -
   ```

The exact piping syntax and notation depends on your shell or the language you are using, but in general any programming or scripting language may be used to perform the above steps.

Two working examples and implementation are distributed with the example files, one using VBA, and other using python. Both are summarized in the following sections.

5.13.1 Excel and VBA Example

The VBA implementation can be found in `Example12-run.xlsm`. This spreadsheet contains the list of cases. This file must reside in the same directory as the base `Example12-base-model.ap12d` input file. Make sure that the path to the APILE executable in the spreadsheet is consistent with the path in your APILE installation.

There is a 'Run Cases' button on the spreadsheet to run the analyses based on the defined cases.

Pressing 'Run Cases' button will run all cases and store the results in a directory labeled `output` directory next to the spreadsheet. Running the defined cases should be done very quickly.

To view the small code associated with the spreadsheet, navigate to

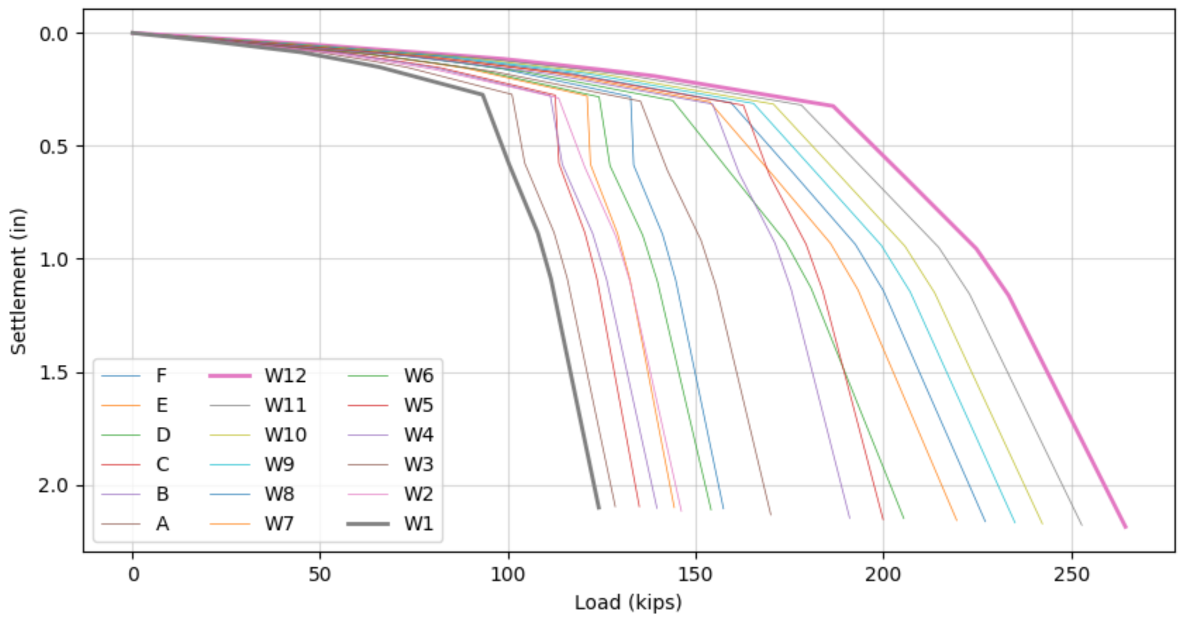
Developer → View Code

5.13.2 Python Example

The python implementation can be found in `Example12-run.py`. This file will read the cases defined in another filed called `Example12-parameters.csv` located in the same directory. Make sure that the APILE path hard-coded in the script file corresponds to the correct installation path of APILE on your system. You can execute this script without any dependencies. As an example, you can run it directly from a shell by executing `python Example12-run.py`.

Running this example will generate a `ex12-load-settlement.csv` file that contains the load settlement data for each case.

The combined load settlement graph for each case is included below. For this example, we learn that the minimum and the maximum of the envelop happens to be Case W1 and Case W12, respectively.



List of Technical References

Alm, T. & Hamre, L., (1998), Soil Model for Driveability Predictions, Offshore Technology Conference, OTC 8835, pp. 13.

Alm, T. & Hamre L., (2001), Soil model for driveability predictions based on CPT interpretations, Proceedings of the International Conference on Soil Mechanics and Geotechnical Engineering, Balkeema, CONF 15; VOL 2, pp. 1297-1302.

American Association of State Highway and Transportation Officials (AASHTO), "AASHTO LRFD Bridge Design Specifications, Customary U.S. Units, 4th Ed., Section 10." Washington, D.C. 2007.

American Association of State Highway and Transportation Officials (AASHTO), "AASHTO Guide Specifications for LRFD Seismic Bridge Design." Prepared by R.A. Imbsen, 2007.

American Petroleum Institute, "API Recommended Practice for Planning, Designing, and Constructing Fixed Offshore Platforms," Report RP-2A, 1986.

American Petroleum Institute, "API Recommended Practice for Planning, Designing, and Constructing Fixed Offshore Platforms," Report RP-2A, 1987.

American Petroleum Institute, "API Recommended Practice for Planning, Designing, and Constructing Fixed Offshore Platforms," Report RP-2A, 1993.

American Petroleum Institute (API), "Recommended Practice for Planning, Designing, and Constructing Fixed Offshore Platforms – Working Stress Design," Report RP 2A-WSD, Twenty Second Edition, November 2014.

American Society of Civil Engineers*, Design of Pile Foundations Handbook*, 1993.

Clausen C., Aas, P., and Karlsrud, K.,, "Bearing Capacity of Driven Piles in Sand, the NGI Approach ", Frontiers in Offshore Geotechnics. ISFOG 2005, Ed. by Gourbenec & Cassidy, Taylor & Francis Group, London, 2005.

Coyle, H. M. and Lymon C. Reese, "Load Transfer for Axially Loaded Piles in Clay," *Proceedings,* American Society of Civil Engineers, Vol.92, No. SM2, 1966.

Coyle, H. M. and I. H. Sulaiman, "Skin Friction for Steel Piles in Sand," *Journal of the Soil Mechanics and Foundations Division*, American Society of Civil Engineers, Vol. 93, SM6, Paper No. 5590, pp. 261, November, 1967.

Federal Highway Administration, *Soils and Foundations, Workshop Manual - Second Edition*, Publication No. FHWA HI-88-009, July 1993.

Jardine, R., and Chow F., "New Design Methods for Offshore Piles", Marine Technology Directorate, London, 1996.

Jardine, R., Chow F., Overy R., and Standing J., "ICP Design Methods for driven Piles in Sands and Clays", Thomas Telford Ltd, London, 2005.

Kraft, Leland M., Jr., John A. Focht, Jr., and Srinath F. Amerasinghe, "Friction Capacity of Piles Driven into Clay", Journal of the Geotechnical Engineering Division. Vol.107, No. GT11, November, 1981.

Karlsrud, K., Clausen C., and Aas, P., "Bearing Capacity of Driven Piles in Clay, the NGI Approach ", Frontiers in Offshore Geotechnics. ISFOG 2005, Ed. by Gourbenec & Cassidy, Taylor & Francis Group, London, 2005.

Lehane, B.M., Lim, J.K., Carotenuto, P., Nadim, F., Lacasse, S., Jardine, R.J., and van Dijk, B.F.J. 2017. Characteristics of Unified Databases for Driven piles. Proceedings of the 8th International Conference of Offshore Site Investigation and Geotechnics OSIG, doi.org/10.3723/OSIG17.162.

Meyerhof, G.G., "Bearing Capacity and Settlement of Pile Foundations", Journal of Geotechnical Engineering, American Society of Civil Engineers, Vol. 102, No. GT3, *pp. 197-227, 1976.*

Mosher, R. L., "Load Transfer Criteria for Numerical Analysis of Axially Loaded Piles in Sand," U. S. Army Waterways Experiment Station, Automatic Data Processing Center, Vicksburg, Mississippi, January, 1984.

National Highway Institute (NHI), "Load and Resistance Factor Design (LRFD) for Highway Bridge Substructures," U.S. Department of Transportation, Federal Highway Administration, Publication No. FHWA HI-98-032, May 2001.

Norwegian Geotechnical Institute, "Bearing Capacity of Driven Piles in Clay," Internal report no. 525211-1, March 2000.

Seed, H. B. and L. C. Reese, "The Action of Soft Clay Along Friction Piles," *Transactions*, American Society of Civil Engineers, Paper No. 2882, Vol. 122, pp. 731-754, 1957.

Skempton, A. W., "The Bearing Capacity of Clays," *Proceedings,* Building Research Congress, Division I, London, England, 1951.

Vesic, A. S., "Tests on Instrumented Piles, Ogeechee River Site", Journal of the Soil Mechanics and Foundation Division, American Society of Civil Engineers, Vol. 96, No. SM2, *pp. 561-584, 1970.*

Vijayvergiya, V. N., "Load-Movement Characteristics of Piles", 4th Symposium of Waterways, Port, Coastal and Ocean Division, American Society of Civil Engineers, Long Beach, California, Vol. 2, *pp. 561-584, 1977.*

Vijayvergiya, V. N. and John A. Focht Jr., "A New Way to Predict the Capacity of Piles in Clay", *Proceedings,* Offshore Technology Conference, Houston, Texas, May 1972.

License Agreement & Disclaimer

PROGRAM LICENSE AGREEMENT & DISCLAIMER

IMPORTANT NOTICE: The software you are about to install or previously have installed from Ensoft Incorporated (“ENSOFT”) is licensed only on the condition that you agree to the terms and conditions set forth below. Please read the terms of this License Agreement & Disclaimer ("LICENSE") carefully.

If you agree to be bound by the terms of this LICENSE, please check mark the box labeled “YES – I Accept the terms of this License Agreement!” during software installation so it can be installed on your computer.

If you do not agree to the terms of this LICENSE, please check mark the box labeled “NO – I DO NOT Accept the terms of this License Agreement!” which will terminate the software installation.

If the software is already installed and licensed, you have already agreed to the terms and conditions of this license, or someone has done so on your behalf.

This LICENSE is a legal agreement between you (“USER”) – either an individual or a single entity– and ENSOFT for the ENSOFT software product that you are about to install or previously have installed (“PRODUCT”). The PRODUCT collectively includes computer software and associated media, printed materials, hardware key (dongle), and electronic documentation. The PRODUCT also includes any updates and supplements to the original PRODUCT that may have been produced by ENSOFT. By installing, copying, downloading, accessing or otherwise using the PRODUCT, the USER agrees to be bound by the terms of this LICENSE. If you (the USER) do not agree to the terms of this LICENSE, do not install or use the PRODUCT.

SOFTWARE LICENSE & DISCLAIMER

The PRODUCT is protected by copyright laws and international copyright treaties, as well as other intellectual property laws and treaties. The PRODUCT is licensed, not sold.

1. GRANT OF LICENSE

This LICENSE grants you the following rights:

1.1 INSTALLATION AND USE

1.1.1 Single-User Licenses

This software is licensed to the USER (company or individual) whose name is registered with ENSOFT and can only be installed in individual computers of employees of one specific physical and licensed site (“SITE”) that is registered with ENSOFT. You may install and use the PRODUCT on any number of computers for employees of the licensed SITE but installations cannot be made for shared access of the PRODUCT over a network. The PRODUCT is fully operational only in the SITE computer that carries the appropriate PRODUCT’s hardware security key (“KEY”) that is used as software protection device.

1.1.2 Network Licenses

This software is licensed to the USER (company or individual) whose name is registered with ENSOFT and can only be accessed by the employees of the specific physical licensed SITE and within white-listed IP ranges registered with ENSOFT.

The most basic local network license for a SITE allows the USER to white list up to four unique /24 (unique third octets) IPv4 ranges for the employees of the licensed SITE. Broader access can be purchased if a network configuration requires the white listing of additional subnets/ranges for the employees of the licensed SITE.

The USER may install and use the PRODUCT on any computer in the licensed SITE that is within the white-listed IPv4 ranges registered with ENSOFT. Access to the PRODUCT from VPN Routers or Remote Desktop or similar may be implemented but must limit access to employees of the licensed SITE.

This Network License strictly prohibits the PRODUCT to be accessed by employees from office locations that are different than the licensed SITE and/or outside the white-listed IPv4 ranges. Employees from office locations other than the registered SITE at ENSOFT are required to purchase additional licenses of the PRODUCT, even if the USER (company) name is the same and/or if the additional offices are located in the same city.

1.1.3 Cloud Licenses

LICENSE is made available to USER (company or individual) for a limited subscription time period, not sold. This software is licensed to the USER whose name is registered with ENSOFT and may only be accessed by an individual employee(s) of the USER, hereby referenced as "LICENSE USER", who has been explicitly authorized to use the LICENSE for the specified subscription time period. The LICENSE USER may install and use the PRODUCT on any computer owned or operated by LICENSE USER.

A LICENSE USER is a single individual that is required to register with ENSOFT in order to activate, access, or use the PRODUCT. The LICENSE USER access to the PRODUCT may not be shared with multiple individuals. You are responsible for anyone who obtains, accesses, or uses PRODUCT with your LICENSE and their compliance with the LICENSE agreement.

PRODUCT may require making automatic connections to the Internet intermittently or on a regular basis to validate the LICENSE, and your LICENSE subscription. ENSOFT may disable, terminate, or suspend your LICENSE if (a) your subscription has expired and has not been renewed; (b) you or your LICENSE USER are in breach of LICENSE agreement and fail to address such breaches within 30 days after written notice of the breach; (c) pose a security risk or adversely impact PRODUCT, its infrastructure, systems, or other users; (d) tamper, remove, disable or otherwise limit the effectiveness of any technical or security protections.

2. OTHER RIGHTS AND LIMITATIONS

2.1 EDUCATIONAL VERSION

If the PRODUCT was licensed with educational discounts, the use of the PRODUCT is strictly limited to academic or research activities of educators and/or students. Any other usage voids all the rights under this LICENSE. If in doubt, please contact ENSOFT to determine if you have a PRODUCT version that was licensed for educational purposes.

2.2 LIMITATIONS ON REVERSE ENGINEERING, DECOMPILATION, AND DISASSEMBLY

You may not reverse engineer, decompile, or disassemble the PRODUCT, except and only to the extent that such activity is expressly permitted by applicable law notwithstanding this limitation.

2.3 RENTAL

You may not rent, lease or lend the PRODUCT to third parties.

2.4 TRADEMARKS

This LICENSE does not grant you any rights in connection with any trademarks or service marks of ENSOFT.

2.5 SUPPORT SERVICES

ENSOFT shall provide you with limited support and maintenance services (“SUPPORT”) related to the PRODUCT during the initial year after purchase and for any additional SUPPORT term that the COMPANY elects to purchase for PRODUCT after the initial warranty period expires.

Use of SUPPORT is limited to the ENSOFT policies and programs described in the PRODUCT’s User’s Manual, in documentation on the ENSOFT web site, and/or in other materials provided by ENSOFT.

Any supplemental software code that may be provided to you as part of the SUPPORT or that is downloaded from the ENSOFT web site shall be considered part of the PRODUCT and subject to the terms and conditions of this LICENSE. With respect to technical information you provide to ENSOFT as part of the SUPPORT, ENSOFT may use such information for its business purposes, including for product support, development or advertisements. However, ENSOFT will not utilize such technical information in a form that personally identifies the USER.

2.6 SOFTWARE TRANSFER

The initial user of the PRODUCT may make a permanent transfer of this LICENSE and PRODUCT and only directly to an end user. This transfer must include all of the PRODUCT (including all component parts, the media and printed materials, any upgrades, this LICENSE, and the PRODUCT's appropriate hardware KEY). Such transfer may not be by way of consignment or any other indirect transfer. The transferee of such one-time transfer must agree to comply with the terms of this LICENSE, including the obligation not to further transfer this LICENSE and PRODUCT.

2.7 TERMINATION

Without prejudice to any other rights, ENSOFT may terminate this LICENSE immediately if you fail to comply with the terms and conditions of this LICENSE. In such event, you must destroy all copies of the PRODUCT and all of its component parts and provide evidence of such destruction in writing to ENSOFT within 3 business days.

2.8 INDEMNIFICATION

Within and during the terms of this LICENSE, ENSOFT warrants that the use of the initially provided PRODUCT does not infringe any patent, copyright, or trademark in the United States, and ENSOFT shall indemnify and hold USER harmless against any and all losses, damages and expenses, (including attorney's fees) which USER may sustain or incur as a result of a breach of this warranty.

2.9 CONFIDENTIAL INFORMATION

ENSOFT and the USER may have access to certain proprietary information and materials of the other that are confidential and of substantial value to the respective party, which value would be impaired if such information were disclosed to third parties ("CONFIDENTIAL INFORMATION"). ENSOFT and the USER agree that neither shall disclose any CONFIDENTIAL INFORMATION to any third party and shall take every reasonable precaution to protect CONFIDENTIAL INFORMATION.

The provisions of this section shall not apply to any information which (i) is or becomes available to the public other than by breach of the LICENSE agreement by the receiving party, (ii) is rightfully received by receiving party from a third party without confidential limitations, (iii) is independently developed by receiving party's employees without access to CONFIDENTIAL INFORMATION, or (iv) is known to the receiving party without any restriction on its use or disclosure prior to first receipt of it from the disclosing party.

3. COPYRIGHT

All title and intellectual property rights in and to the PRODUCT (including but not limited to any images, photographs, animations, video, audio, music, and text that may be incorporated into the PRODUCT), the accompanying printed materials, and any copies of the PRODUCT are owned by ENSOFT. All title and intellectual property rights in and to the content which may be accessed through use of the PRODUCT is the property of the respective content owner and may be protected by applicable copyright or other intellectual property laws and treaties. This LICENSE grants you no rights to use such content. All rights not expressly granted are reserved by ENSOFT. This PRODUCT is protected by the United States Copyright Law and International Copyright Treaty.

4. SOFTWARE DISCLAIMER

Although the PRODUCT has been used with apparent success in many analyses, new information is developed continuously and new or updated PRODUCT releases may be written from time to time. All users are requested to inform ENSOFT immediately if any errors are found in the PRODUCT. As modifications, updates, or new versions are produced, the latest codes are posted on ENSOFT's web site and made available to all visitors for free downloading.

No warranty, expressed or implied, is offered as to the accuracy of results from ENSOFT's PRODUCT. The PRODUCT should not be used for design unless caution is exercised in interpreting the results and independent calculations are available to verify the general correctness of the results. Users are assumed to be knowledgeable of the information in the printed documentation that is distributed with the digital media. Users are assumed to recognize that the input parameters, eg., soil properties, increment length, tolerance on solution convergence, and many others, can have a significant effect on the solution and must be chosen carefully. Users should have a thorough understanding of the relevant theoretical criteria (appropriate references are suggested in the software documentation).

5. GOVERNING LAW

This LICENSE is governed by the laws of the State of Texas and laws and treaties of the United States of America.

6. CONTACT INFORMATION

Should you have any questions concerning this LICENSE or if you desire to contact ENSOFT for any reason, please use the following:

Ensoft Incorporated
3003 West Howard Lane
Austin, Texas 78728
United States of America

NO OTHER WARRANTIES

TO THE MAXIMUM EXTENT PERMITTED BY APPLICABLE LAW, ENSOFT DISCLAIMS ALL OTHER WARRANTIES AND CONDITIONS, EITHER EXPRESSED OR IMPLIED, INCLUDING, BUT NOT LIMITED TO, IMPLIED WARRANTIES OR CONDITIONS OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, AND TITLE, WITH REGARD TO THE PRODUCT, AND THE PROVISION OF SUPPORT SERVICES. THIS LIMITED WARRANTY GIVES YOU SPECIFIC LEGAL RIGHTS. YOU MAY HAVE OTHERS, WHICH VARY FROM STATE/JURISDICTION TO STATE/JURISDICTION.

LIMITATION OF LIABILITY

TO THE MAXIMUM EXTENT PERMITTED BY APPLICABLE LAW, IN NO EVENT SHALL ENSOFT BE LIABLE FOR ANY SPECIAL, INCIDENTAL, INDIRECT, OR CONSEQUENTIAL DAMAGES WHATSOEVER (INCLUDING, WITHOUT LIMITATION, DAMAGES FOR LOSS OF BUSINESS PROFITS, BUSINESS INTERRUPTION, LOSS OF BUSINESS INFORMATION, OR ANY OTHER PECUNIARY LOSS) ARISING OUT OF THE USE OF OR INABILITY TO USE THE SOFTWARE PRODUCT OR THE FAILURE TO PROVIDE SUPPORT, EVEN IF ENSOFT HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES. IN ANY CASE, ENSOFT'S ENTIRE LIABILITY UNDER ANY PROVISION OF THIS LICENSE AGREEMENT SHALL BE LIMITED TO THE GREATER OF THE AMOUNT ACTUALLY PAID BY YOU FOR THE PRODUCT OR U.S.$1.00.