All-Pile

Compression, Settlement, Uplift, and Lateral Capacity

CIVILTECH SOFTWARE

ALL-PILE SOFTWARE MANUAL

Table of Contents

CHAPTER 1 INTRODUCTION

About the Program

The program ALL-PILE for Windows version has a user friendly interface, which makes the program easy to learn and easy to run. It has a powerful pull down menu bar at the top of screen and is very easy to operate. The commands on the menu bar are arranged in a Microsoft-style configuration. Mouse and keyboard are available for data input and retrieval with short-cut keys provided for quick operation.

The program can calculate pile load capacity very efficiently and accurately. All-Pile can handle all types of piles: drilled shaft, driven pile, low case auger-cast pile, steel pipe pile, H-pile, timber pile, Tapered pile, etc... You can even define new piles and change some parameters based on local practices and experience. The program can calculate compression load capacity, uplift capacity, lateral capacity, deflections and location of point of fixity (Free head and fix head condition), and settlement.

After data is input and the program executed, graphical output showing vertical load capacity versus pile length relationship and lateral load capacity versus deflection relationship is provided. The graphics presentation can be printed as a high resolution hard copy using your laser printer.

About the Manual

This manual:

1) Describes software operation and hardware configuration
2) Introduces theory and methods of calculation used in the program (the user should be at least familiar with pile design theory)
3) Describes each input and output parameter
4) Provides typical example problems

About the Company

CivilTech Software is a subsidiary of CivilTech Corporation. CivilTech Software employs engineers with experience in structural, geotechnical, and software engineering. These engineers have many years of experience in design and analysis in these fields as well as in special studies including: seismic analysis, soil-structure interaction, and finite element analysis. Together, CivilTech has developed a series of engineering programs which are efficient, easy to learn, engineering orientated, practical, and accurate.

The series of CivilTech Software includes Shoring, Heave, Lpres, Epres, Tunnel, Buried Structures, All-Pile, Boring Log, and Lab Testing programs. These programs are widely used in US and around the world.

CHAPTER 2 INSTALLATION

Setup

Insert the Setup Disk in a floppy drive.
In Windows 3.1 from the [FILE] menu, select *[RUN]*.
In Windows '95, press <START>; and select *[RUN]*.
Type:

A: **INSTALL** or **B: INSTALL,** then press <OK>

then follow the instructions on the screen. The installation program will automatically create an icon called ALLPILE in your Windows screen.

Configuration

Hardware configuration uses your Window's settings. However, you can run configuration later in Windows. To run configuration check your Windows menu book.

Starting the Program

Double click the icon called ALLPILE from your Windows screen.

Running the Calculation

The program will automatically do the calculation once the input is completed.

View and Print Results

To view the results, press each corresponding button on the tool bar or view menu for soil profile, calculation results, vertical and lateral load curve.

Quit Program

Press *[Exit]* from the [File] menu or Ctrl+X

Registration

You will need to register your copy of this software to use its full capabilities like printing and saving your work. The first thing you need to do to register is to get your code number from the software. This number is located under the [Help] menu in the option [Register]. (Figure 2-1)

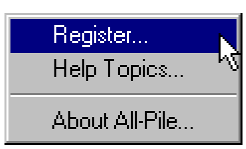


Figure Chapter 2 -1 Register Menu

Clicking [Register…] will open the registration window (Figure 2-2) where you can enter your firm name and get your Code Number.

To get your registration code, call, fax, or email us your Code Number and enter in the

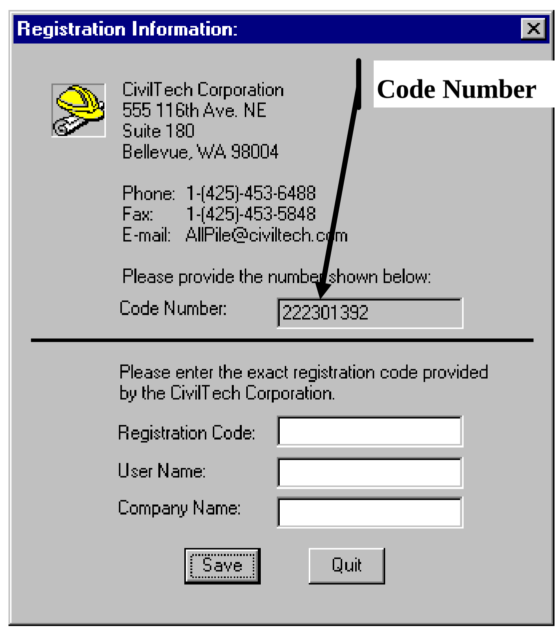


Figure Chapter 2 -2 Registration Window

number we give you in the box next to Registration Code:

If you've done everything correctly you should see Figure 2-3 (below).

Figure Chapter 2 -3 Successful Registration Notice

Menu Command

The following text describes the purpose of each command under the menu item.

File Menu

The [File] menu provides easy data file handling tools**.**

New To clear all the old data from the screen, and provide a blank work space so you can begin a new job. Every time you open the program, the program provides you with a new untitled file. If the file name is **Untitled** you have to name the file before you save it. (See ***Save*** below).

Open To open an existing file saved previously in the hard disk. A dialog box with a list of files will show on the screen. Select the file you want and click open. If you change your mind, press **Esc** or cancel button.

Save Occasionally you should save the file you are working on to avoid losing data. To save the working file you can press the shortcut key F10, or pull down the file menu and click on *[Save]* or *[Save As]*. If the file is untitled, the program will automatically switch to the *[Save As]* command and ask you to provide a file name to save file.

Save As If you want to save a new untitled file or change the file name of an opened file, you should use the *[Save As]* command. A dialog box appears to ask you the file name you want to use. You may type up to 8 letters for file name. Don't type "." and extension. A legal file name cannot contain "# ". If the file name is not valid, another dialog box appears to warn you. You can enter a valid name or click *[Cancel]* to go back.

Exit To quit the program.

A dialog box will appear. You have three choices:

1. Click <YES> to save the working file and exit. A *[Save As]* dialog box will appear, see the description of *[Save As]* command.
2. Click < CANCEL > To go back to the working file. Does not exit.

View Menu The <View> menu provides easy viewing tools.

Profile:	To view soil profile
Report:	To view results summary
Lateral Curve:	To view lateral load capacity versus displacement relationships

	Vertical Curve:	To view vertical load capacity vs depth relationship
Setting Menu	Pile	To set parameters related to pile property
	Soil	To set parameters related to soil property
Help Menu	Provides help information for your convenience.	

Tool Bar and Buttons

The tool bar provides short-cut buttons for menu commands. Figure Chapter 2 -4 shows the buttons and their corresponding meaning showing on the screen. The data button is provided for easy access to go to data input page.

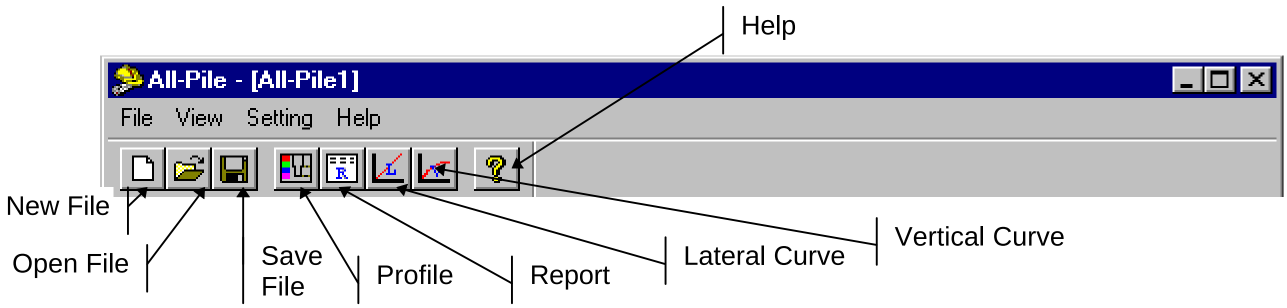


Figure Chapter 2 -4 All-Pile Tool Bar

CHAPTER 3 RUNNING THE PROGRAM

Data Input

The data needed for calculation basically consists of pile and soil information. A more detailed description of the input pages is presented in the following text. The graphical definition is illustrated on Figure Chapter 3 -1.

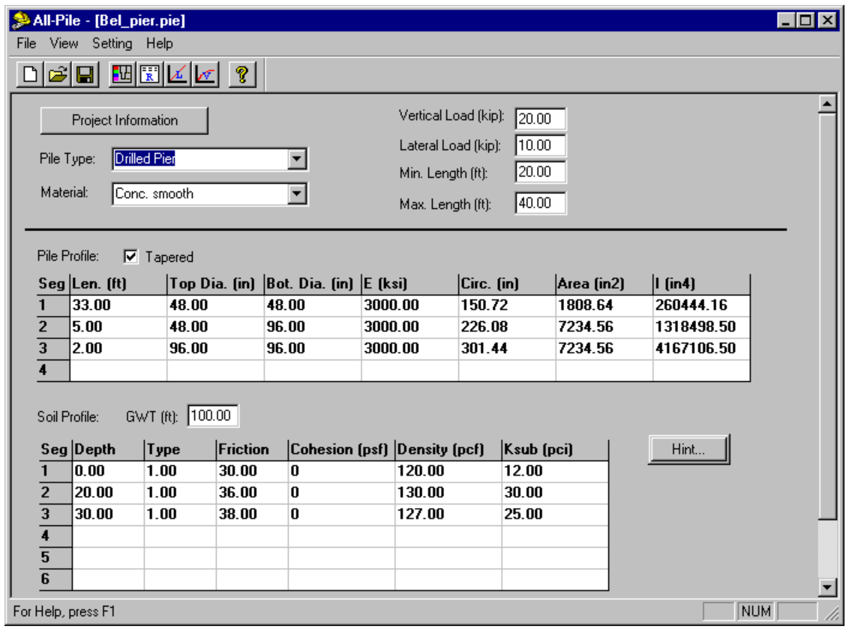


Figure Chapter 3 -1 Data Input Window

Item 1 *Project Information*: Enter project name and other project identification.

Item 2 *Pile Type*: Select pile type.

Item 3 *Material*: Select material type of pile.

Item 4 *Loads*

Vertical Load: Enter vertical load applied on the pile

Lateral Load: Enter to calculate lateral displacement under this lateral load. This lateral load is also being used to calculate the safety factor.

Min Length: Enter the minimum limit to be plotted on vertical curve.

Max Length: Enter the maximum limit of load to be plotted on vertical curve.

Item 5 *Tapped check box* : check this box for tapped pile. If this box is checked, the data input box will ask for both top and bottom pile diameter (refer to the Pile Profile Table in Item 6). Otherwise, only on pile diameter is needed for input.

Item 6 *Pile Profile Table*

Len. - is the length of pile segment, not the depth

Top Dia. - is the diameter of pile at top of the segment

Bot Dia- is the diameter of pile at bottom of segment (for tappered pile only).

E - is the elastic modulus of pile

Cir. - is the perimeter of pile, it is automatically calculated based on circle shape. If the pile is not circle in shape, enter the perimeter of pile.

Area - is the cross sectional area of pile (automatically calculated based on circle shape. If the pile is not circle in shape, enter the actual area of pile)

I- is the moment inertia of pile (it will be automatically calculated based on circle shape. If the pile is not circle in shape, enter the actual area of pile)

Item 7 *Soil Profile*

GWT - Groundwater table may be input here.

Depth	Type	Friction	Cohesion(psf)	Density	Ksub(pci)
0.00	1.00	30.00	0.0	120.00	12
10.00	1.00	36.00	0.0	120.00	30
20.00	1.00	38.00	0.0	120.00	25

Depth - is the depth of top of the soil layer. The program can calculate saturated density based on the input of groundwater table.

Type - is the soil type. Soil type 1 is sand (C=0, ∅≠0), Soil Type 2 is clay (C≠0, ∅=0), and Soil Type 3 is C, ∅ soil (C≠0, and ∅≠0)

Density - is the density of soil. Submerged density is automatically calculated by program based on groundwater table input.

K_{sub} - is the constant of coefficient of subgrade reaction of soil. Note that Ksub is different than the coefficient of subgrade reaction. The user should check Ksub provided in *Hint of Data* input page for different soil conditions.

Recommendations for Granular Material

Condition	Spt	Ø	Ksub (pci)
Very Loose	0-4	<28	0-12
Loose	4-10	28-30	12-20
Medium	10-30	30-36	20-65
Dense	30-50	36-41	65-95
Very Dense	> 50	> 41	95-120

Recommendations for Cohesive Material

Condition	Spt	C (psf)	Ksub (pci)
Very soft	0-2	0-250	0-5
Soft	2-4	250-500	5-10
Medium	4-8	500-1000	10-15
Stiff	8-16	1000-2000	15-45
Very stiff	16-32	2000-4000	45-95
Hard	> 32	> 4000	95-120

OK

Figure Chapter 3 -2 Hint Box

Item 8 *Hint Button*

When soil strength test results are not available, hint provides the correlation between Standard Penetration Test and soil strength parameters. C, ∅ and Ksub. The correlation is shown on Figure Chapter 3 -2.

Change Settings

Pile Parameters

The pile parameters provide three setting items: criteria, friction, and earth pressure coefficient.

Criteria

This table sets the criteria for calculation.

Allowable Disp - is the displacement corresponding to the lateral load capacity.

F.S. friction (up) - is the factor of safety for uplift capacity calculation.

F.S. friction (down) - is the Factor of Safety for skin resistance calculation in compression.

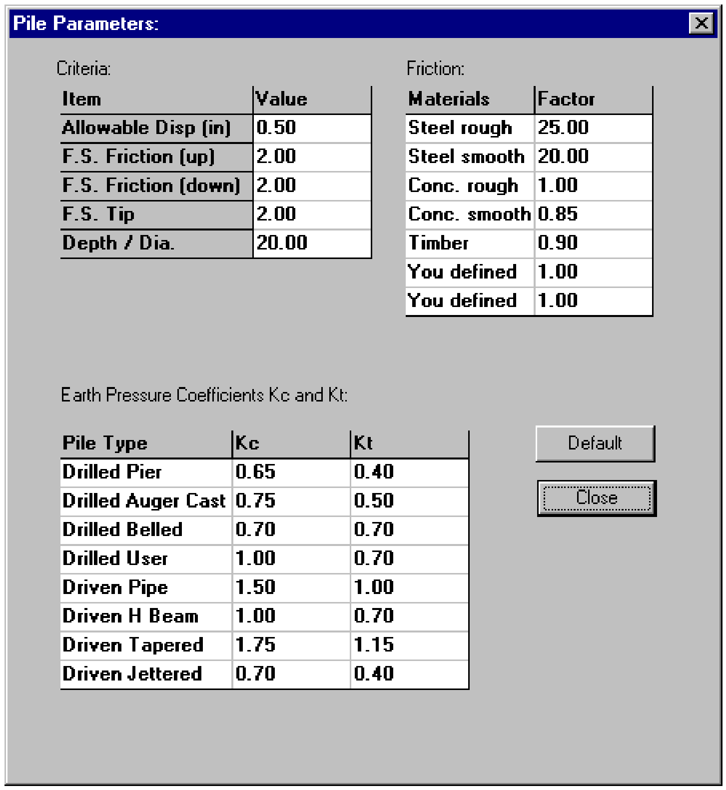
F.S. Tip - is the Factor of Safety for tip resistance calculation in compression.

Depth/ Dia. - is the ratio of depth of bearing layer and pile diameter (D/B). Experience indicated that end bearing and skin friction increase with vertical effective stress up to a limiting depth. Beyond this limiting depth (10B to 40B) the end bearing and skin friction is almost constant. Normally, D/B=20 is used. User may choose different ratios based on local experience. User may also change factor.

Friction

This table sets the friction factor for calculation of friction angle between pile and soil.

Note that if the factor is greater than 2 the program reads as a friction angle δ instead of a factor. If the factor input is less than 2, the program read as a factor, which is δ/ϕ. User may change the default setting based on their own experience.



Item	Value
Allowable Disp (in)	0.50
F.S. Friction (up)	2.00
F.S. Friction (down)	2.00
F.S. Tip	2.00
Depth / Dia.	20.00

Materials	Factor
Steel rough	25.00
Steel smooth	20.00
Conc. rough	1.00
Conc. smooth	0.85
Timber	0.90
You defined	1.00
You defined	1.00

Pile Type	Kc	Kt
Drilled Pier	0.65	0.40
Drilled Auger Cast	0.75	0.50
Drilled Belled	0.70	0.70
Drilled User	1.00	0.70
Driven Pipe	1.50	1.00
Driven H Beam	1.00	0.70
Driven Tapered	1.75	1.15
Driven Jettered	0.70	0.40

Figure Chapter 3 -3 Pile Parameter Window

Earth Pressure Coefficient K_c and K_t

This table sets the earth pressure coefficient to be used in the vertical load capacity calculation. $\mathbf{K_c}$ is used in compression load capacity calculation and $\mathbf{K_t}$ is for uplift calculation. Figure 3-3 shows the default setting. The users may change the default setting based on experience.

Default Button

A default button is provided for use. Click default button will set all pile parameters to the default setting.

Soil Parameters

The soil parameters provide default settings for parameters related to soil.

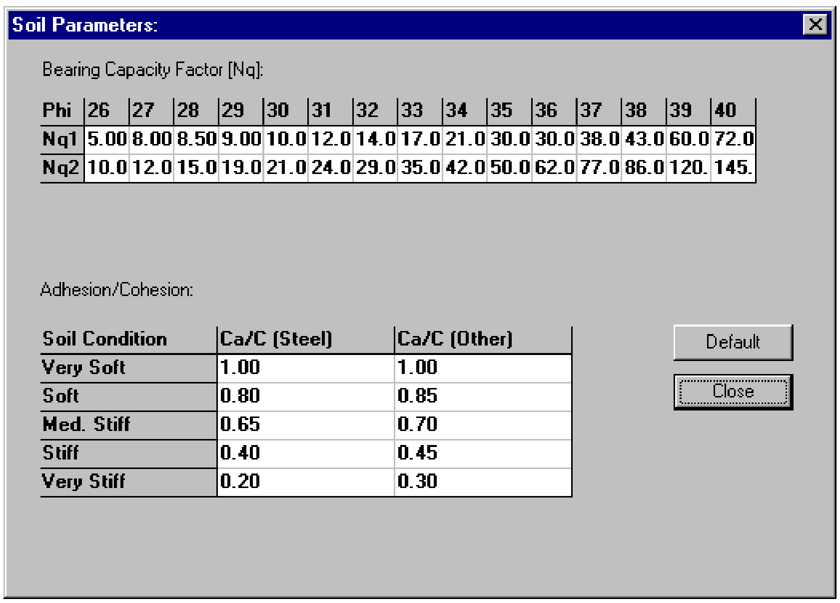
Bearing Capacity Factor (Nq)

This table (Figure 3-4) provides Bearing Capacity Factor to be used in the tip resistance calculation. The Bearing Capacity Factor is the function of soil friction angle. $\mathbf{N_{q1}}$ is for drilled piles and $\mathbf{N_{q2}}$ is for driven piles. The factors shown on Figure 2-5 are adapted from DM7 Manual. In general, the factors are considered to be relatively conservative. The user may refer to other literature for different input.

Adhesion/ Cohesion

This table (Figure 3-4) provides ratios of Adhesion and Cohesion for different soil conditions. The user may change the default settings shown on Figure 2-5 based on their own experience.

Default Button - Click the default button to reset all soil parameters back to the default settings.



Phi	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
Nq1	5.00	8.00	8.50	9.00	10.0	12.0	14.0	17.0	21.0	30.0	30.0	38.0	43.0	60.0	72.0
Nq2	10.0	12.0	15.0	19.0	21.0	24.0	29.0	35.0	42.0	50.0	62.0	77.0	86.0	120.	145.

Soil Condition	Ca/C (Steel)	Ca/C (Other)
Very Soft	1.00	1.00
Soft	0.80	0.85
Med. Stiff	0.65	0.70
Stiff	0.40	0.45
Very Stiff	0.20	0.30

Figure Chapter 3 -4 Soil Parameters Window

Data Output

ALLPILE provides both summary and detail results.

The summary results present vertical ultimate and allowable load capacity, settlement of pile at allowable load capacity, safety factor of load capacity at working load, lateral deflection under working load, lateral load capacity at allowable deflection for free-head and fixed-head conditions.

The detail shows of step by step calculations.

The program also gives users graphical presentation of soil and pile profile, lateral load and deflection curve, compression load capacity versus depth curve. The following is a list of output the program provides:

- Soil profile with pile configuration.
- Summary

The summary report provides results for both vertical and lateral analysis.

Vertical Analysis

Ultimate Capacity - Load capacity prior to factor of safety is applied.

$\mathbf{Q_{skin}}$ **-** Ultimate skin resistance

$\mathbf{Q_{tip}}$ **-** Ultimate tip resistance

$\mathbf{Q_{down}}$ **-** Ultimate compression load capacity, $\mathbf{Q_{down} = Q_{skin} + Q_{tip}}$

$\mathbf{Q_{uplift}}$ **-** Ultimate uplift capacity

Lateral Analysis

$\mathbf{Y_{fixed}}$ and $\mathbf{Y_{free}}$ are the lateral deflection under work loading for the fixed head condition and free head condition, respectively.

$\mathbf{P_{fixed}}$ and $\mathbf{P_{free}}$ are lateral load capacity for lateral deflection of 0.5 inch for the fixed head condition and free head condition, respectively.

T is the stiffness factor, refer to Section 3.4 for definition.

Point of fixity is the point with zero deflection.

- Lateral load capacity and deflection curve and detailed results.
- Compression load capacity and depth curve and detailed results.

CHAPTER 4 CALCULATION THEORY

Pile foundation is widely used to carry the superstructure loads both vertically and laterally, to resist uplift forces, and control settlement. There are many different pile types. The following are common types of piles: (1) driven H-pile, (2) driven steel pipe pile, (3) driven concrete pile, (4) driven tapered pile, (5) driven jetted pile, and (6) drilled cast-in-place pile. This program uses procedures described in the *Foundations & Earth Structures, Design Manual 7.02,* published by Department of Navy, Naval Facilities Engineering Command for vertical, lateral load capacity and settlement calculation..

Compression Load Capacity Calculation

Ultimate Compression Capacity can be determined by the following equation:

$$\mathbf{Q_{ult} = Q_t = + Q_s}$$

Where $\mathbf{Q_{ult}}$ = ultimate load capacity in compression

$\mathbf{Q_t}$ = ultimate tip resistance

$\mathbf{Q_s}$ = ultimate skin resistance

In Cohesionless Soil

$$\mathbf{Q_t = P_t N_q A_t}$$

$$\mathbf{Q_s = \Sigma (K_C) (P_0) (TAN\delta) (S)(\Delta L)}$$

Where $\mathbf{N_q}$ = bearing capacity factor (This is a function of φ. It can be modified in *Setting/ Soil* menu (refer to Section 2.3b)

$\mathbf{A_t}$ = area of pile tip (ΔL **-** of pile segment)

$\mathbf{K_C}$ = ratio of horizontal to vertical effective stress on side of element when element is in compression (refer to *Setting/ Pile* menu, section 2.3a)

$\mathbf{P_o}$ = effective vertical stress

$\boldsymbol{\delta}$ = friction angle between pile and soil

S = surface area of pile per unit length

In Cohesive Soil

$$\mathbf{Q_t = (N_c) A_t}$$

$$\mathbf{Q_s = \Sigma C_A S\Delta L}$$

$\mathbf{N_c}$ = bearing capacity factor

$\mathbf{C_A}$ = adhesion of each soil layer

$\mathbf{C_A = \alpha_C C}$

C = Cohesion of soil

$\boldsymbol{\alpha_C}$ = Factor …. Can be modified in *Setting/ Soil* menu (refer to Section 23b)

ΔL = thickness of each soil layer

Allowable pile load capacity $$Q_{all} = \frac{Q_t}{FS_t} + \frac{Q_s}{FS_s}$$

Where **FS_t** = Factor of Safety for tip resistance

FS_s= Factor of Safety for skin resistance

In this program the individual user may calculate allowable load capacity with different safety factor depending on nature of the structure.

Settlement Calculation Due to Vertical Allowable Load

The settlement at the top of the pile consists of the following three components:

Settlement due to axial deformation of pile shaft, W_s

$$W_s = \frac{(Q_p + \alpha_s Q_s)}{(\frac{L}{AE_p})}$$

Where **Q_p** = point load transmitted to the pile tip in the working stress range

Q_s = shaft friction load transmitted by pile in the working stress range (in force unit)

α_s = 0.5 for parabolic or uniform distribution of shaft friction

0.67 for triangle distribution of shaft friction starting from zero friction at pile head to a maximum value at pile point

0.33 for triangle distribution of shaft friction starting from a maximum at pile head to zero at pile point.

L = pile length

A = pile cross section

E_p = Modulus of elasticity of the pile

Settlement of pile point caused by load transmitted at the point, W_{pp}

$$W_{pp} = \frac{(C_p Q_p)}{Bq_0}$$

Where **C_p** = empirical coefficient depending on soil type and method of construction.

B = pile diameter

q_0 = ultimate end bearing capacity

Settlement of pile point caused by load transmitted along the pile shaft, W_{ps}

$$W_{ps} = \frac{(C_s Q_s)}{(Dq_0)}$$

Where $C_s = (0.93 + 0.16\frac{D}{B})C_p$

D = embedded depth

The total settlement of a single pile, W_0

$W_0 = (W_s + W_{pp} + W_{ps})$

Important Note:

The settlement calculation described in this section is for single pile only. For settlement calculation of pile group, user should refer to the related literature.

Uplift Capacity Calculation

The Ultimate uplift capacity can be calculated as:

$Q_{ult} = \Sigma (K_t)(P_0)(TAN\delta)(S)(H)$

Where Q_{ult} = ultimate load capacity in tension

K_t = ratio of horizontal to vertical effective stress on side of element when element is in tension.

Allowable uplift capacity for pile $Q_{tall} = \frac{Q_{ult}}{FS_u} + W_p$

Where W_p = weight of pile

FS_u = Factor of safety for uplift

Lateral Load Capacity Calculation

A pile loaded by lateral force and/or moment at its top, resists the load by deflecting to mobilize the reaction of the surrounding soil. The magnitude and deflection of the resisting pressure are a function of the stiffness of the surrounding soils, the stiffness of the pile, allowable deflection at the top of pile, and induced moment in the pile. A general solution for determination of moments and deflections of a pile subjected to lateral load and moment at the ground surface has been given by Matlock and Reese (1960). Figure Chapter 4 -1 shows the general nature of the deflected shape of the pile and the soil resistance caused by the applied load and the moment.

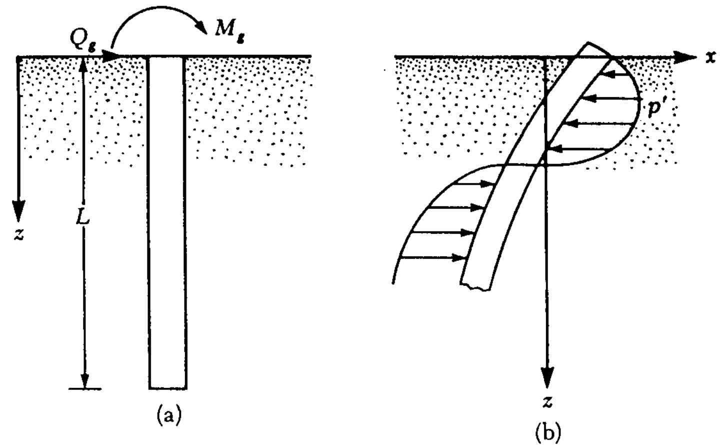


Figure Chapter 4 -1 Laterally loaded pile and soil response.

According to a simpler Winkler's model, an elastic medium (which is soil in this case) can be replaced by a series of infinitely close independent elastic springs. With this assumption, one can write that

$$\mathbf{K_h = \frac{P}{X}}$$

Where **K_h** = coefficient of subgrade reaction (1b/in^3)

P = pressure on soil (1b/in^2)

X = lateral deflection (1b)

Pile deformation and stress can be approximated based on idealized assumptions. In our analysis, pile deformation is estimated assuming the coefficient of subgrade reaction increases linearly with depth.

$$\mathbf{K_h = \frac{k_{sub} Z}{D}}$$

Where **K_{sub}**= constant of coefficient of subgrade reaction

Z = depth(feet)

D = width/diameter of loaded area (feet)

Guidance for selection of **K_{sub}** is given in Figure Chapter 4 -2 for fine-grained and coarse-grained soils. Please note that **K_{sub}** from Figure Chapter 4 -2 should be multiplied by 1.16 to convert to lb/in^3 for the input into the program.

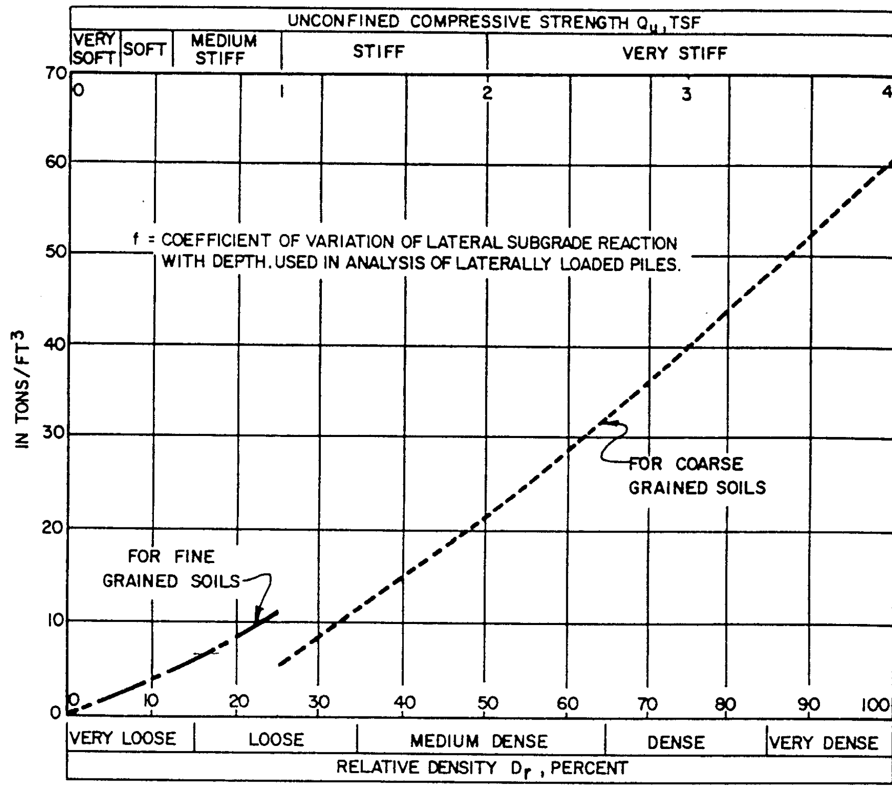


Figure Chapter 4 -2

Using the theory of beams on an elastic foundation, one can write

$$\mathbf{E_p I_p \frac{d^4x}{dz^4} + k_h x = 0}$$

Where **E_P**=Younng's modulus of the pile material

I_P=Moment of inertia of the pile section.

Solving the above equation, we can have the following expressions for pile deflection and moment at any depth Z for a given lateral force P and moment M.

$$\mathbf{S_Z = A_x \frac{PT^3}{EI} + B_x \frac{MT^2}{EI}}$$

$$\mathbf{M_Z = A_M PT + B_M M}$$

Where **A_x**, **B_x**, and **B_m** are coefficients, and

T = stiffness factor

$$\mathbf{T} = \sqrt[5]{\mathbf{\frac{EI}{k}}}$$

Lateral load capacity of pile were calculated for two loading conditions, free-head and fixed-head conditions. For the free-head condition, pile cap is assumed to be flexible or pile is hinged at the top. Fixed-head condition is assumed to have rigid cap fixed against rotation at ground surface.

A pile is considered a long pile when the pile length L>5T. For a long pile, the deflection is almost zero at a depth of 2T, which is called the point of fixity. The soil from the ground surface to the point of fixity usually provides the greatest resistance. For L<2T, the pile is considered to be a rigid pile and does not fully mobilize soil and pile resistance. For L>5T, the lateral capacity does not change significantly.

CHAPTER 5 EXAMPLES

This chapter presents five examples with different soil conditions and pile type. These examples are intended to let users know how to use this program.

Example 1

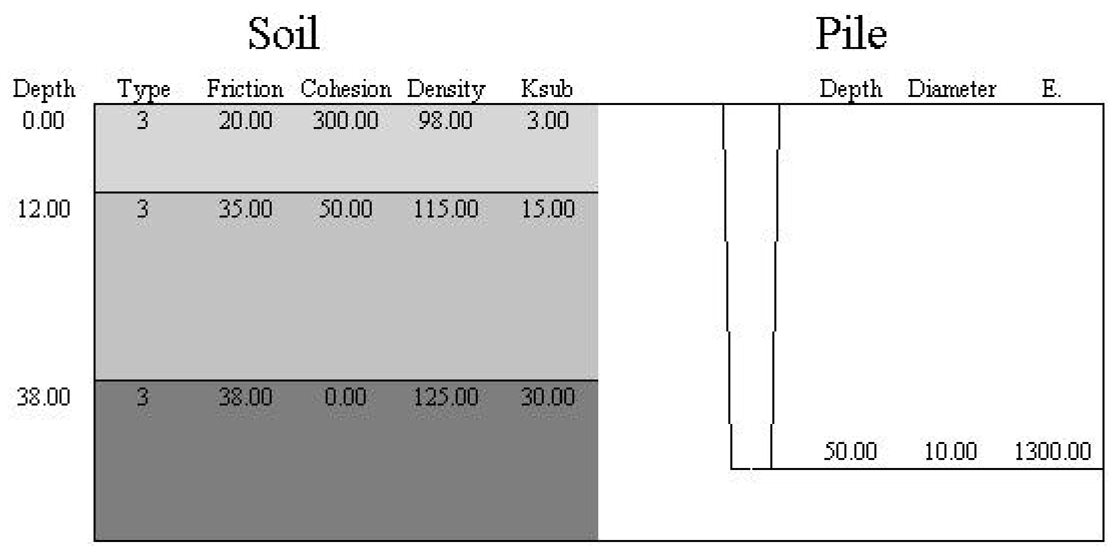
Timber Pile

Information:

Timber piles are needed to support a structure. The soils at the site consist of 3 layers of c.ϕ soil as shown below. The pile is 50 feet long.

Question:

Compute its allowable vertical load capacity and lateral load capacity for the fixed head condition.



Results:

The summary shows that the allowable compress and uplift load capacities are 195.38 kip and 98.71 kip, respectively. Settlement at allowable capacity is 0.63 inches. For a working load of 30 kip, the factor of safety will be about 13 for the vertical load. The lateral load capacity at 0.5 inch displacements for the fixed head condition is 6.83 kip.

Example 2

Steel Pile in a Two-Layer Soil System

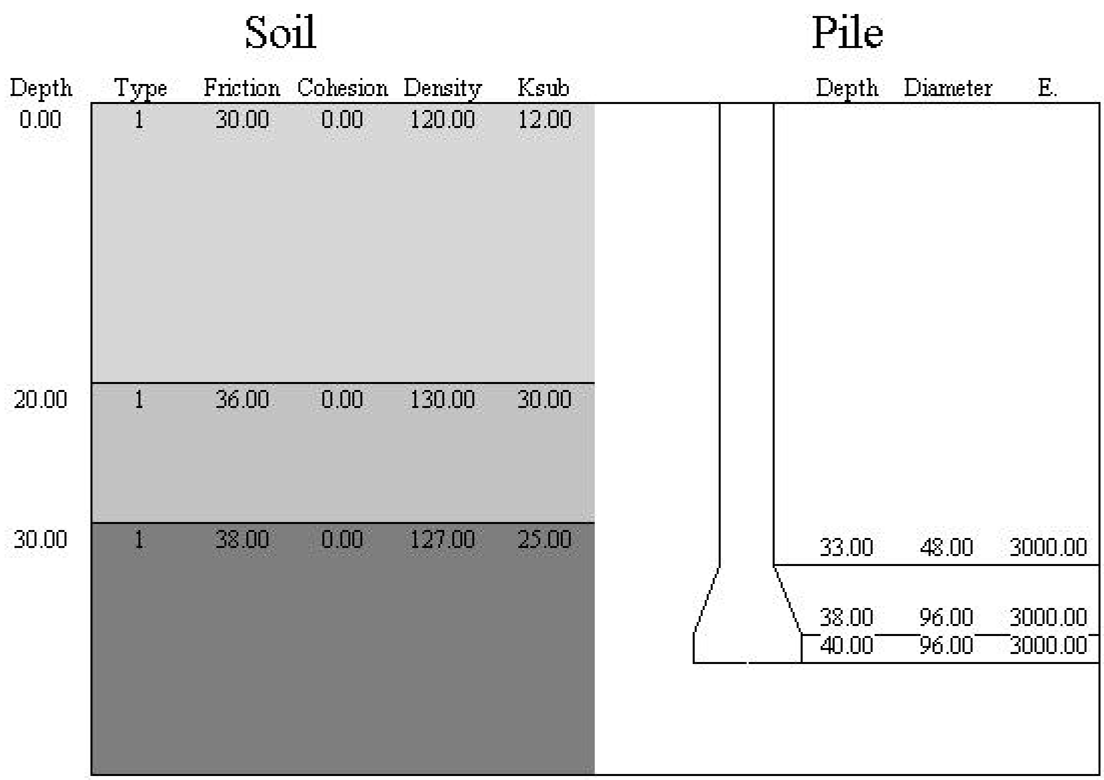
Information:

A steel pipe pile of 18 inches in diameter is used for support of a structure. The soil is type 3 with both friction and cohesion. The working load is 150 kip.

Question:

What is the allowable compression load capacity if the pile is 50 feet long?

How long will the pile need to be for a working load of 400 kip?



Results:

The summary shows that allowable compression load capacity is 436.59 kip for a factor of safety of 2. From the vertical curve and detailed results, you may find a pile length of 411 feet is needed in order to obtain an allowable compression capacity of 400 kip.

Example 3

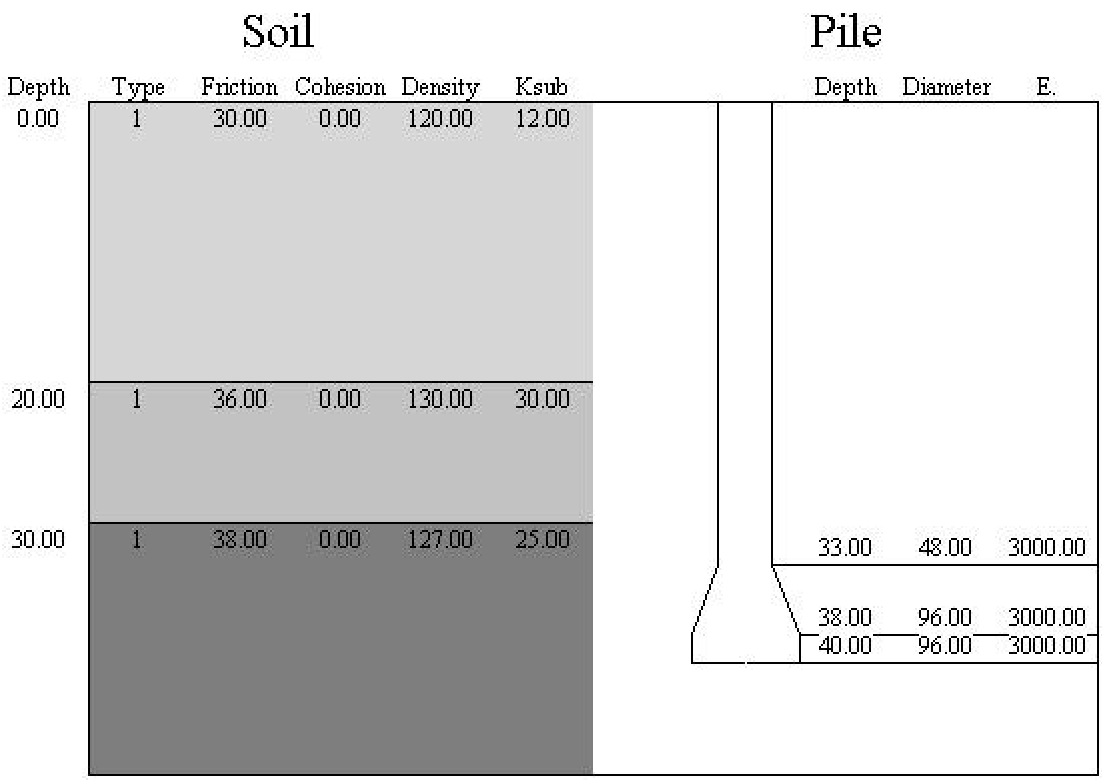
Belled Drilled Shaft in Sandy Soil

Information:

A 40 foot drilled shaft with a bell at the bottom is used. The shaft has a diameter of 48 inches, and the bell is 96 inches in diameter. The soil and pile profile is shown in the figure below.

Question:

What is the allowable compression capacity of the shaft?



Results:

The program indicated that the allowable compression load capacity is 5,653.99 kip.

Example 4

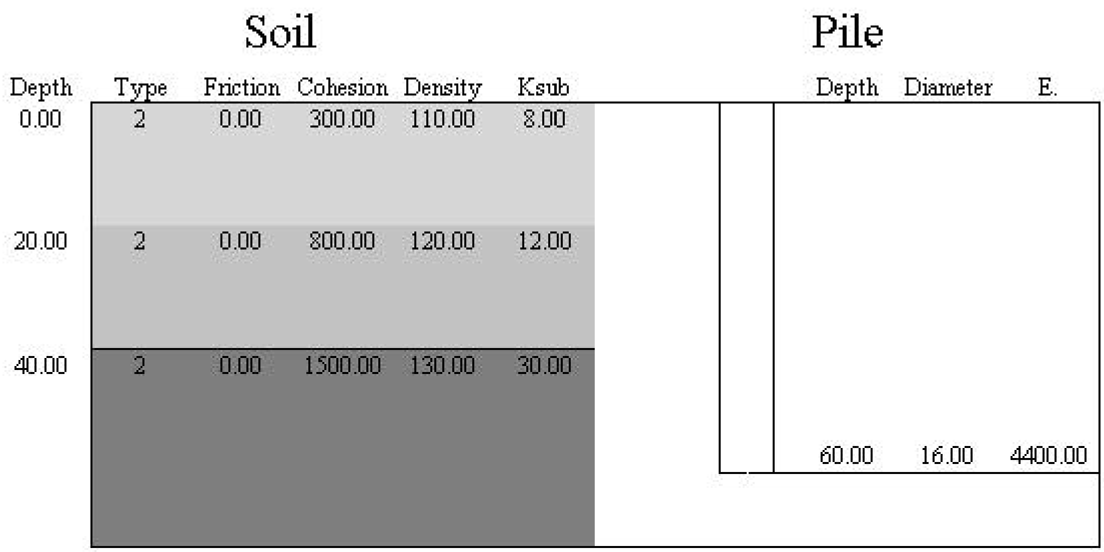
Driven Concrete Pile

Information:

Precast concrete piles are used to support a building. The piles to be used will be circular - 16 inches in diameter and 60 feet driven into thick, clayey soil.

Question:

Computer allowable compression and uplift capacity of each pile.



Results:

The program shows that the allowable compression of each pile is 83.17 kip. The uplift capacity is 73.75 kip.

Example 5

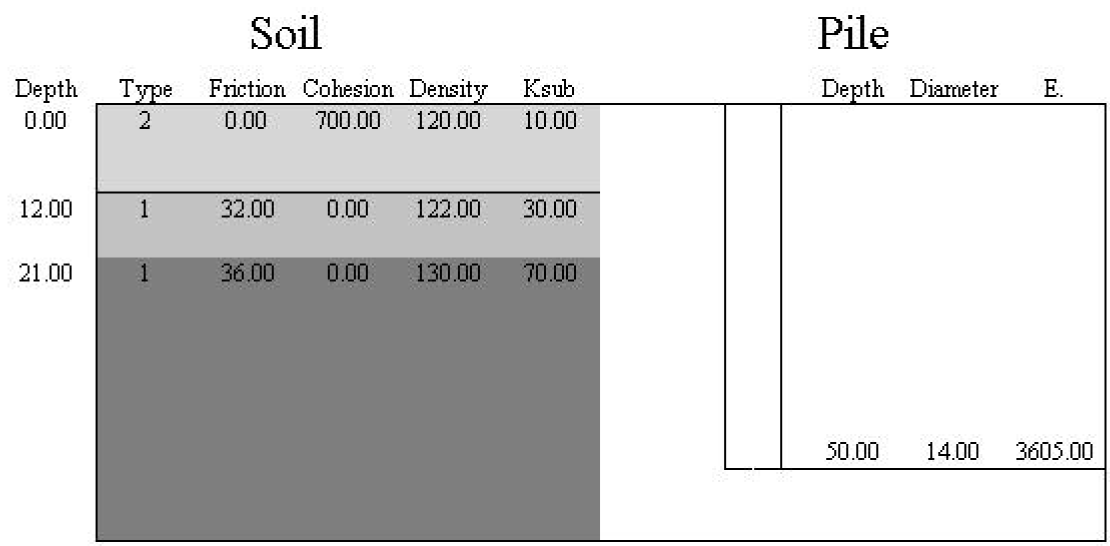
Drilled Auger Cast Pile

Information:

A 50 foot long drilled auger cast pile with a diameter of 14 inches will be constructed in the soils shown below.

Question:

Compute the allowable compression load capacity and lateral load capacitty at deflection of 0.5 inches for the free head condition.



Results:

The program shows that allowable compression load capacity at 0.5 inch deflection is 9.65 kip for the free head condition.