

UPGRADE OF AXIALLY LOADED PILE-SOIL MODELING WITH

THE IMPLEMENTATION OF LRFD DESIGN PROCEDURE

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DISCLAIMER

This report/user manual and the accompanying design software (WBUZPILE) were prepared for use by the Alabama Department of Transportation (ALDOT) technical staff. Neither the Alabama Department of Transportation nor the Principal Investigator warrants the manual, the software and results to be free of defects. All users are warned that they must have the technical training and experience to apply the information to their needs, and they must be responsible for the outcomes of such applications. Methods and techniques applicable to one locale or situation may not be suitable for others, and users are responsible for recognizing such deviations and for making appropriate adjustments. Some errors may exist in both the manual and software that may affect the results obtained. It is the user's responsibility to check results and to assure correctness and suitability of those results. This report and the accompanying design software do not constitute standard specifications, or regulations.

FORWARD

This report and the accompanying computer code (Software, WBUZPILE) describe the characterization and analysis of piles under axial loads. A combination of different formulas obtained from ALDOT long time experience along with fundamental equations of deep foundations are employed in this program to assess the axial capacity of driven piles. The report focuses on the entry of input data, interpretation of the output results and description of the employed soils and equations. In addition to sand and clay models developed by ALDOT, the report presents modeling formula for silt soils that include sandy silt and clayey silt and weathered rock (soft rock). The current program analysis allows the utilization of the LRFD approach that determines the geotechnical resistance factor based on the calibration by fitting as presented in Chapter 1. In addition to the use of varying values of safety factors and DL/LL, the program user can also use a default resistance factor of 0.71 which is based on a commonly used safety factor of 2 and DL/LL ratio of 2 as recommended by ALDOT.

The obtained results are presented numerically and graphically through the output data files and plotted graphs. Several warning messages are built in the program to avoid many of the common mistakes. It should be mentioned that the current version of the program WBUZPILE has the capability of directly uploading the input data files created earlier by the original program BUZPILE with no need for any modifications.

This report/user manual and related software have been developed by Dr. Mohamed Ashour, Mr. Amr Helal and Mr. Hamed Ardalan at the University of Alabama, Huntsville for the Alabama Department of Transportation (ALDOT) under the Research Project 930-769.

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CHAPTER 1

IMPLEMENTATION OF LRFD IN THE DESIGN OF DRIVEN PILES USING THE CALIBRATION BY FITTING

1.1 Introduction

In the Allowable Stress Design (ASD), the uncertainties or risks (errors and variations) in the calculations of loads and resistances are accounted for through one single factor of safety (FS). That factor of safety is applied to the sum of unfactored loads {Dead Load (DL), Live Load (LL),} to compare with the nominal resistance (R_n)

$$R_n \ge FS (DL + LL)$$

Unlike the ASD, the Load and Resistance Factored Design (LRFD) accounts for

- 1. the uncertainties associated with the estimated design load through the load factor (γ); and
- 2. the uncertainties associated with the estimated nominal geotechnical resistance (R_n) via the resistance factor, ϕ .

In the LRFD, the sources of uncertainties are separated to make it simpler and more rational to evaluate them (determine ϕ and γ) based on scientific methods (Abu-Hejleh et al. 2009).

The way the loads are combined in the LRFD for the strength limit and compared to resistances is significantly different from the ASD. Strength I is the most common and basic load group (no wind). The load factors (γ) for the same load type vary among the different strength groups (Strength I, II, III, IV, and V). The Strength I load factors are considered in the calibration of the geotechnical resistance factors, where the dominant loads are the Dead Load (DL, load factor 1.25) and Live Load (LL, load factor 1.75), with an average load factor of 1.4 (Abu-Hejleh et al.

2009). The load factors of the other load groups (Strength II, III, IV, and V) are selected to reflect the certainty and importance of these loads and to generate overall reliability with the loads close to that of the Strength I loads. Consequently, it is suggested the calibration of resistance factors using the Strength I Load Group be reasonable for use with other load groups.

There are two calibration methods to determine the LRFD resistance factor (ϕ).

- 1. The first method is the calibration by fitting with factors of safety of the allowable stress design (ASD) method to avoid unacceptable deviation from the past safe and satisfactory practices. With this approach, the LRFD geotechnical design results would be similar to those generated in the ASD method. This method is usually used to determine the resistance factors when a database or case histories are not available.
- 2. The second calibration method is to use the reliability analysis that would be considered when reliable/adequate number of load test data is available.

1.2 Calibration of Geotechnical Resistance Factor (φ) by Fitting to the ASD Factor of Safety (FS)

ALDOT uses in-house design method for the evaluation of the static axial capacity of driven piles based on the correlation between the SPT-N and soil properties to obtain pile tip and side ultimate resistance. With this approach, the LRFD geotechnical design results would be similar to those generated in the ASD method. This approach requires the Factor of safety (FS) of the ASD method and Strength I load factors with a load factor of 1.25 for Dead Loads (DL) and 1.75 for Live Loads (LL), as appeared in AASHTO LRFD 2010.

Fitting the geotechnical resistance factor (ϕ) with the ASD Factor of Safety (FS) is expressed as,

$$\phi = \frac{\gamma_{DL}(DL/LL) + \gamma_{LL}}{(DL/LL+1)FS}$$

1-2

 γ_{DL} = 1.25 and γ_{LL} = 1.75 where typical DL/LL ratio ranges between 1.5 to 3.

| DL/LL | Resistance Factor (\$) | | | | | | | |
|-------|------------------------|----------|----------|----------|--|--|--|--|
| | FS = 1.5 | FS = 2.0 | FS = 2.5 | FS = 3.0 | | | | |
| 1.5 | 0.97 | 0.73 | 0.58 | 0.48 | | | | |
| 2 | 0.94 | 0.71 | 0.57 | 0.47 | | | | |
| 2.5 | 0.93 | 0.70 | 0.56 | 0.46 | | | | |
| 3 | 0.92 | 0.69 | 0.55 | 0.46 | | | | |

 Table 1.1 Resistance factors fitting with different ASD factors of safety

Based on DL/LL ratio = 2 and desired Factor of Safety (FS = 2.0) as an example, the Geotechnical resistance Factor (ϕ) is calculated (0.71) and employed to obtain the Pile Factored Resistance. To facilitate the implementation of the LRFD, the computer program WBUZPILE internally employs a resistance factor (ϕ) of 0.71 as a default value in the program that has been determined based on the method of calibration by fitting to the ASD safety factor. However, the program allows the user to enter different values of DL/LL and FS to obtain different Geotechnical resistance Factor (ϕ).

CHAPTER 2

INPUT DATA

The user needs to enter the following data as shown in Fig. 2-1:

1. Number of Soil Layers:

Enter the total number of soil layers in the soil profile with maximum of 15 layers. The program does not allow the user to enter more than 15 layers.

Press Enter or click Update Screen to update the soil tables for the new soil layers.

2. Elevation of Zero Depth (ft):

Enter the elevation of the ground surface (zero, positive or negative value).

3. Table of Soil Profile and Properties:

a) Soil Type (Fig. 2-2):

The program provides five different types of soil (sand, clay, weak rock, sandy silt, clay silt). Click the appropriate type of soils.

SandClayWeathered RockSandy Silt:Use sandy silt for fine soil with plasticity index (PI) < 4</td>Clayey Silt:Use clayey silt for fine soil with plasticity index $7 \ge (PI) \ge 4$

b) Soil Description (Fig. 2-3):

The user can type up to 30 characters for soil description.

c) Depth to Bottom of Layer:

Enter a positive value for the depth of the soil layer measured from the ground surface (Not the elevation of the ground surface)

d) Blowcounts (N):

Enter the Standard Penetration Test blowcounts per foot (N) after correcting N for the hammer efficiency of 60% (N₆₀).

$$N = N_{60} = N_{field} \frac{Hammer Efficiency \%}{60\%}$$

• Use the mouse click or click Enter to move among the same soil table cells. Use the tab key to alternate between the soil and pile properties tables.

| WBuzpile | | | | | | | |
|---------------------------|----------------------------|------|---------------------------------------|------------------|-------------------------|--|---|
| e Units Profile | e LRFD | Run | Plot Results Ou | utput Files Manu | ial/Help | | |
| | | | | | | | |
| | | | | | | | |
| Project Numbe | er. | 10-2 | 45-90 | | _ | | Update Screen |
| County | | Mad | | | - | | |
| county | | Mad | ison | | | | |
| Project Title | | ALD | OT | | | | |
| | | | | | | | |
| | | 14 | | | | 201 | |
| Number of Soil | Layers | 1 | | Elevation of Z | ero Depth (ft) | 0.0 | |
| | | | | | | | |
| | | | | | | | |
| | | | 1 | | | | |
| Soil Layer | Soil | | S | Soil Discription | De | epth to Bottom | Blowcounts (N) |
| Soil Layer No. | Soil Type | 1 | s | Goil Discription | De | epth to Bottom of Layer (ft) | Blowcounts (N) Blows/ft |
| Soil Layer No. 1 | Soil Type and | | 5 | Soil Discription | De | epth to Bottom of Layer (ft) | Blowcounts (N) Blows/ft |
| Soil Layer No. 1 Sa | Soil Type and | _ | • | Goil Discription | De | epth to Bottom of Layer (ft) | Blowcounts (N) Blows/ft |
| Soil Layer No. 1 St | Soil Type and | Ŀ | <u> </u> | Goil Discription | De | epth to Bottom of Layer (ft) | Blowcounts (N) Blows/ft |
| Soil Layer No. 1 | Soil Type and | | | Goil Discription | De | epth to Bottom of Layer (ft) | Blowcounts (N) Blows/ft |
| Soil Layer No. 1 Se | Soil Type and | | . <u></u> 5 | Goil Discription | | epth to Bottom of Layer (ft) | Blowcounts (N) Blows/ft |
| Soil Layer No. 1 S | Soil Type and | | · · · · · · · · · · · · · · · · · · · | Goil Discription | | epth to Bottom of Layer (ft) | Blowcounts (N) Blows/ft |
| Soil Layer No. 1 S | Soil Type and | | Soil-Pile Perimeter | Pile End Area | Depth of Pile Tip | epth to Bottom of Layer (ft) Water Depth | Blowcounts (N) Blows/ft Pile Tip Resistance |
| Soil Layer No. 1 S | Soil Type and ype | | Soil-Pile Perimeter ft 4 670 | Pile End Area | Depth of Pile Tip ft | epth to Bottom of Layer (ft) Water Depth ft | Blowcounts (N) Blows/ft Pile Tip Resistance Every 1 ft |

Fig. 2-1 Basic image for the software initial front page

| Soil Layer | Soil | Soil Discription | Depth to Bottom | Blowcounts (N) |
|------------|---|------------------|-----------------|----------------|
| No. | Туре | | of Layer (ft) | Blows/ft |
| 1 | Sand | | | |
| | Sand Clay Weathered Rock Sandy Silt Clayey Silt | | | |

Fig. 2-2 The different types of soil employed in the software

| Number of Sc | il Layers 11 | Elevation of Zero Depth (ft) | 90.0 | | |
|--------------|--------------|------------------------------|-----------------|----------------|---|
| Soil Layer | Soil | Soil Discription | Depth to Bottom | Blowcounts (N) | |
| No. | Туре | | of Layer (ft) | Blows/ft | |
| 1 | Sand | Loose Moist Sand | 1.00 | 4 | |
| 2 | Sand | Medium Moist Sand | 5.00 | 11 | |
| 3 | Sand | Loose Moist Sand | 11.00 | 8 | |
| 4 | Sand | Medium Damp Silty Sand | 15.00 | 21 | |
| 5 | Sand | Dense Sand | 25.00 | 30 | - |

Fig. 2-3 Input soil profile and field data

4. Table of Pile Properties (Fig. 2-4):

a) Pile Type:

The user can choose the pile type from a drop-down menu that contains 11 different types of piles (most common type of piles used by ALDOT).

- 14" Solid Concrete Pile
 16" Solid Concrete Pile
 18" Solid Concrete Pile
 20" Solid Concrete Pile
 HP 10" x 42 Steel Pile
 HP 12" x 53 Steel Pile
 HP 14" x 73 Steel Pile
 24" Hollow PSPT
 30" Hollow PSPT
 36" Hollow PSPT
 New Steel Pile
 New Concrete Pile
- <u>By clicking the appropriate pile type</u>, the following pile properties of the pile section will be uploaded,

| Soil-Pile Perimeter: | Pile perimeter in contact with soils that is used to |
|----------------------|--|
| | determine the soil-pile frictional resistance along |
| | the pile side (shaft) |
| Pile End Area: | Pile tip/base area used to calculate the pile tip |
| | bearing capacity (i.e. tip resistance) |

• The user can also click "New Steel Pile" or "New Concrete Pile" option at the end of the Pile Type drop-down menu to enter new properties (Soil-Pile Perimeter and Pile End Area) for unregistered piles.

b) Depth of Pile Tip:

Enter the depth of the pile tip measured from the ground surface (i.e. the embedded length of the pile)

c) Water Depth:

Enter the depth of free water table (positive value) measured from the ground surface. If the water table is too deep, use a water depth value larger than the pile length.

d) Pile Tip Resistance:

- Check the pile tip resistance box every unit length to get the pile tip and side resistance every unit length (1 ft or 1 meter). This provides a profile for the pile side and tip resistance during the pile driving. Regardless of the value entered for the "Depth of Pile Tip", the embedded pile length (i.e. the analysis) continues down to the depth of the bottom of the last soil layer entered in the Soil Property Table.
- Uncheck the box of "Pile Tip Resistance every 1 ft" to get the pile capacity, pile tip resistance and side resistance just at the value assigned for the "Depth of Pile Tip" (not every unit length of the pile)

| Pile Type | _ | Soil-Pile Perimeter | Pile End Area | Depth of Pile Tip | Water Depth | Pile Tin Resistance |
|--|---|---------------------|---------------|-------------------|-------------|---------------------|
| | | ft | ft2 | ft | ft | Every 1 ft |
| 14" Solid Concrete Pile | • | | | | | Yes 🔽 |
| 14" Solid Concrete Pile 16" Solid Concrete Pile 18" Solid Concrete Pile 20" Solid Concrete Pile HP 10" x 42 Steel Pile HP 12" x 53 Steel Pile HP 14" x 73 Steel Pile HP 14" x 89 Steel Pile | < | | | | | |

Fig. 2-4 Pile database in the software

5. Program Features for Input Data

a) Save Input Data File:

- Click *File* on the upper menu and then *Save As* to save the input data for the first time with a specific file name. The user can choose/create any folder to save the new file (Fig. 2-5). The name of the file will appear on the left upper corner of the program window. The program saves the input data file with an extension (*.INP)
- Click *File* and then *Save* to save the data input at anytime during the process of entering data. If the user clicks *Save* before the file yet has a name assigned, the Save As window will be opened.
- The user can upload any saved input data file that was created earlier by clicking *Open File* on the *File* menu (Fig. 2-5). A new window will be opened to list all saved input data file in that folder with extension (*.INP) (Fig. 2-6).
- Click *Exit* on *File* menu to close the program

b) Units:

The program has the capability to use Imperial and SI units with the input and output data. It can also convert the SI units to Imperial ones and vise versa by clicking the desired units (**Fig. 2-7**).

| S WBuz | pile | | | | | | | | | | | |
|--|-------------|------|-------|-------|---------|--------------|-----------------------|----|---|--|---------------|---|
| File Units | Profile | LRFD | Run | Plot | Results | Output Files | Manual/Help | | | | | |
| New File Open File Save Save As | ber | | 10-24 | 15-90 | | | | | | | Update Screen | J |
| Exit | 19 | | Madi | son | | | | | | | | |
| Project | Title | | ALDO | т | | | | | | | | |
| Number | of Soil Lay | yers | 1 | - | | Elevati | on of Zero Depth (ft) | 0. | 0 | | | |

Fig. 2-5 Save and Open options in the software

| Open | | ? 🗙 |
|---|---|---|
| Look in: | 🗀 Pile | - 🗈 📸 🖛 |
| My Recent Documents Desktop My Documents | A1.INP AA.INP Aa.INP Aaa.INP Abut6.INP Bent2.INP Bent2.INP BUZ MOBILE ABUT1B IN.inp BUZ MOBILE BENT2B IN.inp BUZPILE1.INP BUZPILE2.INP BUZPILE3.INP BUZPILE3.INP | BUZPILE-4.INP Buzpile MLD MEMORIAL ABUT1.inp Buzpile SPC MEMORIAL BENT2.inp Buzpile SPC MEMORIAL BENT3.inp Buzpile SPC MEMORIAL BENT4.inp BuzpileFowIRAbut5.inp BuzpileFowIRAbut5.inp BuzpileFowIRBent3.inp BuzpileFowIRBent5.inp BuzpileFowIRBent5.inp |
| My Computer | < | |
| | File name: | ▼ Open |
| My Network Places | Files of type: Iput Data File (*.INP) | ▼ Cancel |

Fig.2-6 Open existing input data file

c) **Profile:**

Click *Profile* in the upper menu to plot the pile as embedded in the given soil layers. Plotted soil layers will be numbered from the top down listed in the Soil Property Table. The pile and values of soil layer depths below the ground surface will be plotted on the soil profile. As seen in **Fig. 2-8**, every soil type (sand, clay, ----) will have a distinctive color after selection. In addition to the table of soil properties, the user can plot the soil profile to locate any mistake in soil layer thicknesses.

| .xampte | .INP | | | | | | |
|--|---|--|--|---|---------------|--|--|
| Units Pro | file LRFD | Run | Plot Results Ou | itput Files 🛛 Manu | ıal/Help | | |
| Imperia | E . | | | | | | |
| SI | | | | | | | |
| Project Number ALPHA-####(NNN) | | | | | | Update Screen | |
| County | | Mobile | | | | | |
| Project Title | É. | Bent2 | 14in Concrete | | ar. | | |
| lumber of So | oil Layers | 5 | 1 | Elevation of Z | ero Depth (m) | 27.45 | |
| Number of Si | oil Layers | 5 | | Elevation of Z | ero Depth (m) | 27.45 | |
| lumber of So Soil Layer | oil Layers | 5 | s | Elevation of Z | ero Depth (m) | 27.45 Depth to Bottom | Blowcounts (N) |
| lumber of So Soil Layer No. | oil Layers Soil Type | 5 | s | Elevation of Z | ero Depth (m) | 27.45 Depth to Bottom of Layer (m) | Blowcounts (N) Blows/0.3m |
| lumber of So Soil Layer No. 1 | oil Layers Soil Type Sand | 5 | Loose moist sand | Elevation of Z | ero Depth (m) | 27.45 Depth to Bottom of Layer (m) 5.49 | Blowcounts (N) Blows/D.3m 4 |
| Soil Layer No. 1 2 | oil Layers Soil Type Sand Clay | 5 | Loose moist sand Medium stiff clay | Elevation of Z ioil Discription | ero Depth (m) | 27.45 Depth to Bottom of Layer (m) 5.49 12.20 | Blowcounts (N) Blows/0.3m 4 11 |
| lumber of Si Soil Layer No. 1 2 3 | oil Layers Soil Type Sandy Sandy | 5 9 9 9 9 9 9 9 9 | Loose moist sand Medium stiff clay Sandy silt soil | Elevation of Z coil Discription d (CL) | ero Depth (m) | 27.45 Depth to Bottom of Layer (m) 5.49 12.20 15.86 | Blowcounts (N) Blows/0.3m 4 11 8 |
| Soil Layer No. 1 2 3 4 | oil Layers Soil Type Sandy Sandy Clay | 5 9 9 Silt Silt | Loose moist sand Medium stiff clay Sandy silt soil Clay silt soil | Elevation of Z coil Discription d (CL) | ero Depth (m) | 27.45 Depth to Bottom of Layer (m) 5.49 12.20 15.86 21.35 | Blowcounts (N) Blows/0.3m 4 11 8 21 |
| Soil Layer No. 1 2 3 4 5 | oil Layers Soil Type Sandy Clay Sandy Clayey Weathered | 5 5 5 5 Silt Silt 6 Rock | Loose moist sand Medium stiff clay Sandy silt soil Clay silt soil Weak rock | Elevation of Z coil Discription J (CL) | ero Depth (m) | 27.45 Depth to Bottom of Layer (m) 5.49 12.20 15.86 21.35 24.40 | Blowcounts (N) Blows/0.3m 4 11 8 21 30 |
| Soil Layer No. 1 2 3 4 5 | oil Layers Soil Type Sandy Clay Sandy Clayey Weathered | 5 3 Silt Silt Rock | Loose moist sand Medium stiff clay Sandy silt soil Clay silt soil Weak rock | Elevation of Z coll Discription d (CL) | ero Depth (m) | 27.45 Depth to Bottom of Layer (m) 5.49 12.20 15.86 21.35 24.40 | Blowcounts (N) Blows/0.3m 4 11 8 21 30 |
| Soil Layer No. 1 2 3 4 5 5 | oil Layers Soil Type Sandy Clay Sandy Clayey Weathered | 5 Silt Silt Rock | Loose moist sand Medium stiff clay Sandy silt soil Clay silt soil Weak rock | Elevation of Z coll Discription (CL) Pile End Area | ero Depth (m) | 27.45 Depth to Bottom of Layer (m) 5.49 12.20 15.86 21.35 24.40 p Water Depth | Blowcounts (N) Blows/0.3m 4 11 8 21 30 Pile Tip Resistance |
| Soil Layer No. 1 2 3 4 5 5 | oil Layers Soil Type Sandy Clay Sandy Clayey Weathered | 5 Silt Silt Silt Silt Silt | Loose moist sand Medium stiff clay Sandy silt soil Clay silt soil Weak rock oil-Pile Perimeter m | Elevation of Z ioil Discription (CL) Pile End Area m2 | ero Depth (m) | 27.45 Depth to Bottom of Layer (m) 5.49 12.20 15.86 21.35 24.40 p Water Depth m | Blowcounts (N) Blows/0.3m 4 11 8 21 30 Pile Tip Resistance Every 1 m |

Fig. 2-7a Program flexibility of using SI units including unit conversion

| Example | .INP | | | | | | |
|--|--|---------------------------|--|---|----------------|---|---|
| e Units Pro | file LRFD | Run | Plot Results Ou | itput Files Manu | ıal/Help | | |
| Imperia SI | | | | | | | |
| Project Num | iber | ALPH | A-####(NNN) | | | | Update Screen |
| County | | Mobile | e | | - | | |
| Project Title | 6 | Bent2 | 14in Concrete | | | _ | |
| | | | | | | | |
| Number of So | oil Layers | 5 | | Elevation of Z | ero Depth (ft) | 90.0 | |
| Number of So Soil Layer | oil Layers Soil | 5 | s | Elevation of Z | ero Depth (ft) | 90.0 epth to Bottom | Blowcounts (N) |
| Number of So Soil Layer No. | oil Layers Soil Type | 5 | ε | Elevation of Z Goil Discription | ero Depth (ft) | 90.0 epth to Bottom of Layer (ft) | Blowcounts (N) Blows/ft |
| Number of So Soil Layer No. 1 | oil Layers Soil Type Sand | 5 | Loose Moist San | Elevation of Z Coll Discription | ero Depth (ft) | 90.0 epth to Bottom of Layer (ft) 18.00 | Blowcounts (N) Blows/ft 4 |
| Number of So Soil Layer No. 1 2 | oil Layers Soil Type Sand Clay | 5 | Loose Moist San Medium stiff clay | Elevation of Z Soil Discription d (CL) | ero Depth (ft) | 90.0 epth to Bottom of Layer (ft) 18.00 40.00 | Blowcounts (N) Blows/ft 4 11 |
| Number of So Soil Layer No. 1 2 3 | oil Layers Soil Type Sand Clay Sandy S | 5 Silt | Loose Moist San Medium stiff clay Sandy silt soil | Elevation of Z Coll Discription d (CL) | ero Depth (ft) | 90.0 epth to Bottom of Layer (ft) 18.00 40.00 52.00 | Blowcounts (N) Blows/ft 4 11 8 |
| Number of So Soil Layer No. 1 2 3 4 | oil Layers Soil Type Sand Clay Sandy S Sandy S | 5 Silt | Loose Moist San Medium stiff clay Sandy silt soil Clayey Silt soil | Elevation of Z Coll Discription d (CL) | ero Depth (ft) | 90.0 epth to Bottom of Layer (ft) 18.00 40.00 52.00 70.00 | Blowcounts (N) Blows/ft 4 11 8 21 |
| Number of So Soil Layer No. 1 2 3 4 5 | oil Layers Soil Type Sand Clay Sandy S Clayey S Weathered | 5 Silt Silt Rock | Loose Moist San Medium stiff clay Sandy silt soil Clayey Silt soil Weak rock | Elevation of Z Goil Discription d (CL) | ero Depth (ft) | 90.0 epth to Bottom of Layer (ft) 18.00 40.00 52.00 70.00 80.00 | Blowcounts (N) Blows/ft 4 11 8 21 30 |
| Number of So Soil Layer No. 1 2 3 4 5 | oil Layers Soil Type Sand Clay Sandy S Clayey S Weathered | 5 Silt Silt Rock | Loose Moist San Medium stiff clay Sandy silt soil Clayey Silt soil Weak rock | Elevation of Z Goil Discription d (CL) | ero Depth (ft) | 90.0 of Layer (ft) 18.00 40.00 52.00 70.00 80.00 | Blowcounts (N) Blows/ft 4 11 8 21 30 |
| Number of So Soil Layer No. 1 2 3 4 5 5 | oil Layers Soil Type Sand Clay Sandy S Clayey S Weathered | 5 Silt Silt Rock | Loose Moist San Medium stiff clay Sandy silt soil Clayey Silt soil Weak rock | Elevation of Z Goil Discription d (CL) Pile End Area | ero Depth (ft) | 90.0 epth to Bottom of Layer (ft) 18.00 40.00 52.00 70.00 80.00 Water Depth | Blowcounts (N) Blows/ft 4 11 8 21 30 Pile Tip Resistance |
| Number of So Soil Layer No. 1 2 3 4 5 Pile | oil Layers Soil Type Sand Clay Sandy S Clayey S Weathered | 5 Silt Silt Rock | Loose Moist San Medium stiff clay Sandy silt soil Clayey Silt soil Weak rock | Elevation of Z Goil Discription d (CL) Pile End Area ft2 | ero Depth (ft) | 90.0 epth to Bottom of Layer (ft) 18.00 40.00 52.00 70.00 80.00 Water Depth ft | Blowcounts (N) Blows/ft 4 11 8 21 30 Pile Tip Resistance Every 1 ft |

Fig. 2-7b Program flexibility of using Imperial units including unit conversion

| oject Num | | | | A real procession of the second se | | |
|------------------------------|--|---|--|---|------------------------------|-------|
| | IN ALPH | IV DEED (NNN) | | Update Screen | | |
| inty | Mobi | le | | | | |
| ject Title | Bent | 2 14in Concrete | | Pér | nt | |
| | | | | | 0 m | |
| | | | | | | |
| ber of So | I Lavers 5 | Elevation of Zero Depth (| m) 27.45 | | | |
| | i and in the | | | | | |
| | | | | | | |
| Layer | Soil | Soil Discription | Depth to Bottom | Blowcounts (N) | 5.49 m | - |
| No. | Type | 1 | of Layer (m) | Blows/0.3m | | |
| 1 | Sand | Loose moist sand | 5.49 | 4 | | |
| 2 | Clay | Medium stiff clay (CL) | 12.20 | 11 | | |
| 3 | Sandy Silt | Sandy silt soil | 15.86 | 8 | | |
| | and a local state of the local s | Alass all and | 21.35 | 21 | | |
| 4 | Clayey Sm | Clay sin son | | | | |
| 4 5 | Weathered Rock | Weak rock | 24.40 | 30 | 12.2 m | |
| 4 5 | Weathered Rock | Veak rock | 24.40 | 30 | 12.2 m | |
| 4 5 | Weathered Rock | Veak rock | 24.40 | 30 | 12.2 m - | _ |
| 4 5 Pile | Veathered Rock | Ciay sint soli Weak rock Soli-Pile Perimeter Pile End Area Depth of F | 24.40 Nile Tip Water Depth | 30 Pile Tip Resistance | 12.2 m | |
| 4 5 Pile | Veathered Rock | Viay sin son Weak rock Soli-Pile Perimeter Pile End Area Depth of F m m2 m | 24.40 Pile Tip Water Depth | 30 Pile Tip Resistance Every 1 m | 12.2 m | |
| 4 5 Pile | Type | Usy sin son Weak rock Soli-Pile Perimeter Pile End Area Depth of A m m2 m 1.424 0.126 30.5 | 24.40 Pile Tip Water Depth m 0 0.00 | 30 Pile Tip Resistance Every 1 m Yes | 12.2 m 15.86 m | |
| 4 5 Pile | Type : | View sin son Weak rock Soli-Pile Perimeter Pile End Area Depth of f m m2 m 1.424 0.126 30.5 | 24.40 Pile Tip Water Depth m 0 0.00 | 30 Pile Tip Resistance Every 1 m Yes V | 12.2 m | |
| 4 5 Pile | Type | Usy sin son Weak rock Soli-Pile Perimeter Pile End Area Depth of m m2 m 1.424 0.126 30.5 | 24.40 Pile Tip Water Depth m 0 0.00 | 30 Pile Tip Resistance Every 1 m Yes | 122m | |
| 4 5 Pile | Type | Usy sin son Weak rock Soli-Pile Perimeter Pile End Area Depth of A m m2 m 1.424 0.126 30.5 | 24.40 Nile Tip Water Depth m 0 0.00 | 30 Pile Tip Resistance Every 1 m Yet | 12.2 m | |
| 4 5 Pile | Type | View sin son Weak rock Soli-Pile Perimeter Pile End Area Depth of f m m ² m 1.424 0.126 30.5 | 24.40 Pile Tip Water Depth m 0 0.00 | 30 Pile Tip Resistance Every 1 m Yes | 122m 1586m | |
| 4 5 Pile Solid Cont | Type : | Usy sin son Weak rock Soli-Pile Perimeter Pile End Area Depth of F m m2 m 1.424 0.126 30.5 | 24.40 Pile Tip Water Depth m D 0.00 | 30 Pile Tip Resistance Every 1 m Yes v | 12.2 m | |
| 4 5 Pile | Veathered Rock | Usy sin son Weak rock Soli-Pile Perimeter Pile End Area Depth of f m m2 m 1.424 0.126 30.5 | 24.40 | 30 Pile Tip Resistance Every 1 m Yes | 122m 1536m 21.35m | |
| 4 5 Pile | Type : | Usy sin son Weak rock Soli-Pile Perimeter Pile End Area Depth of f m m2 m 1.424 0.125 30.5 | 24.40 216 Tip Water Depth m D 0.00 | 30 Pile Tip Resistance Every 1 m Yes | 12.2 m 15.86 m 21.35 m | |

Fig. 2-8a Plot of input soil profile in SI units

| at LPHA ####91800/ Update Server nty Makain nty Makain ect Title Bent2 Tim Concrete ber of Soil Layers 5 Elevation of Zero Depth (th) 90.0 at Layer Soil No. Type 1 Soid 2 Clayer Medum stift clay (CL) 40.00 3 Sandy Sitt 3 Sandy Sitt 4 Clayer Sitt 40 th 820 30.1 Weak mock 80.3 30.1 | |
|---|--|
| Interaction Part Pertor Part Dir Dir Dir Dir Layer Soil Soil Oncorption Depth to Bottom Blowcounts (N) Dir Layer Soil Soil Oncorption Depth to Bottom Blowcounts (N) 16 h Layer Soil Soil Oncorption Depth to Bottom Blows/R 100 4 1 Sand Losse Meist Sand 1000 4 100 11 3 Sandy Sitt | |
| Perez Perez title Perez er of Soil Layers 5 Elevation of Zero Depth (th) 50.0 Layers 5 Layers 6 Type 10 1 Sand 1 Sand 1 Sand 2 Clay Medium stiff clay (CL) 40.00 11 Sandy silt soil 3 Sandy silt soil 4 Clayy Weathered Back Woak rock 80 30 | |
| Christian Definition Depth to Bottom Oit er of Soil Layers 5 Elevation of Zero Depth (#) 90.0 Layer Soil Soil Discription Depth to Bottom Blowcounts (N) io. Type of Layer (#) Blowcounts (N) 18 ft 2 Clayer Medium stift clay (CL) 40.00 11 3 Sandy Silt 52.00 8 40 ft 4 Clayer Soil 700.0 21 40 ft | |
| er of Soil Layers 5 Elevation of Zero Depth (t) 50.0 | |
| er of Soil Layers 5 Elevation of Zero Depth (ft) 90.0 Layer Soil Soil Discription Depth to Bottom Blowcaurds (N) 40. Type 10. Sond Loose Meist Sand 10.00 4 2 Clay Medium stift clay (CL) 40.00 111 3 Sandy Silt Sandy silt sol 52.00 8 4 Copye Silt Soil 70.00 211 5 Wnothered Rock Weak rock 80 30 40 h | |
| Layar Soil Soil Discription Depth to Battom Blowcounts (N) 10 0. Type of Layer (N) Blows/M Blows/M 1000 4 2 Clay Medium stiff clay (CL) 4000 11 13 Sandy Silt Sandy Silt Sandy Silt 52.00 8 4 Chays Silt Soil 70.00 2.1 5 Weathered Ruck 80 30 40 h 40 h 10 <t< td=""><td></td></t<> | |
| Livyer Soil Soil Discription Depth to Bettorm Blowcaunts (N) 10 Type of Layer (t) Blows/th 1 Sand Loose Meist Sand 10:00 4 2 Clay Medium still clay (CL) 40:00 11 3 Sandy Sith Sandy Sith Sail 52:00 8 4 Clayer Sith Clayer Sith soil 70:00 21 5 Weathmed Rock 80 30 | |
| Layer Soil Soil Description Depth to Bottom Blowcaunts (N) 10 Type of Layer (%) Blowcaunts (N) 1 Sand Losse Moist Sand 1800 2 Clay Medium stiff clay (CL) 4000 3 Sandy Silt Sandy silt soil 5200 8 4 Clayey Salt Sandy Silt Sandy Silt 70.00 21 5 Weathered Rock 80 30 40 th | |
| Type of Layer (t) Blownit Sand Losse Moist Sand 1800 4 Clay Medium stiff clay (CL) 40.00 11 Sendy Stit Sandy sit soil 52.00 6 Clays Sit Sandy sit soil 70.00 2.1 Weathered Rock 80 30 40 it | |
| 1 Sand Loses Moist Sand 16:00 4 2 Clay Medium stiff clay (CL) 40:00 11 3 Sandy Sitt Sandy Sitt Sandy Sitt Sandy Sitt 4 Clays Sitt Claysy Sitt soil 70:00 21 5 Weathernd Rock 80 30 40 ft | |
| 2 Clay Medium shift Cary (CL) 40.00 11 3 Sandy Shit Sandy shit soil 5200 8 4 cbayey Shit Sandy shit soil 70.00 21 5 Weak mack 80 30 40 ft | |
| 3 Sandy Sitt Sandy Sitt | |
| Model Clayey Sift sol 70.00 21 5 Weathend Rock 80 30 | |
| s Weathend Hock Weak rack 8U 3U 40 ft | |
| | |
| | |
| Pile Type Sol Pile Permeter Pile End Area Depth of Pile Tip Water Depth Pile Tip Resistance | |
| | |
| alid Concrete Pile + 4 670 1.360 100 0.00 Yes | |
| | |
| | |
| | |
| | |
| 70 # | |

Fig. 2-8b Plot of input soil profile in Imperial units

d) LRFD:

Click *LRFD* in the upper menu to show the LRFD table parameters (**Fig. 2-9**) DL/LL and FS that was previously employed in the ASD method. The user can check the default option to use a geotechnical resistance factor (ϕ) of 0.71 as

explained in Chapter 1. The calculated ϕ will be shown on the load-depth plot after executing the program. The value of ϕ will be also printed in the output data file.

| Example | .INP | | | | | | |
|---|---|-------------------------------|---|--|------------------------------|--|--|
| le Units Pro | file LRFD | Run Pl | ot Results Output I | Files Manual/Help | | | |
| Project Num County Project Title | ıber | ALPHA-# Mobile Bent2 14 | i###(NNN) lin Concrete | | | Update Screen | |
| | | 92 | | | (<u></u>)) | | |
| Number of So | oil Layers | 5 | E | levation of Zero Depth (m) | 27.45 | | |
| Number of So | bil Layers | 5 | E Soil D | levation of Zero Depth (m) iscription | 27.45 Depth to Bottom | Blowcounts (N) | |
| Number of So Soil Layer No. | bil Layers Soil Type | 5 | E Soil D | levation of Zero Depth (m) iscription Input for Resistance | 27.45 Depth to Bottom | Blowcounts (N) Blows/0.3m | |
| Number of So Soil Layer No. 1 | oil Layers Soil Type Sand | 5 | E Soil D oose Moist Sand | levation of Zero Depth (m) iscription Input for Resistant | Depth to Bottom | Blowcounts (N) Blows/0.3m 4 | |
| Number of So Soil Layer No. 1 2 | bil Layers Soil Type Sand Clay | 5 | E Soil D oose Moist Sand 1edium stiff clay (CL) | levation of Zero Depth (m) iscription Input for Resistant DLALL FS | Depth to Bottom ce Factor | Blowcounts (N) Blows/0.3m 4 11 | |
| Number of So Soil Layer No. 1 2 3 | oil Layers Soil Type Sand Clay Sandy S | 5 L Silt S | E Soil D oose Moist Sand 1edium stiff clay (CL) iandy silt soil | levation of Zero Depth (m) iscription Input for Resistant DLAL FS 0. C | Depth to Bottom re Factor | Blowcounts (N) Blows/0.3m 4 11 8 | |
| Number of So Soil Layer No. 1 2 3 4 | oil Layers Soil Type Sand Clay Sandy S Clayey S | 5 L Silt S Silt C | E Soil D oose Moist Sand 1edium stiff clay (CL) andy silt soil layey Silt soil | levation of Zero Depth (m) iscription Input for Resistant DLAL FS 0. | Depth to Bottom ce Factor | Blowcounts (N) Blows/0.3m 4 11 8 21 | |

Fig. 2-9 LRFD parameters input to determine the geotechnical resistance factor (ϕ)

CHAPTER 3

OUTPUT DATA

1. Run:

Click *Run* to execute the program. Once the calculation process is achieved, the table shown in **Fig. 3-1** will be visible. The values of

Pile tip elevation (based on entered ground surface elevation);

Pile tip embedment below ground surface;

Pile tip <u>ultimate</u> resistance; and

Pile side <u>ultimate</u> resistance

will be displayed in the results table. This table is available when the "*Pile Tip Resistance Every Unit Length*" option is checked.

If the "*Pile Tip Resistance Every Unit Length*" option is unchecked, just the pile tip and side resistance only for the case of assigned "*Depth of Pile Tip*" is displayed (**Fig. 3-2**).

2. Plot:

As shown in **Figs. 3-3 and 3-4**, click *Plot* and choose either the *Ultimate Resistance* (pile side and tip resistance with no safety factors, **Fig. 3-3**) or *Factored Resistance* (using the LRFD resistance factored, $\phi = 0.71$, **Fig. 3-4**, given in Chapter 1). Notice that the designer should use factored loads (DL and LL), as described in Chapter 1, to compare with the plotted factored resistance.

3. Results:

Click *Results* Tab in the upper menu bar to get the input and output data formatted as shown in **Fig. 3-5**. The user can print out this file or create a pdf-file by clicking the *Print* command as shown in **Fig. 3-6**.

4. Output Files:

The input and output data is also saved in a file with the same name of the input data file with extension (*.out). Click *Output Files* tab on the upper menu bar to open the window shown in **Fig. 3-7**. The open windows display only the output data files with extension. By default, the output data files will be created in the same folder where the input data file is saved. However, the user can rename and relocate these files in any other folder.

The user can open the input and output data files with the program <u>Notepad</u> (automatically defined in the file windows) as shown in **Fig. 3-8**.

| i B | uzpile | owlRBen | t3. | inp | | | | | | | |
|-----|--------------|--------------|-----|-----------------|-------|--------------------|----------------|-------------|-------------|---------------------|----------|
| ile | Units Pr | ofile LRFD | Run | Plot Result | s Oi | utput Files - Manu | ual/Help | | | | |
| | | | | | | | | | | | |
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| | | | | | | | | | | | |
| D | roject Nu | mhor | | | | | _ | | | | |
| | тојестна | linei | ALP | HA-####(NNN) | | | | | | Update Screen | <u>۱</u> |
| c | ounty | | Mob | ilo | | | _ | | | | |
| ~ | Joung | | MOD | ile. | | | | | | | |
| Р | Project Titl | e | Ron | t3 14in Concret | • | | | | _ | | |
| 1 | | , . | Den | to 14in concrea | c | | | | _ | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| - N | lumber of S | Soil Layers | 7 | _ | | Elevation of Z | ero Depth (ft) | 91. | 0 | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| Г | Call Laws | 0.0 | _ | | | Dell Diseviation | | David | D | Discussion (b) | |
| - | SUILAYER | | | | c | Soli Discription | | Dept | | | ⊢ |
| | INO. | Type | | | | | | OT | Layer (π) | Blows/π | |
| | 1 | Sand | | Loose Mois | t San | id . | | | 2.00 | 4 | - |
| | 2 | Sand | | Medium Mo | ust S | and | | | 6.00 | 11 | _ |
| | 3 | Sand | | Loose Mois | t Sar | ıd | | | 13.00 | 8 | |
| | 4 | Sand | | Dense San | 4 | | | | 32.00 | 30 | |
| | 5 | Sand | | Very Loose | Dam | p Silty Sand | | | 56.00 | 2 | _ |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| Γ | P | ile Type | | Soil-Pile Perin | neter | Pile End Area | Depth of Pile | Tip \ | Nater Depth | Pile Tip Resistance | e 🗌 |
| | | • • | | ft | | ft2 | ft | | ft | Every 1 ft | 10 |
| 1 | 14" Solid Co | ncrete Pile | - | 4.670 | | 1.360 | 999.00 | | 0.00 | Yes | 7 |
| Ŀ | | | | | | | | _ | | | |
| | | | | | | | | | | | |
| Γ | Pile Tin | Embedment in | | Pile Canacity | | Pile Tin | Pile Side | e | | | |
| | Elev.(ft) | Ground (ft) | | (kips) | B | esistance (kips) | Resistance | - (kips) | | | |
| ľ | 90 | 1 | | 0.4 | | 03 | 01 | | | | |
| | 89 | 2 | | 2.8 | | 2.54 | 0.1 | | | | |
| | 88 | 3 | | 3.4 | | 2.54 | 0.9 | | | | |
| | 87 | 4 | - | 4 | | 2.54 | 1.5 | | | | |
| | 86 | 5 | | 4.6 | | 2.54 | 2.1 | | | | |
| | 85 | 6 | | 6.8 | | 4.14 | 2.7 | | | | |
| | 84 | 7 | | 8.2 | | 4.14 | 4 | | | | |
| | 83 | 8 | | 9.6 | | 4.14 | 5.4 | | | | |
| | 82 | 9 | | 10.9 | | 4.14 | 6.8 | | | | |

Fig. 3-1 Output data per one foot increment of pile driving after running the software

4.14

4.14

4.14

46.11

46.11

46.11

46.11

46.11

46.11

46.11

46.11

46.11

8.2

9.5

10.9 12.3

16.3

20.4

24.5

28.5

32.6

36.6

40.7

44.8

12.3

13.7

15

58.4

62.4

66.5

70.6

74.6

78.7

82.7

86.8

90.9

81

80

79

78

77

76

75

74

73

72

71 70 10

11

12

13

14

15

16

17

18

19

20 21

•

| s B | BuzpileFowlRBent3.inp | | | | | | | | | | | | | |
|------|---|-------------------------------|-------------|-----|---------|-----------|-------|----------------|--------------|---------------|--------|---------------|--------------------|---|
| File | Units | Profile | e LRFD | Run | Plot | Results | OL | itput Files | Manu | ıal/Help | | | | |
| | | | | | | | | | | | | | | |
| F | roject l | oject Number jalpha-####(NNN) | | | | | | | Update Scree | ≥n | | | | |
| 6 | County Mobile | | | | | | | | | | | | | |
| | Mobile | | | | | | | | | | | | | |
| F | Project] | Fitle | | Ben | t3 14in | Concrete | • | | | | | | | |
| Ν | Number of Soil Layers 7 Elevation of Zero Depth (ft) 91.0 | | | | | | | 11.0 | | | | | | |
| | Soil Lag | /er | Soil | | | | S | oil Discript | tion | | De | pth to Bottom | Blowcounts (N) | |
| | No. | | Туре | , | | | | | | | | of Layer (ft) | Blows/ft | |
| | 1 | | Sand | ł | Loo | ise Moist | San | d | | | | 2.00 | 4 | |
| | 2 | | Sand | ł | Me | dium Moi | st Sa | and | | | | 6.00 | 11 | |
| | 3 | | Sand | ł | Loo | ise Moist | San | d | | | | 13.00 | 8 | |
| | 4 | | Sand | ł | Der | nse Sand | | | | | | 32.00 | 30 | |
| | 5 | _ | Sand | ł | Ver | y Loose I | Dam | p Silty San | nd | | | 56.00 | 2 | |
| F | | | | | | | | | | | | | | |
| - | | Pile T | уре | | Soil-P | ile Perim | eter | Pile End | Area | Depth of Pile | Tip | Water Depth | Pile Tip Resistand | e |
| | ft | | | | ft2 | _ | tt 00 | | t | Every 1 ft | _ | | | |
| | 14'' Solid | Concre | ete Pile | _ | | 4.b/U | _ | 1.361 | J | 80 | | 0.00 | Tes | |
| | | | | | | | | | | | | | | |
| | Pile Tip | E | mbedment ir | n | Pile Ca | pacity | | Pile Tip | | Pile Side | э | | | |
| | Elev.(ft) | | Ground (ft) | | (kip | ps) | R | esistance (kij | ps) | Resistance | (kips) | | | |
| | 11 | | 80 | | 343 | 7.1 | | 45.9 | | 301.2 | | | | |

Fig. 3-2 Output data of pile capacity at specific driving depth



Fig. 3-3 Plot of the nominal axial load capacity (Diagram of pile tip/side resistance vs. depth)



Fig. 3-4 Plot of the factored axial load capacity (Diagram of pile tip/side resistance vs. depth)

| BuzpileFowlRBe | nt3.inp | | | | | | |
|---------------------------|---------------------------|--|-------------------------------|-------------------------------|---------------------------------|---------------------------|----------|
| File Units Profile LRFD | Run Plot Results O | utput Files Manual/Help | | | | | |
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| Contraction of the second | - | | | | | | |
| Project Number | ALPHA-####(NNN) | | | Update Screen | | | |
| County | Mobile | - 1 - 1 | | | | | <u> </u> |
| Project Title | Close Input/Outp Bent3 | ut Data Print | | | | | |
| | | | | | | | ^ |
| Number of Coll Laures | - | | D .1. D .1. 1 | | | | |
| Number of Son Layers | / Tree | t File Name: BuggileFord | Plie Capacity a | nalysis ***** | ***** | | |
| | Pro | iect Number: AIPHA_#####/N | NDents: Inp | | | | |
| Soil Layer Soil | Cour Depr | ity Name: Mobile | rete | | | | |
| 1 San | d Pile | type: 14 inch Solid Con vation at beginning of dr | crete Pile iving = 91.0 ft | | | | |
| 2 San | d Pile | e tip embedment = 999 ft vation at desired pile ti | p = Every 1 ft | | | | |
| 3 San 4 San | d Wate d LRFI | er table depth = 0 ft) resistance factor = 0.7 | 1 | | | | |
| 5 San | <u>d</u> | | | | | | |
| | Soi | . Layer Soil unber Description | | Soil Depth (ft) From To | Soil Total Unit Weight (pcf) | Blow-Counts (N per ft) | / |
| Pile Type | s | Loose Moist Sand | | 0.00 2.00 | 115.00 | 4.00 | - |
| | | Medium Moist San Loose Moist Sand | a | 6.00 6.00 13.00 | 115.00 | 8.00 | |
| 14" Solid Concrete Pile | | . Very Loose Danp Medium Moist San | Silty Sand | 32.00 56.00 56.00 70.00 | 115.00 | 2.00 | |
| Die Tie - Feihe derecht | | Very Stiff Moist | Gray Clay | 70.00 101.00 | 125.00 | 30.00 | |
| Elev.(it) Ground (it) | | | | | | | r r |
| 90 1 | | ************ | OUTPUT DATA *** | ****** | | | |
| 88 3 | Pi. Elev | le Tip Pile embedment 7. (ft) in Ground (ft) | Pile Capacity (kips) | Pile Tip Resistance (kips) | Pile Side Resistance (kip | os) | |
| 87 4 86 5 | | 0.00 1.00 | 0.40 | 0.30 | 0.10 | | |
| 85 6 | | 39.00 2.00 38.00 3.00 | 2.80 | 2.54 | 0.90 | | / |
| 83 8 | | 37.00 4.00 36.00 5.00 | 4.00 | 2.54 | 2.10 | | |
| 82 9 | | 35.00 6.00 34.00 7.00 | 8.20 | 4.14 | 4.00 | | |
| 80 11 79 12 | | 32.00 9.00 10.00 10.00 | 10.90 | 4.14 | 6.80 | | |
| 78 13 | | 30.00 11.00 29.00 12.00 | 13.70 | 4.14 | 9.50 | | |
| 76 15 | | 78.00 13.00 | 58.40 | 46.11 | 12.30 | | |
| 75 16 74 17 | | 76.00 15.00 75.00 16.00 | 66.50 70.60 | 46.11 | 20.40 | | |
| 73 18 | | 24.00 17.00 23.00 18.00 | 74.60 78.70 | 46.11 | 28.50 | | |
| 72 19 | | 2.00 19.00 | 82.70 86.80 | 46.11 46.11 | 36.60 | | ~ |
| 70 21 | | | | | | | |

Fig. 3-5 Input/Output data (printable file)

| Print | ? 🛛 |] | | | | |
|---|---|---|---|---|---|--|
| General Select Printer Adobe PDF CEE Office Laser | Dell Laser Printer 17 | | Update Sore | en _ | | |
| Comment: Page Range All Selection C Current Page Pages: | Print to file Preferences Find Printer | File Capacity i FowlREent2.inp ##(NNN) Concrete f driving = 90.0 ft ft e tip = Every 1 ft | analysis | ***** | ***** | |
| Pile Type S | Print Cancel 1. Loose Moist 2. Medium sti 3. Sandy silt 4. Clayey Silt 5. Weak rock | : Sand if clay (CL) soil : soil | Soil Dept From 0.00 18.00 40.00 52.00 70.00 | h (ft) To 18.00 40.00 52.00 70.00 80.00 | Soil Total Unit Weight (pcf) 115.00 120.00 115.00 125.00 125.00 | Blow-Counts (N per ft) 4.00 11.00 8.00 21.00 30.00 |
| | ********** | **** OUTPUT DATA *** | ********* | ***** | | |

Fig. 3-6 Printing the Input/output data file as pdf-file

| Buzp File Uni | bileFowlRB ts Profile LRFI | ent3.inp D Run Plot | Results Output Files | Manual/Help | | | |
|------------------|--------------------------------------|---|---------------------------|--|--|---|----------|
| Proi | 0 | | | | | lind ste Serree | 1 |
| Cour | Look in: | Pile | | . + € # . | ▲ <u>`</u> • | opune scieen | 1 |
| Proje | My Recent Documents | A1.out AA.out aaa.out | | Buzpile SPC MEMOR Buzpile SPC MEMOR Buzpile SPC MEMOR | RIAL BENT2.out RIAL BENT3.out RIAL BENT4.out | | |
| Numl | Desktop | Bent2.out Bent2B.out BUZ MOBILE | ABUT1B IN.out | BuzpileFowlRAbut6. BuzpileFowlRAbut6. BuzpileFowlRBent2. BuzpileFowlRBent3. | out out out | | |
| Soi | My Documents | BUZPILE1.ou BUZPILE3.ou BUZPILE3.ou buzpile-2.ou | IBENTZBIN.OUT It It | BuzpileFowIRBent4. | out out nt3.out .out | Blowcounts (N) Blows/ft 4 | |
| | My Computer | BUZPILE-4.0 | ut MEMORIAL ABUT1.out | 률Example-1-Report.c ■F_Creek.out | out. | 11 8 30 | |
| | Mu Network | File name: Files of type: | WBUZBLE Files (* out) | • | Open Cancel | 2 | <u> </u> |
| 14" St | Places | | C Open as read-only | , | 0.00 | Pile Tip Resistance Every 1 ft <mark>Yes /</mark> | |

Fig. 3-7 Access to the output data as a text file

| File Edit Vew Inset Format Help Image: Second Secon | BUDD7C~1 - | WordPad | | | | | | |
|---|------------------------|---|------------------------------------|--------------|---------|-------------------|-------------|---|
| D B B B B A K B B C B Image: Second Secon | File Edit View Ir | nsert Format Help | | | | | | |
| Pile Capacity Analysis ************************************ | 0 🖻 🖬 🎒 🖪 | - # * 10 🛍 い | B | | | | | |
| File Capacity Analysis ************************************ | | | | | | | | ^ |
| Input File Name: BurpileFoulEBent3.inp Project Number: ALPIA-####(NNN) Communication Sential Peterspine: Bential Peterspine: Bential Peterspi | ********** | ** Pile Capa | city Analysis | ******* | ***** | | | |
| Project Number: LlFHA-#### (NNN) County Name: Mobile Description: Bends lini Concrete Pile type: 14 inch Solid Concrete Pile Elevation at beginning of driving = 91.0 ft Pile tip embedment = 999 ft Elevation at description Soil Depth (ft) Number Soil Total Unit Blow-Counts Weight (pcf) Number (N per ft) Soil Layer Soil Soil Depth (ft) Soil Total Unit Blow-Counts Weight (pcf) Number (N per ft) Number Description From To To Weight (pcf) N(N per ft) 1. Loose Moist Sand 0.00 2.00 15.00 4.00 3. Loose Moist Sand 0.00 15.00 30.00 15.00 30.00 5. Very Locse Demp Silry Sand 22.00 56.00 115.00 30.00 6. Medium Moist Sand 55.00 70.00 101.00 125.00 30.00 700* Pile Tip Pile Embedment Pile Capacity Pile Tip Pile Side Elev. (ft) in Ground (ft) Pile Capacity Pile Tip Pile Side Elev. 100 2.54 0.20 80.00 2.000 2.60 4.14 4.00 4.00 4.00 4.00 80.00 5.00 1.100 12.70 4.14 4.00 4.00 4.00 | Input Fil | le Name: BuzpileFo | wlRBent3.inp | | | | | |
| County Name: Noble Description: Bent3 Him Concrete Pile type: 14 nuch Solid Concrete Pile Flevetion at degining of diving = 91.0 ft Pile tip embedment = 999 ft Flevetion at degining of diving = 91.0 ft Pile tip embedment = 999 ft LarDr Dresistance factor = 0.71 Soil Layer Soil Soil Cotal Unit Blow-Counts Number Description From To Weight (pcf) (N per ft) 1. Loose Hoist Sand 0.00 2.00 115.00 4.00 2. Medium Knist Sand 2.00 6.00 120.00 115.00 3. Loose Hoist Sand 3.00 125.00 30.00 5. Very Loose Demp Slity Sand 32.00 56.00 115.00 2.00 6. Medium Knist Sand 55.00 70.00 125.00 30.00 7. Very Stiff Moist Gray Clay 70.00 101.00 125.00 30.00 7. Very Stiff Moist Gray Clay 70.00 101.00 125.00 30.00 File Tip File Embedment File Capacity File Tip File Side Elev. (ft) in Ground (ft) (kips) Resistance (kips) 80.00 1.00 0.40 2.54 0.30 80.00 5.00 4.60 2.54 0.30 80.00 5.00 4.60 2.54 0.40 80.00 5.00 4.60 2.54 1.40 80.00 6.00 6.60 4.14 4.00 80.00 7.00 8.20 4.14 4.00 80.00 7.00 8.20 4.14 4.00 80.00 7.00 8.60 4.14 2.70 84.00 7.00 8.20 4.14 5.00 80.00 11.00 11.70 4.14 5.00 80.00 11.00 11.70 4.14 5.00 80.00 11.00 11.70 4.14 5.00 80.00 11.00 12.30 4.14 4.00 80.00 11.00 13.00 56.40 46.11 12.30 77.00 14.00 62.40 46.11 12.30 77.00 14.00 62.40 46.11 12.30 77.00 15.00 66.50 46.11 42.80 73.00 15.00 66.50 46.11 42.80 73.00 15.00 66.50 46.11 42.80 73.00 15.00 66.50 46.11 42.80 73.00 15.00 7.70 46.11 32.80 73.00 15.00 7.70 46.11 32.80 73.00 15.00 7.70 46.11 32.80 73.00 15.00 7.70 46.11 42.80 73.00 15.00 7.70 46.11 44.80 85.00 7.70 7.70 7.70 7.70 7.70 7.70 7.70 | Project N | Jumber: ALPHA-#### | (NNN) | | | | | |
| Pile type: 14 inch Solid Concrete Pile Elevation at beginning of driving = 91.0 ft Pile tip embedment = 999 ft Elevation at desired pile tip = Every 1 ft Water table depth = 0 ft LRPD resistance factor = 0.71 Soil Layer Soil Number Description From To User Koist Sand 0.00 2. Medium Koist Sand 2.00 6.00 4. Dense Sand 1. Loce Moist Sand 2.00 56.00 4. Dense Sand 50 Very Mode Pamp Silty Sand 2.00 56.00 6. Medium Moist Sand 2.00 115.00 700* To Pile Tip Pile Capacity 70* Very Stiff Hoist Gray Clay 700* 1.00 0.40 88.00 2.00 2.54 9.00 1.00 2.40 9.00 1.00 2.54 9.00 1.00 2.54 9.00 1.00 2.54 9.00 | County Na Descripti | ame: Mobile ion: Bent3 14in Co | ncrete | | | | | |
| Pile tip embedment = 599 ft Flevation at desired pile tip = Every 1 ft Water table depth = 0 ft IRPD resistance factor = 0.71 Soil Layer Soil Number Description From To Versistance factor = 0.71 Soil Layer Soil Number Description From To Versistance factor = 0.71 Soil Layer Soil Construction Number Description Prom To Medium Moist Sand 2.00 Soil Construction 6.00 Heidnum Moist Sand 56.00 To Very Used Pamp Silty Sand Soil O 115.00 Number Pile Tip Pile Tip Pile Embedment Pile Conduct Pile Capacity Pile Tip Pile Embedment Pile Conduct Pile Capacity Pile Tip Pile Embedment Pile Conduct Pile Capacity Pile Tip Pile Side Stool 1.60 86.00 3.00 | Pile type Elevation | e: 14 inch Solid C n at beginning of | Concrete Pile driving = 91.0 ft | ; | | | | |
| Elevation at desired pile tip = Every 1 ft Water table depth = 0 ft LFPP resistance factor = 0.71 Soil Layer Soil Sond 0.00 2.00 115.00 4.00 1. Loose Moist Sand 0.00 2.00 115.00 4.00 2. Medium Moist Sand 2.00 6.00 120.00 11.00 3. Loose Moist Band 32.00 56.00 115.00 3.00 4. Dense Sand 13.00 32.00 125.00 30.00 5. Very Loose Damp Silty Sand 32.00 56.00 115.00 2.00 6. Medium Moist Sand 56.00 70.00 120.00 16.00 7. Very Stiff Moist Gray Clay 70.00 101.00 125.00 30.00 7. Very Stiff Moist Gray Clay 70.00 101.00 125.00 30.00 7. Very Stiff Moist Gray Clay 70.00 101.00 125.00 30.00 86.00 3.00 3.40 2.54 0.30 87.00 4.00 4.00 2.54 0.30 87.00 4.00 4.00 2.54 0.30 87.00 4.00 4.00 2.54 1.50 87.00 13.00 5.00 4.01 4.14 4.00 83.00 6.00 9.60 4.14 4.2.10 84.00 7.00 8.20 4.14 4.4.00 83.00 6.00 10.90 4.14 6.80 81.00 10.00 12.30 4.14 5.00 81.00 10.00 12.30 4.14 5.00 82.00 9.00 10.90 4.14 5.80 77.00 12.00 15.00 4.611 12.30 77.00 14.00 62.40 46.11 12.30 77.00 14.00 62.40 46.11 12.30 77.00 14.00 77.70 46.11 32.60 77.00 15.00 76.60 46.11 44.50 77.00 15.00 76.60 46.11 44.50 77.00 15.00 76.70 46.11 32.60 77.00 15.00 76.70 46.11 32.60 77.00 15.00 76.70 46.11 32.60 77.00 15.00 76.70 46.11 44.50 77.00 15.00 77.70 46.11 32.60 77.00 15.00 76.70 46.11 44.50 77.00 15.00 76.70 46.11 44.50 77.00 15.00 77.70 46.11 52.50 77.00 15.00 77.70 46.11 52.50 77.00 15.00 77.70 46.11 52.50 77.00 15.00 77.70 46.11 52.50 77.00 15.00 77.70 46.11 55.50 66.00 22.00 99.00 46.11 44.80 67.00 22.00 99.00 46.11 44.80 68.00 22 | Pile tip | embedment = 999 f | it | | | | | |
| IRPD resistance factor = 0.71 Soil Layer Soil Number Description 1. Loose Moist Sand 0.00 2.00 1. Loose Moist Sand 0.00 2.00 1. Loose Moist Sand 1.00 3. Loose Moist Sand 6.00 1.00 3. Loose Moist Sand 5.00 5. Very Loose Damp Silty Sand 32.00 15.00 6. Medium Moist Sand 7. Very Stiff Moist Gray Clay 70.00 101.00 70.01 101.00 700* Pile Tip Pile Embedment Pile Capacity Pile Tip Pile Side 86.00 3.00 87.00 4.00 86.00 5.00 86.00 5.00 86.00 5.00 87.00 4.00 87.00 4.00 80.00 11.00 81.00 10.00 82.00 9.00 | Elevation Water tab | h at desired pile $f(x) = 0$ ft | tip = Every 1 ft | | | | | ≡ |
| Soil Layer Soil Description From To Weight (pcf) Soil Total Unit Blow-Counts 1. Loose Moist Sand 0.00 2.00 15.00 100 1.00 2. Medium Moist Sand 0.00 120.00 115.00 4.00 3. Loose Moist Sand 6.00 120.00 11.00 4. Pense Sand 13.00 32.00 56.00 115.00 8.00 5. Very Loose Damp Silty Sand 32.00 56.00 115.00 2.00 6. Medium Moist Sand 56.00 70.00 101.00 125.00 30.00 7. Very Stiff Moist Gray Clay 70.00 101.00 125.00 30.00 80.00 2.00 2.60 2.54 0.30 30.00 80.00 3.00 3.40 2.54 1.50 30.00 80.00 5.00 4.14 2.70 34.00 30.00 30.00 81.00 7.00 4.00 4.00 4.0 | LRFD resi | istance factor = C | .71 | | | | | |
| Soil Layer Soil Soil Depth (ft) Soil Total Unit Blow-Counts Number Description From To Weight (pcf) (N per ft) 1. Locse Moist Sand 2.00 6.00 115.00 4.00 2. Medium Moist Sand 2.00 6.00 115.00 8.00 3. Locse Moist Fand 6.00 13.00 115.00 8.00 4. Dense Sand 13.00 32.00 156.00 115.00 2.00 5. Very Locse Demp Silty Sand 32.00 10.00 120.00 16.00 7. Very Stiff Moist Gray Clay 70.00 101.00 125.00 30.00 90.00 1.00 0.40 0.30 0.10 125.00 30.00 80.00 3.00 3.40 2.54 0.10 10.00 128.00 90.00 1.00 4.00 2.54 1.10 1.60 81.00 3.00 3.40 2.54 2.10 1.60 82 | | | | | | | | |
| Number Description From To Weight (pcf) (N per ft) 1. Loose Moist Sand 0.00 2.00 115.00 4.00 2. Medium Moist Sand 2.00 6.00 120.00 11.00 3. Loose Moist Sand 6.00 13.00 325.00 30.00 5. Very Loose Damp Silty Sand 32.00 55.00 100.00 16.00 6. Medium Moist Sand 56.00 70.00 120.00 16.00 7. Very Stiff Moist Gray Clay 70.00 101.00 125.00 30.00 *00* 1.00 0.40 0.30 0.10 125.00 30.00 *00* 2.00 2.80 2.54 0.30 120.00 16.00 88.00 3.00 3.40 2.54 0.30 15.00 4.00 86.00 5.00 4.60 2.54 1.50 15.00 16.00 86.00 5.00 4.14 2.70 16.00 16.00 | Soil Laye | er Soil | | Soil Dep | th (ft) | Soil Total Unit | Blow-Counts | |
| 1. Loose Moist Sand 0.00 2.00 115.00 4.00 2. Medium Moist Sand 2.00 6.00 120.00 11.00 3. Loose Moist Sand 6.00 13.00 135.00 30.00 4. Dense Sand 13.00 32.00 125.00 30.00 5. Very Lose Damp Silty Sand 32.00 56.00 115.00 2.00 6. Medium Moist Sand 56.00 70.00 120.00 16.00 7. Very Stiff Moist Gray Clay 70.00 101.00 125.00 30.00 *00* *00* 1.00 0.40 0.30 0.10 30.00 *00* 1.00 0.40 0.30 0.10 30.00 89.00 2.00 2.54 0.30 30.00 3.40 2.54 1.50 86.00 5.00 4.60 2.54 1.50 30.00 30.00 30.00 30.00 30.00 30.00 30.00 30.00 30.00 30.00 30.00 30.00 30.00 30.00 30.00 30.00 | Number | Description | _ | From | То | Weight (pcf) | (N per ft) | |
| 2. Interlain Noise Statu 2.00 0.00 120.00 12.00 115.00 8.00 4. Dense Sand 13.00 32.00 125.00 30.00 5. Very Loose Damp Silty Sand 32.00 125.00 30.00 6. Medium Moist Sand 56.00 70.00 120.00 16.00 7. Very Stiff Moist Gray Clay 70.00 101.00 125.00 30.00 *00* *********************************** | 1. | Loose Moist Sa Medium Moist S | ind | 0.00 | 2.00 | 115.00 | 4.00 | |
| 4. Dense Sand 13.00 32.00 125.00 30.00 5. Very Loose Damp Silty Sand 32.00 56.00 115.00 2.00 6. Medium Moist Sand 56.00 70.00 120.00 16.00 7. Very Stiff Moist Gray Clay 70.00 101.00 125.00 30.00 *********************************** | 2. | Loose Moist Sa | anu Ind | 6.00 | 13.00 | 115.00 | 8.00 | |
| 5. Very Losse Pamp Silty Sand 32.00 56.00 115.00 2.00 6. Medium Moist Sand 56.00 70.00 120.00 16.00 7. Very Stiff Moist Gray Clay 70.00 101.00 125.00 30.00 *00* Pile Tip Pile Embedment Pile Capacity Pile Tip Pile Side Elev. (ft) in Ground (ft) (kips) Resistance (kips) Resistance (kips) 80.00 2.00 2.00 2.80 2.54 0.300 87.00 4.00 4.00 4.00 2.54 1.50 86.00 5.00 4.00 4.00 4.14 4.00 83.00 8.00 | 4. | Dense Sand | | 13.00 | 32.00 | 125.00 | 30.00 | |
| 6. Medium Moist Sand 56.00 70.00 120.00 16.00 7. Very Stiff Moist Gray Clay 70.00 101.00 125.00 30.00 *00* Pile Tip Pile Side Elev. (ft) in Ground (ft) (kips) Resistance (kips) Resistance (kips) 90.00 1.00 0.40 0.30 0.10 89.00 2.00 2.80 2.54 0.30 87.00 4.00 4.00 2.54 1.50 86.00 5.00 4.60 2.54 2.10 85.00 5.00 6.80 4.14 2.70 84.00 7.00 8.20 4.14 4.00 83.00 8.00 9.60 4.14 5.0 80.00 11.00 13.70 4.14 8.20 80.00 11.00 13.70 4.14 9.50 77.00 14.00 66.11 16.00 76.00 77.00 14.00 66.11 28.50 77.00 77.00 14.00 66.11 28.50 </td <td>5.</td> <td>Very Loose Dam</td> <td>p Silty Sand</td> <td>32.00</td> <td>56.00</td> <td>115.00</td> <td>2.00</td> <td></td> | 5. | Very Loose Dam | p Silty Sand | 32.00 | 56.00 | 115.00 | 2.00 | |
| 7. Very Stiff Moist Gray Clay 70.00 101.00 125.00 30.00 *00* Pile Tip Pile Side Pile Tip Pile Embedment Pile Capacity Pile Tip Pile Side Elev. (ft) in Ground (ft) (kips) Resistance (kips) Resistance (kips) 90.00 1.00 0.40 0.30 0.10 89.00 2.00 2.80 2.54 0.30 88.00 3.00 3.40 2.54 0.90 87.00 4.00 4.60 2.54 1.50 86.00 5.00 4.60 2.54 2.10 85.00 6.00 6.80 4.14 2.70 84.00 7.00 8.20 4.14 4.00 83.00 80.00 9.00 10.90 4.14 6.80 81.00 10.00 12.30 4.14 9.50 79.00 79.00 12.00 15.00 4.14 10.90 76.00 75.00 16.00 70.60 46.11 12.30 77.00 14.00 | 6. | Medium Moist S | and | 56.00 | 70.00 | 120.00 | 16.00 | _ |
| *00* Pile Tip Pile Embedment Pile Capacity Pile Tip Pile Side Elev. (tt) in Ground (ft) (kips) Resistance (kips) Resistance (kips) 90.00 1.00 0.40 0.30 0.10 89.00 2.00 2.80 2.54 0.30 88.00 3.00 3.40 2.54 0.90 87.00 4.00 4.00 2.54 1.50 86.00 5.00 4.60 2.54 2.10 85.00 6.00 6.80 4.14 2.70 84.00 7.00 8.20 4.14 4.00 82.00 9.00 10.90 4.14 5.40 82.00 9.00 10.90 4.14 5.40 82.00 9.00 10.90 4.14 10.90 79.00 12.00 15.00 4.14 10.90 79.00 12.00 15.00 46.11 12.30 77.00 14.00 62.40 46.11 2.30 77.00 14.00 62.40 46.11 2.50 | 7. | Very Stiff Moi | st Gray Clay. | 70.00 | 101.00 | 125.00 | 30.00 | |
| Pile Tip Pile Embedment Pile Capacity Pile Tip Pile Side Elev. (ft) in Ground (ft) (kips) Resistance (kips) Resistance (kips) 90.00 1.00 0.40 0.30 0.10 89.00 2.00 2.80 2.54 0.30 88.00 3.00 3.40 2.54 0.90 87.00 4.00 4.00 2.54 1.50 86.00 5.00 4.60 2.54 2.10 85.00 6.00 6.80 4.14 2.70 84.00 7.00 8.20 4.14 4.00 83.00 8.00 9.60 4.14 6.80 81.00 10.00 12.30 4.14 9.50 79.00 12.00 15.00 4.14 10.90 78.00 13.00 58.40 46.11 12.30 76.00 15.00 66.50 46.11 24.50 74.00 17.00 74.60 46.11 24.50 | *00* | | | | | | | |
| Pile Tip Pile Embedment Pile Capacity Pile Tip Pile Side Elev. (ft) in Ground (ft) (kips) Resistance (kips) Resistance (kips) 89.00 2.00 2.80 2.54 0.30 88.00 3.00 3.40 2.54 0.90 87.00 4.00 4.00 2.54 0.90 87.00 6.00 6.80 4.14 2.70 85.00 6.00 6.80 4.14 2.70 85.00 6.00 9.60 4.14 5.40 82.00 9.00 10.90 4.14 5.40 82.00 9.00 10.90 4.14 6.80 82.00 9.00 13.70 4.14 9.50 79.00 12.00 15.00 4.11 10.90 77.00 14.00 62.40 46.11 16.30 77.00 14.00 62.40 46.11 28.50 73.00 18.00 78.70 46.11 28.50 | | | | | | | | |
| Elev. (ft) in Ground (ft) (kips) Resistance (kips) Resistance (kips) 90.00 1.00 0.40 0.30 0.10 89.00 2.00 2.80 2.54 0.30 88.00 3.00 3.40 2.54 0.90 87.00 4.00 4.00 2.54 1.50 86.00 5.00 4.60 2.54 2.10 85.00 6.00 6.80 4.14 2.70 84.00 7.00 8.20 4.14 4.00 83.00 8.00 9.60 4.14 5.40 82.00 9.00 10.90 4.14 6.80 81.00 10.00 12.30 4.14 9.50 79.00 12.00 15.00 4.14 10.90 78.00 13.00 58.40 46.11 12.30 77.00 14.00 62.40 46.11 24.50 74.00 17.00 74.60 46.11 24.50 73.00 16.00 70.60 46.11 24.50 73.00 16.00 <td>Pile Tip</td> <td>Pile Embedment</td> <td>Pile Capacity</td> <td>Pile 7</td> <td>lip</td> <td>Pile Side</td> <td></td> <td></td> | Pile Tip | Pile Embedment | Pile Capacity | Pile 7 | lip | Pile Side | | |
| 90.00 1.00 0.40 0.30 0.10 89.00 2.00 2.80 2.54 0.30 88.00 3.00 3.40 2.54 0.90 87.00 4.00 4.00 2.54 1.50 86.00 5.00 4.60 2.54 2.10 85.00 6.00 6.80 4.14 2.70 84.00 7.00 8.20 4.14 4.00 83.00 8.00 9.60 4.14 5.40 82.00 9.00 10.90 4.14 6.80 81.00 10.00 12.30 4.14 9.50 79.00 12.00 15.00 4.14 10.90 78.00 13.00 58.40 46.11 12.30 77.00 14.00 62.40 46.11 20.40 75.00 16.00 70.60 46.11 20.40 74.00 17.00 74.60 46.11 32.60 71.00 20.00 86.80 46.11 40.70 70.00 12.00 9.90 46.11 </td <td>Elev. (ft)</td> <td>in Ground (ft)</td> <td>(kips)</td> <td>Resistance</td> <td>(kips)</td> <td>Resistance (kips)</td> <td></td> <td></td> | Elev. (ft) | in Ground (ft) | (kips) | Resistance | (kips) | Resistance (kips) | | |
| 89.00 2.00 2.80 2.54 0.30 88.00 3.00 3.40 2.54 0.90 87.00 4.00 2.54 1.50 86.00 5.00 4.60 2.54 2.10 85.00 6.00 6.80 4.14 2.70 84.00 7.00 8.20 4.14 4.00 83.00 8.00 9.60 4.14 5.40 82.00 9.00 10.90 4.14 6.80 80.00 11.00 12.30 4.14 9.50 79.00 12.00 15.00 4.14 10.90 78.00 13.00 58.40 46.11 12.30 76.00 15.00 66.50 46.11 20.40 75.00 16.00 70.60 46.11 28.50 73.00 18.00 78.70 46.11 32.60 71.00 21.00 90.90 46.11 48.80 69.00 22.00 94.90 46.11 48.80 69.00 22.00 94.90 46.11 4 | 90.00 | 1.00 | 0.40 | 0.30 | | 0.10 | | |
| 88.00 3.00 3.40 2.54 0.90 87.00 4.00 4.00 2.54 1.50 86.00 5.00 4.60 2.54 2.10 85.00 6.00 6.80 4.14 2.70 84.00 7.00 8.20 4.14 4.00 83.00 8.00 9.60 4.14 5.40 82.00 9.00 10.90 4.14 6.80 81.00 10.00 12.30 4.14 8.20 80.00 11.00 13.70 4.14 9.50 79.00 12.00 15.00 4.14 10.90 76.00 13.00 58.40 46.11 12.30 77.00 14.00 62.40 46.11 16.30 76.00 15.00 66.50 46.11 24.50 74.00 17.00 74.60 46.11 28.50 73.00 18.00 78.70 46.11 36.60 71.00 20.00 82.70 46.11 48.80 68.00 23.00 99.00 | 89.00 | 2.00 | 2.80 | 2.54 | | 0.30 | | |
| 87.00 4.00 4.00 2.54 1.50 86.00 5.00 4.60 2.54 2.10 85.00 6.00 6.80 4.14 2.70 84.00 7.00 8.20 4.14 4.00 83.00 8.00 9.60 4.14 5.40 82.00 9.00 10.90 4.14 6.80 81.00 10.00 12.30 4.14 8.20 80.00 11.00 13.70 4.14 10.90 79.00 12.00 15.00 4.14 10.90 78.00 13.00 58.40 46.11 12.30 77.00 14.00 62.40 46.11 16.30 76.00 15.00 66.50 46.11 24.50 73.00 18.00 78.70 46.11 28.50 73.00 18.00 78.70 46.11 32.60 71.00 20.00 86.80 46.11 40.70 70.00 21.00 90.90 46.11 48.80 69.00 22.00 94.90 | 88.00 | 3.00 | 3.40 | 2.54 | | 0.90 | | |
| 66.00 5.00 4.60 2.54 2.10 85.00 6.00 6.80 4.14 2.70 84.00 7.00 8.20 4.14 4.00 83.00 8.00 9.60 4.14 5.40 82.00 9.00 10.90 4.14 6.80 81.00 10.00 12.30 4.14 8.20 80.00 11.00 13.70 4.14 9.50 79.00 12.00 15.00 4.14 10.90 78.00 13.00 58.40 46.11 12.30 77.00 14.00 62.40 46.11 24.50 74.00 17.00 70.60 46.11 24.50 73.00 18.00 78.70 46.11 32.60 71.00 20.00 86.80 46.11 32.60 71.00 20.00 86.80 46.11 48.80 69.00 22.00 94.90 46.11 48.80 69.00 23.00 99.00 46.11 51.00 66.00 25.00 107.10 | 87.00 | 4.00 | 4.00 | 2.54 | | 1.50 | | |
| 83.00 5.00 6.00 1.11 2.10 84.00 7.00 8.20 4.14 4.00 83.00 8.00 9.60 4.14 5.40 82.00 9.00 10.90 4.14 6.80 81.00 10.00 12.30 4.14 8.20 80.00 11.00 13.70 4.14 9.50 79.00 12.00 15.00 4.14 10.90 78.00 13.00 58.40 46.11 12.30 77.00 14.00 62.40 46.11 16.30 76.00 15.00 66.50 46.11 20.40 75.00 16.00 70.60 46.11 28.50 72.00 19.00 82.70 46.11 32.60 71.00 20.00 86.80 46.11 40.70 70.00 21.00 90.90 46.11 48.80 69.00 22.00 94.90 46.11 48.80 69.00 23.00 99.90 46.11 52.90 67.00 24.00 103.10 <td>85.00</td> <td>5.00</td> <td>4.60</td> <td>2.54 2.14</td> <td></td> <td>2.10</td> <td></td> <td></td> | 85.00 | 5.00 | 4.60 | 2.54 2.14 | | 2.10 | | |
| 61100 1000 1000 1111 1100 82.00 9.00 10.90 4.14 6.80 81.00 10.00 12.30 4.14 8.20 80.00 11.00 13.70 4.14 9.50 79.00 12.00 15.00 4.14 10.90 78.00 13.00 58.40 46.11 12.30 77.00 14.00 62.40 46.11 16.30 76.00 15.00 66.50 46.11 20.40 75.00 16.00 70.60 46.11 24.50 74.00 17.00 74.60 46.11 32.60 72.00 19.00 82.70 46.11 32.60 71.00 20.00 86.80 46.11 40.70 70.00 21.00 90.90 46.11 48.80 69.00 22.00 94.90 46.11 56.90 67.00 24.00 103.10 46.11 56.90 66.00 25.00 107.10 46.11 61.00 65.00 26.00 <td< td=""><td>84.00</td><td>7.00</td><td>8.20</td><td>4.14</td><td></td><td>4.00</td><td></td><td></td></td<> | 84.00 | 7.00 | 8.20 | 4.14 | | 4.00 | | |
| 82.00 9.00 10.90 4.14 6.80 81.00 10.00 12.30 4.14 8.20 80.00 11.00 13.70 4.14 9.50 79.00 12.00 15.00 4.14 10.90 78.00 13.00 58.40 46.11 12.30 77.00 14.00 62.40 46.11 16.30 76.00 15.00 66.50 46.11 20.40 75.00 16.00 70.60 46.11 24.50 74.00 17.00 74.60 46.11 28.50 73.00 18.00 78.70 46.11 32.60 71.00 20.00 82.70 46.11 40.70 70.00 21.00 90.90 46.11 48.80 69.00 22.00 94.90 46.11 48.80 68.00 23.00 99.00 46.11 59.90 67.00 24.00 103.10 46.11 59.90 66.00 25.00 107.10 46.11 61.00 65.00 26.00 | 83.00 | 8.00 | 9.60 | 4.14 | | 5.40 | | |
| 81.00 10.00 12.30 4.14 8.20 80.00 11.00 13.70 4.14 9.50 79.00 12.00 15.00 4.14 10.90 78.00 13.00 58.40 46.11 12.30 77.00 14.00 62.40 46.11 12.30 76.00 15.00 66.50 46.11 20.40 75.00 16.00 70.60 46.11 24.50 74.00 17.00 74.60 46.11 28.50 73.00 18.00 78.70 46.11 32.60 71.00 20.00 86.80 46.11 44.80 69.00 22.00 94.90 46.11 48.80 68.00 23.00 99.00 46.11 56.90 66.00 25.00 107.10 46.11 61.00 46.11 | 82.00 | 9.00 | 10.90 | 4.14 | | 6.80 | | |
| 80.00 11.00 13.70 4.14 9.50 79.00 12.00 15.00 4.14 10.90 78.00 13.00 58.40 46.11 12.30 77.00 14.00 62.40 46.11 16.30 76.00 15.00 66.50 46.11 20.40 75.00 16.00 70.60 46.11 24.50 74.00 17.00 74.60 46.11 28.50 73.00 18.00 78.70 46.11 32.60 72.00 19.00 82.70 46.11 44.80 69.00 22.00 94.90 46.11 48.80 69.00 23.00 99.00 46.11 52.90 67.00 24.00 103.10 46.11 56.90 66.00 25.00 107.10 46.11 61.00 Image: Colored ColoredC | 81.00 | 10.00 | 12.30 | 4.14 | | 8.20 | | |
| 79.00 12.00 15.00 4.14 10.90 78.00 13.00 58.40 46.11 12.30 77.00 14.00 62.40 46.11 16.30 76.00 15.00 66.50 46.11 20.40 75.00 16.00 70.60 46.11 24.50 74.00 17.00 74.60 46.11 28.50 73.00 18.00 78.70 46.11 32.60 72.00 19.00 82.70 46.11 40.70 70.00 20.00 86.80 46.11 48.80 69.00 22.00 94.90 46.11 48.80 68.00 23.00 99.00 46.11 56.90 67.00 24.00 103.10 46.11 56.90 66.00 25.00 107.10 46.11 61.00 V | 80.00 | 11.00 | 13.70 | 4.14 | | 9.50 | | |
| 78.00 13.00 58.40 46.11 12.30 77.00 14.00 62.40 46.11 16.30 76.00 15.00 66.50 46.11 20.40 75.00 16.00 70.60 46.11 24.50 74.00 17.00 74.60 46.11 28.50 73.00 18.00 78.70 46.11 32.60 72.00 19.00 82.70 46.11 40.70 70.00 20.00 86.80 46.11 40.70 70.00 21.00 90.90 46.11 48.80 69.00 22.00 94.90 46.11 52.90 67.00 24.00 103.10 46.11 56.90 66.00 25.00 107.10 46.11 61.00 | 79.00 | 12.00 | 15.00 | 4.14 | | 10.90 | | |
| 77.00 14.00 62.40 46.11 16.30 76.00 15.00 66.50 46.11 20.40 75.00 16.00 70.60 46.11 24.50 74.00 17.00 74.60 46.11 28.50 73.00 18.00 78.70 46.11 32.60 72.00 19.00 82.70 46.11 40.70 70.00 20.00 86.80 46.11 40.70 70.00 21.00 90.90 46.11 48.80 69.00 22.00 94.90 46.11 52.90 67.00 24.00 103.10 46.11 56.90 66.00 25.00 107.10 46.11 61.00 | 78.00 | 13.00 | 58.40 | 46.11 | | 12.30 | | |
| 76.00 15.00 66.50 46.11 20.40 75.00 16.00 70.60 46.11 24.50 74.00 17.00 74.60 46.11 28.50 73.00 18.00 78.70 46.11 32.60 72.00 19.00 82.70 46.11 36.60 71.00 20.00 86.80 46.11 40.70 70.00 21.00 90.90 46.11 48.80 69.00 22.00 94.90 46.11 48.80 68.00 23.00 99.00 46.11 56.90 66.00 25.00 107.10 46.11 61.00 V | 77.00 | 14.00 | 62.40 | 46.11 | | 16.30 | | |
| 75.00 16.00 70.60 46.11 24.50 74.00 17.00 74.60 46.11 28.50 73.00 18.00 78.70 46.11 32.60 72.00 19.00 82.70 46.11 36.60 71.00 20.00 86.80 46.11 40.70 70.00 21.00 90.90 46.11 48.80 69.00 22.00 94.90 46.11 48.80 68.00 23.00 99.00 46.11 56.90 67.00 24.00 103.10 46.11 56.90 66.00 25.00 107.10 46.11 61.00 | 76.00 | 15.00 | 66.50 | 46.11 | | 20.40 | | |
| 73.00 18.00 78.70 46.11 32.60 72.00 19.00 82.70 46.11 36.60 71.00 20.00 86.80 46.11 40.70 70.00 21.00 90.90 46.11 44.80 69.00 22.00 94.90 46.11 48.80 68.00 23.00 99.00 46.11 52.90 67.00 24.00 103.10 46.11 56.90 66.00 25.00 107.10 46.11 61.00 | 75.00 | 10.00 | 70.60 | 40.11 | | 24.30 | | |
| 72.00 19.00 82.70 46.11 36.60 71.00 20.00 86.80 46.11 40.70 70.00 21.00 90.90 46.11 44.80 69.00 22.00 94.90 46.11 48.80 68.00 23.00 99.00 46.11 52.90 67.00 24.00 103.10 46.11 56.90 66.00 25.00 107.10 46.11 61.00 | 73.00 | 18 00 | 78.70 | 46 11 | | 20.30 32 60 | | |
| 71.00 20.00 86.80 46.11 40.70 70.00 21.00 90.90 46.11 44.80 69.00 22.00 94.90 46.11 48.80 68.00 23.00 99.00 46.11 52.90 67.00 24.00 103.10 46.11 56.90 66.00 25.00 107.10 46.11 61.00 | 72.00 | 19.00 | 82.70 | 46.11 | | 36.60 | | |
| 70.00 21.00 90.90 46.11 44.80 69.00 22.00 94.90 46.11 48.80 68.00 23.00 99.00 46.11 52.90 67.00 24.00 103.10 46.11 56.90 66.00 25.00 107.10 46.11 61.00 65.00 26.00 111.20 46.11 65.10 | 71.00 | 20.00 | 86.80 | 46.11 | | 40.70 | | |
| 69.00 22.00 94.90 46.11 48.80 68.00 23.00 99.00 46.11 52.90 67.00 24.00 103.10 46.11 56.90 66.00 25.00 107.10 46.11 61.00 65.00 26.00 111.20 46.11 65.10 | 70.00 | 21.00 | 90.90 | 46.11 | | 44.80 | | |
| 68.00 23.00 99.00 46.11 52.90 67.00 24.00 103.10 46.11 56.90 66.00 25.00 107.10 46.11 61.00 65.00 26.00 111.20 46.11 65.10 For Help press F1 | 69.00 | 22.00 | 94.90 | 46.11 | | 48.80 | | |
| 67.00 24.00 103.10 46.11 56.90 66.00 25.00 107.10 46.11 61.00 65.00 26.00 111.20 46.11 65.10 | 68.00 | 23.00 | 99.00 | 46.11 | | 52.90 | | |
| 66.00 25.00 107.10 46.11 61.00 | 67.00 | 24.00 | 103.10 | 46.11 | | 56.90 | | |
| For Hole proce E1 | 66.00 | 25.00 | 107.10 | 46.11 | | 61.00 | | ~ |
| | For Help, proce E1 | 26.00 | 111 20 | 46 11 | | 65 10 | | |

Fig. 3-8 Input/output data file as opened with Notepad

CHAPTER 4

SOIL MODELING

4.1. Silt Model

Fine soil with low Plasticity Index (PI) less than 7 and considerable percentage of grain size finer than 0.075 mm can be treated as silt. The user can use D_{50} (grain size of 50% finer) as a measure to identify the type of soil.

- Soil is treated as sandy silt if 5 μ m < D₅₀ < 0.075 mm and PI < 4
- Soil is treated as clayey silt if 5 μ m < D₅₀ < 0.075 mm and 4 < PI < 7
- Soil is considered as clay if PI > 7

Using D_{50} , the correlation presented by Kulhawy and Mayne, 1990 (**Fig. 4-1**) is used to convert the SPT-N (where $N = N_{60}$) to the CPT bearing resistance (q_c). The atmospheric pressure is represented by p_a. The average values of the term (q_c/p_a)/N are equal to 2.25 and 1.5 (in the program) for sandy silt and clayey silt soils, respectively.

As presented in the chart of Robertson and Kampanella, 1983 (**Fig. 4-2**), N values for sandy silt and clayey silt soil (corrected for hammer efficiency) are expected to be less than 8 and 6, respectively. If N is less than 6, soil type will be assumed to be silty clay as seen below.

The chart of soil classification based on CPT test results that were developed by Robertson and Kampanella, 1983 is utilized to determine the friction ratio (Rf) for sand silt and clayey silt soils (**Fig. 4-3**).

| $R_{f}(\%) = [\ln(q_{c}) - 2.58] / 0.742$ | sandy silt |
|---|-------------|
| R_f (%) = [ln(q_c) - 1.894] / 0.547 | clayey silt |

adhesion = $R_f q_c$

The failure to capture a positive value for the friction ratio (R_f) using the above soil classification (according to the user assigned soil type) results in the downgrade of the soil type to silty clay. Such an adjustment is undertaken internally in the program because of the conflict between the utilized SPT-N and the chosen type of silt.

 R_f (%) = [ln(q_c) - 0.817] / 0.36 silty clay

The silt effective angle of internal friction is calculated using Caquot's relationship (Caquot and Kerisel 1948) that is formulated as follows,

Friction angle (ϕ) = [ln(q_c) + 1.386] / 0.184

Pile bearing resistance = q_c

Pile tip (base) resistance = q_c (Area of pile tip)



Fig. 4-1 CPT-SPT correlation with grain size (Kulhawy and Mayne, 1990)



Fig. 4-2 Soil classification based on CPT test results (Robertson and Kampanella, 1983)



Fig. 4-3 The Use of soil classification based on CPT test results (Robertson and Kampanella, 1983)

4.2 Current Sand and Clay Models

Sand and clay properties (unit weight, friction angle) are determined using SPT-N and an empirical equation proposed by ALDOT. The suggested empirical formula was developed based on field and test data assessed by ALDOT over several years of experience.

Sand

 $\begin{array}{l} \mbox{Friction angle } (\phi) = 27.9877 + 0.0951663 \ N + 0.0137846 \ N^2 - 0.000354596 \ N^3 + 0.00000290751 \ N^4 \\ \mbox{Bearing factor} = 76103.3 - 11496.7 \ \phi + 691.929 \ \phi^2 - 20.7312 \ \phi^3 + 0.309012 \ \phi^4 - 0.00183079 \ \phi^5 \\ \end{array}$

Clay

 Cohesion (C) = 125 N (psf)
 if N < 100</td>

 Cohesion (C) = 0.375 * 144 N (psf)
 if N > 100

 Bearing factor = 9 C (psf)

4.3 Weathered Rock

Bearing factor = 0.59 (N₆₀) ^{0.8} $\overline{\sigma}_{vo}$ (psf) O'Neill and Reese (1999) N₆₀ = N corrected for the Hummer efficiency $\overline{\sigma}_{vo}$ = effective stress at the pile tip

4.4 Example:

The following example shows the effect of assuming the sandy silt and clayey silt soils to be sand and clay, respectively, for the same number of blowcounts (N). Compared to the modified soil profile (**Fig 4-5**), the use of the actual soil classification (silty soils, **Fig. 4-4**) provides larger tip resistance and less side resistance which is realistic response with silt properties (**Fig. 4-6**).

| Number of So | il Layers 3 | | Elevation of Zero Depth (ft) 94.0 | | | | | |
|---------------|-----------------------------|---------------------|-----------------------------------|-----------------|-----------------|---------------------|--|--|
| Soil Layer | Soil | Soil Discription | | | Depth to Bottom | Blowcounts (N) | | |
| No. | Туре | | | | | Blows/ft | | |
| 1 | Sand | Loose Moist San | Loose Moist Sand | | | 4 | | |
| 2 | Sandy Silt | Sandy silt | Sandy silt | | | 5 | | |
| 3 | Clayey Silt | Clayey Silt | | | 40.00 | 6 | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| Pile Type S | | Soil-Pile Perimeter | Pile End Area | Depth of Pile 1 | Fip Water Depth | Pile Tip Resistance | | |
| | | ft | ft2 | ft | ft | Every 1 ft | | |
| 14" Solid Con | <mark>crete Pile 🛛 👻</mark> | 4.670 | 1.360 | 999.00 | 0.00 | Yes 🔽 | | |

Fig. 4-4 Example 1a using actual soil profile of silty soils

| Soil Layer | Soil | S | Soil Discription | | | Blowcounts (N) |
|-----------------------------|------|---------------------|------------------|-------------------|---------------|---------------------|
| No. | Туре | | | | of Layer (ft) | Blows/ft |
| 1 | Sand | Loose Moist San | Loose Moist Sand | | | 4 |
| 2 | Sand | Sandy silt | Sandy silt | | | 5 |
| 3 | Clay | Clayey Silt | Clayey Silt | | | 6 |
| D. | - | 0 1 D1 D 1 | | | | |
| Pile Type | | Soil-Pile Perimeter | Pile End Area | Depth of Pile Tip | VVater Depth | Pile Tip Resistance |
| | | ft | ft2 | ft | ft | Every 1 ft |
| 14" Solid Concrete Pile 🔍 👻 | | 4.670 | 1.360 | 999.00 | 0.00 | Yes 🔽 |

Fig. 4-5 Example 1b using modified soil profile of sand and clay soils



Fig. 4-6 Pile tip and side resistance along actual (Fig. 4-4) and modified (Fig. 4-5) soil profile

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