Upgrade of Axially Loaded Pile-Soil Modeling with the Implementation of LRFD Design Procedure

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Objectives:

UAHuntsville
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Phase 1

- Implementation of LRFD using calibration by fitting.
- Development of silt model based on SPT-N
- Upgrade the current computer program BuzPile to be a window-based software with graphic-user interface (WBuzPile)

Phase 2

- Evaluation of the LRFD resistance factor (ϕ) based on reliability analysis
- Dividing the State of Alabama into geological regions based on soil profile
- Calibration of ALDOT existing design method using adequate number of static load tests.

Phase 3

- Implementation of LRFD service limit (serviceability)

Calibration by Fitting to the ASD Method Factor of Safety

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

- 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

- Fitting the geotechnical resistance factor **(φ)** with the ASD Factor of Safety

γ_{DL} = 1.25 and γ_{LL} = 1.75 where typical DD/LL ratio ranges between 1.5 to 3 and γ_{ave} of 1.4 can be also used

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

For DL/LL = 2

FS	1.5	2.0	2.5	3.0	3.5	4.0
φ	0.94	0.71	0.57	0.47	0.4	0.35

For DL/LL = 1.5

FS	1.5	2.0	2.5	3.0	3.5	4.0
φ	0.97	0.73	0.58	0.48	0.41	0.36

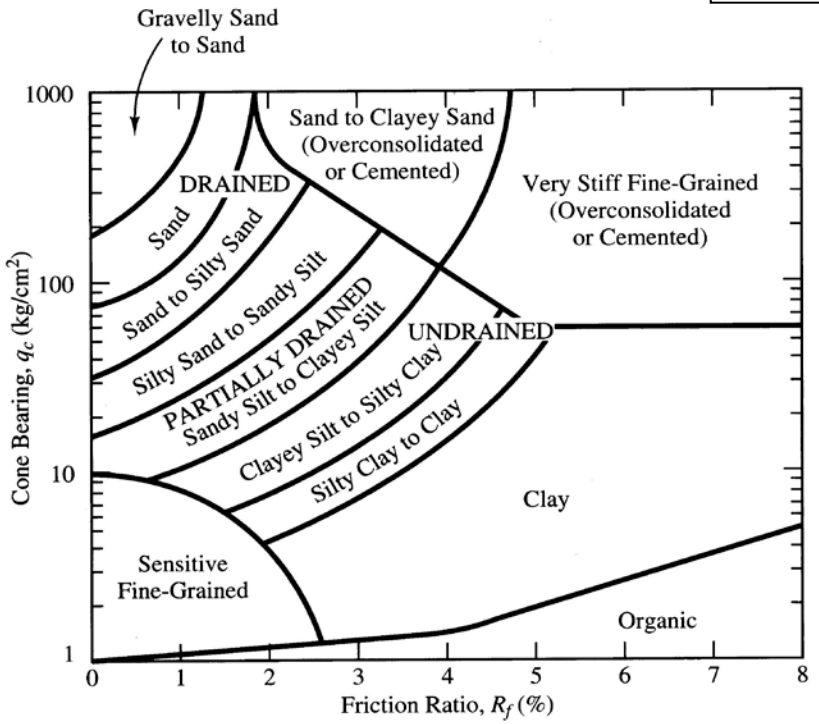
Based on DL/LL ratio and desired Factor of Safety (FS = 2.0),
the Geotechnical Resistance Factor (φ) is calculated and employed to obtain the Pile Factored Resistance as implemented in the program WBUZPILE.

SILTY SOIL MODEL

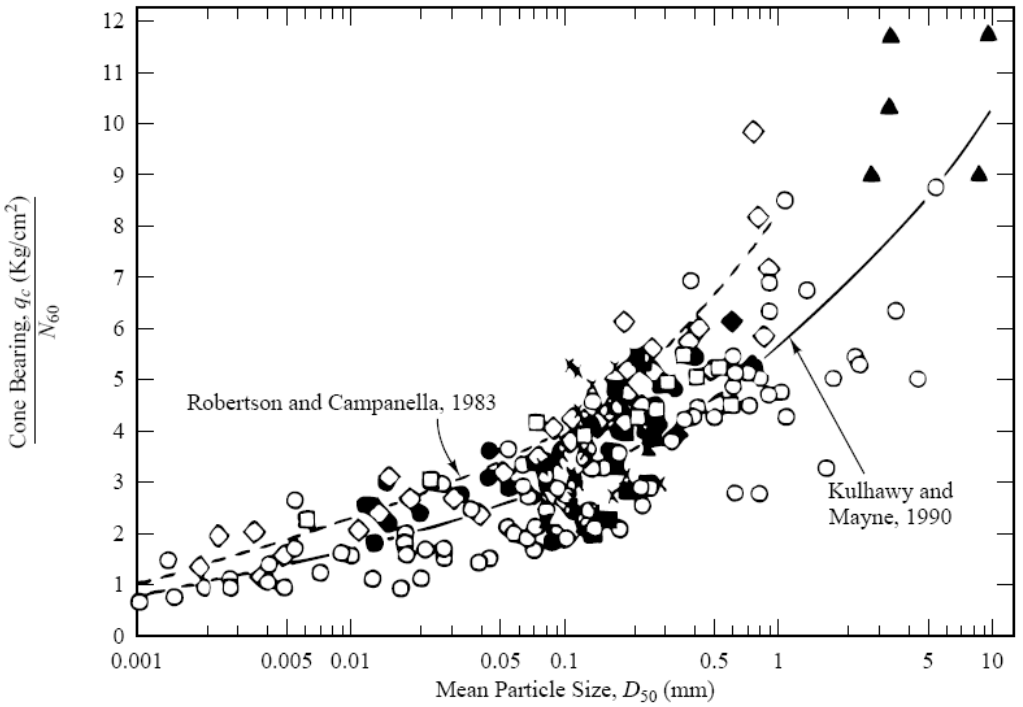
Sandy Silt
PI < 5

Clayey Silt
12 > PI > 5

(C and φ)



Classification of soil based on CPT test results (Robertsonand Campanella, 1983).



Correlation between q_c/N_{60} and the mean grain size, D_{50}. (Kulhawy and Mayne, 1990)

PROGRAM DEMONSTRATION

CURRENT EVALUATION OF φ HAS THE FOLLOWING LIMITATIONS:

1. Pile type (H-Pile, Steel pipe pile, Pre-stressed pile) is not accounted
2. Local regional geology is not considered
3. No consideration of actual bias in the variables
4. No information of failure probability (reliability index β)
5. No consideration of service limit state.

PHASE II

RESISTANCE FACTOR CALIBERATION BASED ON RELIABILITY ANALYSIS

1. The state of Alabama local geology will be divided into regions according to dominant types of soils

2. The resistance factor evaluation is established based on the static pile load test which is a reliable method (static method, dynamic analysis method and dynamic formula)

3. A bias factor (λ) is developed using adequate number of static load tests (available and planned tests using different pile types installed in different regions)

4. Three types of piles (H-Pile, steel pipe pile and pre-stressed concrete piles) will be used to test and calibrate the in-house design method

5. Establish a targeted reliability index (βT) for substructure design between 2.3 and 3.5.

RESISTANCE FACTOR BASED ON RELIABILITY ANALYSIS

A. Fitting using First Order Second Moment (FOSM) method

$$\phi = \frac{\lambda_R \sum \gamma_i Q_i \sqrt{\left(1+COV_Q^2\right)/\left(1+COV_R^2\right)}}{\overline{Q}\exp\left[\beta_T \sqrt{\ln\left[\left(1+\mathrm{COV}_Q^2\right)\left(1+\mathrm{COV}_R^2\right)\right]}\right]}$$

λ_R is the bias of resistance,

COV are the coefficients of variations of resistance (R) and load (Q),

γ_i are the LRFD load factors and

β_T is the target reliability index.

Calculated φ provides the factored static resistance

B. OR Fitting using First Order Reliability Method (FORM) with Monte Carlo Simulation

This method is used when test data indicates distributions which are not Normal or Lognormal, which is most often the case.

OUTCOME

- Window-based, user-friendly software with graphic-interface for pile design (LRFD)
- Well calibrated design method (i.e. significant cost saving)
- Evaluation of the efficiency of the applied (calibrated) method
- LRFD guidelines for axially loaded piles
- Pile-Load settlement model (serviceability)

ACKNOWLEDGEMENT

1. Alabama Department of Transportation
2. Buddy Cox, Kaye Chancellor Davis and David Dunlap

BUZPILE3.INP

File Profile Run Results Plot Output Files Help

Project Number BR-015(510)

County Bridge in Lee County

Project Title Abutment 1

Update Screen

Number of Soil Layers 3

Elevation of Zero Depth (ft) 603

Soil Layer No.	Soil Type	Soil Discription	Depth to Bottom of Layer (ft)	Total Unit Wt. pcf	Blowcounts (N) Blows/ft
1	Clay	Soft Damp Silty sandy clay	4.6		3
2	Clay	Very Dense Weathered Gneiss	10.3		70
3	Sand	Hard Gneiss	16.5		2000

Pile Type	Soil-Pile Perimeter	Pile End Area	Depth of Pile Tip	Water Depth	Pile Tip Resistance
	ft	ft2	ft	ft	Every 1 ft
16" Solid Concrete Pile	5.33	1.78	999	999	Yes

BUZPILE3.INP

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Print

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3	Clay	Hard Gneiss	16.5		2000

Sand
Clay
Rock
Sandy Silt
Clayey Silt

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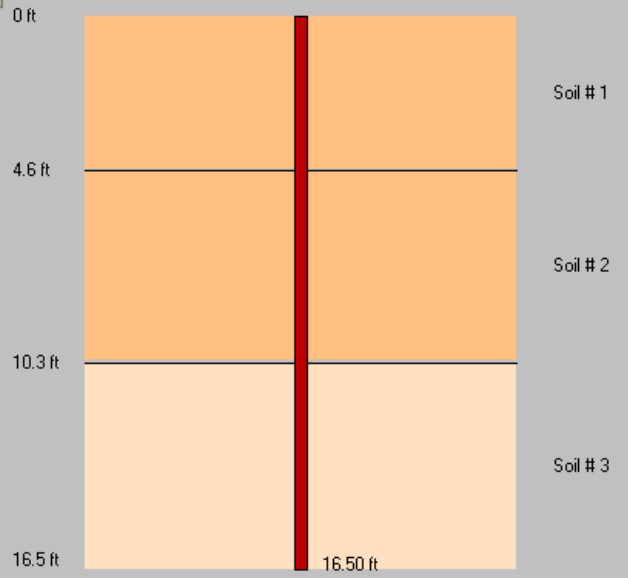

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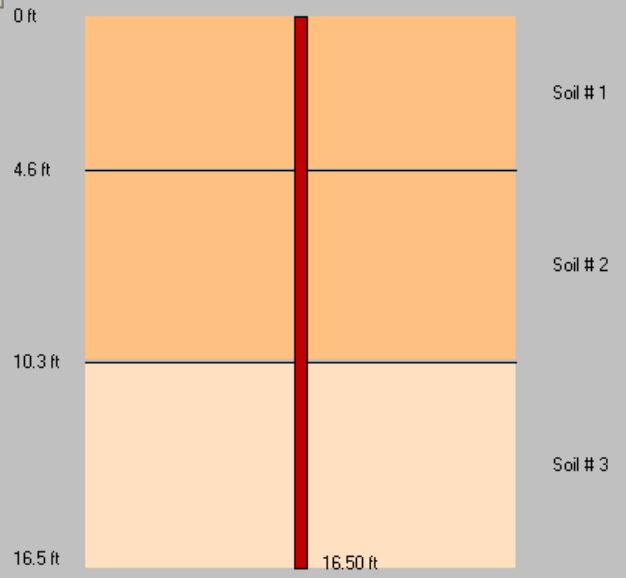
16" Solid Concrete Pile	5.33	1.78	999	999	Yes

16" Solid Concrete Pile
18" Solid Concrete Pile
20" Solid Concrete Pile
AP 10" x 42 Steel Pile
HP 12" x 53 Steel Pile
HP 14" x 73 Steel Pile
HP 14" x 89 Steel Pile
24" Hollow PSPT



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Pile Tip Elev.(ft)	Embedment in Ground (ft)	Pile Capacity (kips)	Pile Tip Resistance (kips)	Pile Side Resistance (kips)
602	1	8	6.01	2
601	2	10.1	6.01	4.1
600	3	12.1	6.01	6.1
599	4	14.1	6.01	8.1
598	5	153	140.18	12.8
597	6	161.7	140.18	21.5
596	7	170.3	140.18	30.2
595	8	179	140.18	38.8

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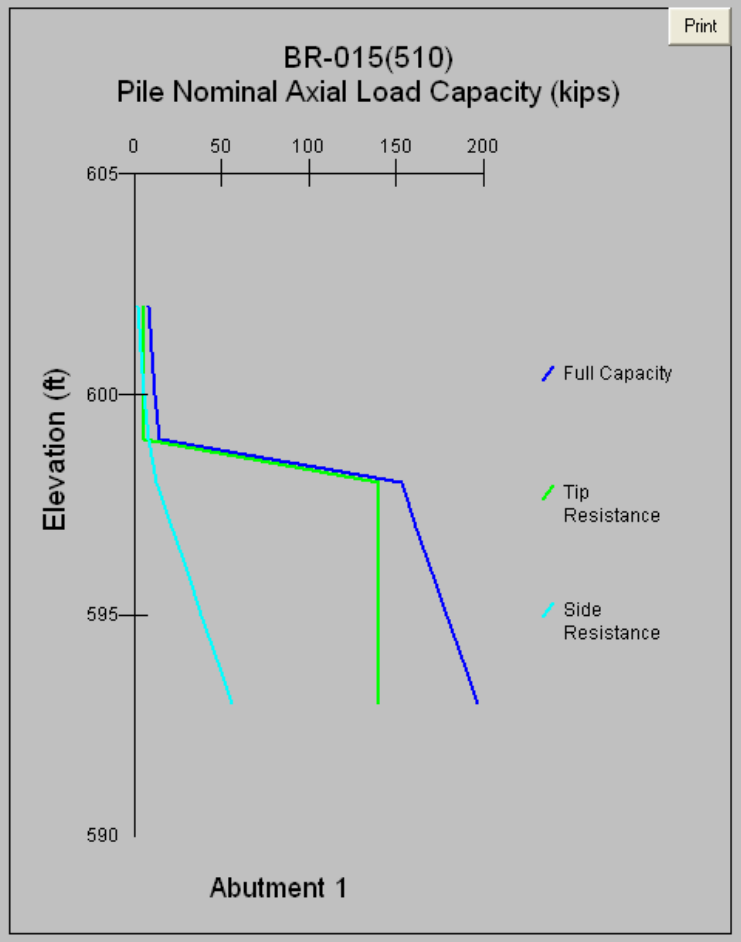

BUZPILE3.INP

File Profile Run Results Plot Output Files Help

- Ultimate Resistance
- Factored Resistance

Project Number BR-015(510)

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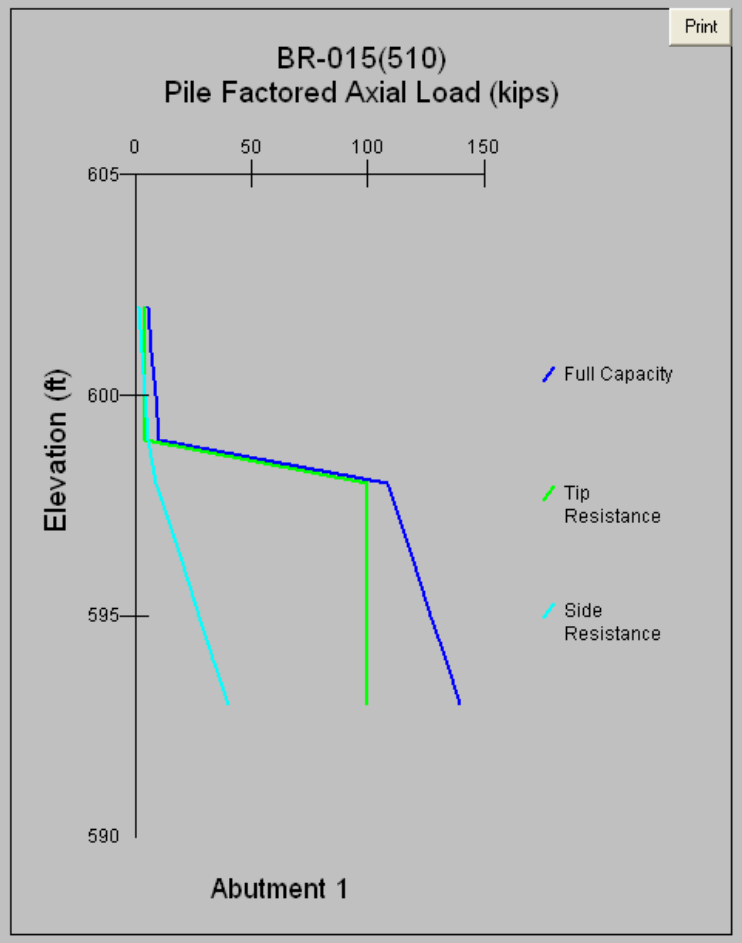
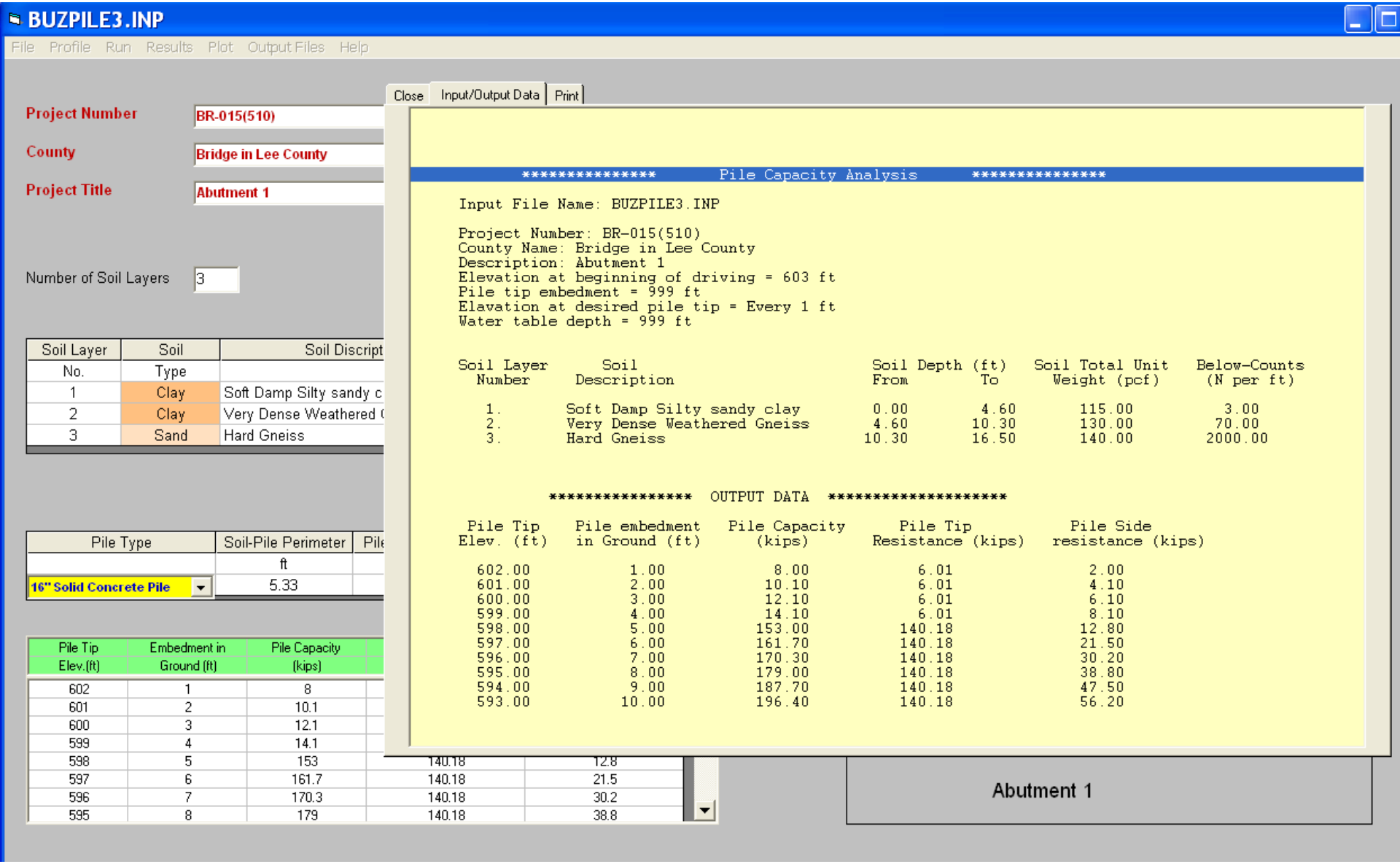
596	7	170.3	140.18	30.2
595	8	179	140.18	38.8

Print




BUZPILE3.INP
File Profile Run Results Plot Output Files Help
Project Number
BR-015(510)
County
Bridge in Lee County
Project Title
Abutment 1
Number of Soil Layers
3
Soil Layer No.
Soil Type
Soil Discript
1 Clay Soft Damp Silty sandy c
2 Clay Very Dense Weathered
3 Sand Hard Gneiss
Pile Type
Soil-Pile Perimeter
ft
16" Solid Concrete Pile
5.33
Pile Tip Elev.(ft)
Embedment in Ground (ft)
Pile Capacity (kips)
602 1 8
601 2 10.1
600 3 12.1
599 4 14.1
598 5 153 140.18 12.8
597 6 161.7 140.18 21.5
596 7 170.3 140.18 30.2
595 8 179 140.18 38.8
Close
Input/Output Data
Print
********** Pile Capacity Analysis **********
Input File Name: BUZPILE3.INP
Project Number: BR-015(510)
County Name: Bridge in Lee County
Description: Abutment 1
Elevation at beginning of driving = 603 ft
Pile tip embedment = 999 ft
Elavation at desired pile tip = Every 1 ft
Water table depth = 999 ft
Soil Layer Number
Soil Description
Soil Depth (ft) From To
Soil Total Unit Weight (pcf)
Below-Counts (N per ft)
1. Soft Damp Silty sandy clay 0.00 4.60 115.00 3.00
2. Very Dense Weathered Gneiss 4.60 10.30 130.00 70.00
3. Hard Gneiss 10.30 16.50 140.00 2000.00
********** OUTPUT DATA **********
Pile Tip Elev. (ft)
Pile embedment in Ground (ft)
Pile Capacity (kips)
Pile Tip Resistance (kips)
Pile Side resistance (kips)
602.00 1.00 8.00 6.01 2.00
601.00 2.00 10.10 6.01 4.10
600.00 3.00 12.10 6.01 6.10
599.00 4.00 14.10 6.01 8.10
598.00 5.00 153.00 140.18 12.80
597.00 6.00 161.70 140.18 21.50
596.00 7.00 170.30 140.18 30.20
595.00 8.00 179.00 140.18 38.80
594.00 9.00 187.70 140.18 47.50
593.00 10.00 196.40 140.18 56.20
Abutment 1