User’s Guide for SHAFTSPT
F.C. Townsend

Intro: SHAFTSPT is a windows program marketed by the BSI, Civil & Coastal Engr. Dept, University of Florida, 352-392-9537 X 1514. The demo version furnished is good for 30 runs. SHAFTSPT is a combination of SHAFT 98, which uses the FHWA O’Neill & Reese method for drilled shafts and intermediate geomaterials, and SPT97, which is the FDOT version for driven piles. The program is design such that the SPT boring log only is entered once, and either shafts or piles can be analyzed.

SPT97 Example

SPT 97 Uniform Sand (N=15) Example

<table>
<thead>
<tr>
<th>Depth</th>
<th>N</th>
<th>ST</th>
</tr>
</thead>
<tbody>
<tr>
<td>40 ft</td>
<td>15</td>
<td>3</td>
</tr>
<tr>
<td>20 ft</td>
<td>15</td>
<td>3</td>
</tr>
<tr>
<td>30 ft</td>
<td>15</td>
<td>3</td>
</tr>
<tr>
<td>50 ft</td>
<td>15</td>
<td>3</td>
</tr>
<tr>
<td>55 ft</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Opening screen
Units = English, Type = Pile
Unit wt. = 150 pcf,
Section = Square (psc)
Click – Insert Pile
Single, L=40ft, W=24”

Click boring log icon in Toolbar
Boring Log Screen
Click “Insert Layer”
Depths = 0 to 50 ft
Soil Type = 3 (sand)
SPT N = 15 blows
Click OK
Note: Last entry doesn’t = 0
As for old SPT97

Main Screen
Click “Cap. Report”

Results

Pile Capacity

Estimated Davisson capacity = 155.20(tons)
Allowed pile capacity = 77.50(tons)
Ultimate pile capacity = 283.20(tons)
SPT 97 Uniform Sand (N=15) Example

<table>
<thead>
<tr>
<th>Depth</th>
<th>N</th>
<th>ST</th>
</tr>
</thead>
<tbody>
<tr>
<td>40 ft</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sand ST=3</td>
<td>0</td>
<td>15</td>
</tr>
<tr>
<td>N = 15 blows</td>
<td>20</td>
<td>15</td>
</tr>
<tr>
<td>2 ft x 2 ft</td>
<td>30</td>
<td>15</td>
</tr>
<tr>
<td>50</td>
<td>15</td>
<td>3</td>
</tr>
<tr>
<td>55</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

**F. Bearing Capacity**

- **8 B above**: \(40 - 8(2) = 24\) ft
- **3.5 B below**: \(40 + 3.5(2) = 47\) ft

**Elev** | **N** | **q_t (tsf)** for sand (ST = 3) **q_t = 3.2N/3 = 3.2(15)/3 = 16tsf**
--- | --- | ---
24 | 15 | 16
40 | 15 | 16
    Ave[AQPTA] = 2(16)/2 = 16tsf
    Ave = (16 +16)/2=16tsf
40 | 15 | 16
74 | 15 | 16

Check depth of embedment to see if correction required: \(D_e = 9B = 9(2)=18 < D_a = 40\); **NO correction required**.

- **Maximum BC = 16tsf (2x2) = 64T**
- **Corrected CMAXB (no correction) = 64T**

**E. Skin Friction Capacity**

- **A. Skin friction above bearing layer = 0 (air)**
- **B. Ultimate skin friction in bearing layer (note: “trick” @ elva = 0 N=15, uniform distribution.)**

\[ f_s = 0.019N = 0.019(15) = 0.285 \text{ tsf} \]

- **C. Ultimate SFBL = 0.285(2x4)(40ft) = 91.2T** Since uniform no corrections required.

**G. Pile Capacity**

- Estimated Davisson (USF + CMAXB) = \(91.2^T + 64^T = 155.2^T\) (310^k)
- **Allowable = Davisson ÷ 2 = 155.2^T / 2 = 77.6^T**
- **Ultimate (for driving) USF + 3(CMAXB) = 91.2^T + 3(64^T) = 283.6^T**

**Deformation @ Davisson**

- Offset \((x) = 0.15 + B/120 = 0.15 + 24”/120 = 0.35”\)
- \(PL = \frac{310.4^T(40\times12)}{24^2(4415ksi)} = 0.058”\)
- \(\therefore \delta = 0.35” + 0.058” = 0.41” @ 310^k\)
To design a range of pile Lengths and widths, Click “Insert Range” Range 20 to 40 ft long in increments of 5ft. Click “Graph cap.”

SHAFT98 Example

**CLAYS:**

**Example File:** Clay1.dat

1. Multi Layer Clay with Casing

   ![Diagram of multi layer clay with casing]

   - **N = 8,**
     - $\gamma = 100 \text{ pcf}$,
     - $q_c = 16 \text{ tsf}$

   - **N = 12,**
     - $\gamma = 100 \text{ pcf}$, $q_c = 30 \text{ tsf}$

Graphics screen
Opening Screen: Drilled Shaft
Units = English
Water Table = deep
R% = 0.0
Insert Shaft"
Case = 6ft, L = 40ft,
Diam =36”, Bell L = 0.0ft
Bell Diam = 36”

Click Boring Log Icon
In upper toolbar to get
Boring log.

Boring Log Screen
Ground Surface = 0.0ft
C_u Calcs = CPT (Lower Left)
Click “Insert Layer”
Depth ST γ CPT
0 1(clay) 100pcf 16tsf
20 1 100 16
20 1 100 30
40 1 100 40
50 1 100 50

Rock Friction – Not included

Click “OK” to return to main menu
For results

Results show

Cap = 293.15T @ 0.3"
APPENDIX A - Examples

CLAYS:
Example File: Clay1.dat

2. Multi Layer Clay with Casing

3. Multi Layer Clay with Casing B > 75"

\[ N = 8, \quad \gamma_c = 100 \text{pcf}, \quad q_c = 16 \text{tsf} \]

\[ N = 12, \quad \gamma_c = 100 \text{pcf}, \quad q_c = 30 \text{tsf} \]

\[
c = \frac{q_c - \sigma_0}{15}
\]

Clay Layer # 1 : 
\[ c = \frac{16 \times 2000 - 10 \times 100}{15} = 2066.67 \text{ psf} \ (1.0333 \text{ tsf}) \]

Clay Layer # 2 : 
\[ c = \frac{30 \times 2000 - 30 \times 100}{15} = 3800 \text{ psf} \ (1.90 \text{ tsf}) \]

Clay Layer # 2 Tip : 
\[ c = \frac{30 \times 2000 - 40 \times 100}{15} = 3733.3 \text{ psf} \ (1.867 \text{ tsf}) \]

1. **Multi Layer Clay with Casing**: Full Capacity (40 ft Shaft)
   
a) Skin Friction:
   \[ Q_s = \pi \times 3.0 \times \left[ (20' - 6') \times (0.55 \times 1.033) + (20' - 3') \times (0.55 \times 1.9) \right] \]
   \[ = 9.4248 \times \left[ 7.9567 + 17.765 \right] \]
   \[ = 242.42 \text{ Tons} \]

b) End Bearing:
   \[ Q_b = q_b \times \frac{\pi b^2}{4} \]
\[ q_b = N_e C_u \], \quad N_e = 6.0 \left[ 1 + 0.2 \frac{40}{3} \right] = 22 \quad > \quad 9 \quad (use \quad 9) \]

\[ Q_b = (9 \times 1.867 \text{tsf}) \frac{\pi \times 3^2}{4} = 118.75 \text{Tons} \]

c) Total Capacity = Skin Friction + End Bearing

\[
= 242.42 + 118.75 = 361.17 \text{Tons (ultimate)}
\]

d) Calculation of Skin Friction:

\[
\begin{array}{c}
\text{Settlement: } S = (i) 0.3'' \quad \text{and} \quad (ii) S = 3.0'' \\
Q_s = 242.42^T, \quad Q_b = 118.75^T, \quad Q_T = 361.17^T
\end{array}
\]

\[ Q_T @ 0.3'' = 234.70 + 58.60 = 293.30 \text{T} \]
For range of shaft lengths
Click “Insert Range”
Min L = 20ft Max L = 40ft
Increment = 2ft.
Click “Cap. Graph”

Graphical Results

Example: Sand overlying Rock (IGM) Socket

<table>
<thead>
<tr>
<th>Depth</th>
<th>N</th>
<th>ST</th>
<th>(q_u)</th>
<th>(q_t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>15</td>
<td>3</td>
<td>10tsf</td>
<td>1.0tsf</td>
</tr>
<tr>
<td>5'</td>
<td>15</td>
<td>3</td>
<td>10tsf</td>
<td>1.0tsf</td>
</tr>
<tr>
<td>10'</td>
<td>15</td>
<td>3</td>
<td>10tsf</td>
<td>1.0tsf</td>
</tr>
<tr>
<td>15'</td>
<td>15</td>
<td>3</td>
<td>10tsf</td>
<td>1.0tsf</td>
</tr>
<tr>
<td>20'</td>
<td>15</td>
<td>3</td>
<td>10tsf</td>
<td>1.0tsf</td>
</tr>
<tr>
<td>25'</td>
<td>15</td>
<td>3</td>
<td>10tsf</td>
<td>1.0tsf</td>
</tr>
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<td>30'</td>
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<td>50'</td>
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</tr>
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<td>60'</td>
<td>4</td>
<td></td>
<td>10tsf</td>
<td>1.0tsf</td>
</tr>
<tr>
<td>65'</td>
<td>4</td>
<td></td>
<td>10tsf</td>
<td>1.0tsf</td>
</tr>
</tbody>
</table>

Diam = 36-in
SAND N=15
ST=3
\(\gamma = 100\text{pcf}\)

ROCK
\(q_u = 10\text{tsf}\)
\(q_t = 1.0\text{tsf}\)
\(q_b = 0.5\text{tsf}\)
\(E_m = 115q_u\)
Opening Screen:
Units = English
Type = Drilled Shaft
\( \gamma_c = 130 \text{pcf}, \text{slump}=6.89" \)
\( E_c = 57,000(5000\text{psi})^{1/2} = 4030 \)
Click “Insert Shaft”
\( L = 45\text{ft}, D=36" \)

Click “Boring Log” Icon
In top toolbar

Enter Boring Log Data
Depth ST N \( q_u \) \( q_t \)
0 3 15 100
40 3 15 100
40 4 10 1
65 4 10 1

Check “Use Default values”
Depth \( q_b \) \( E_m \) RQD Socket
40 5 default 1.0 0
65 5 default 1.0 0

\( q_b \) is not default, but \( \frac{1}{2} q_u \)
\( E_m \) is 115 \( q_u \times 2/144 \)
RQD = 1.0, no reduction
Socket = 0 = smooth sides

McVay’s Friction
\[ = \frac{1}{2} \sqrt{q_u} \sqrt{q_t} \]
Click “OK”
Set R% = 0.1
Click “Cap. Report”

Results

Case 5) – Shaft in rock under sand with smooth socket
(Example file: 5shaftsandsmoothrocksocket.spc)

36” diameter

\[ \gamma_c = 130 \text{pcf} \quad E_c = 4030 \text{ksi} \]

<table>
<thead>
<tr>
<th>Depth</th>
<th>N</th>
<th>ST</th>
<th>q_u</th>
<th>q_t</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>15</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5'</td>
<td>15</td>
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<tr>
<td>10'</td>
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<td>15'</td>
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<td>25'</td>
<td>15</td>
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<td>30'</td>
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<td>35'</td>
<td>15</td>
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<td>40'</td>
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<td></td>
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<tr>
<td>40'+</td>
<td>4</td>
<td>10tsf</td>
<td>1.0tsf</td>
<td></td>
</tr>
<tr>
<td>45'</td>
<td>4</td>
<td>10tsf</td>
<td>1.0tsf</td>
<td></td>
</tr>
<tr>
<td>50'</td>
<td>4</td>
<td>10tsf</td>
<td>1.0tsf</td>
<td></td>
</tr>
<tr>
<td>55'</td>
<td>4</td>
<td>10tsf</td>
<td>1.0tsf</td>
<td></td>
</tr>
<tr>
<td>60'</td>
<td>4</td>
<td>10tsf</td>
<td>1.0tsf</td>
<td></td>
</tr>
<tr>
<td>65'</td>
<td>4</td>
<td>10tsf</td>
<td>1.0tsf</td>
<td></td>
</tr>
</tbody>
</table>

End Bearing

User defined \( q_b = \frac{1}{2} q_u = \frac{1}{2} (10 \text{tsf}) = 5 \text{tsf} \)
Total End Bearing

\[ Q_T = q_T \times A_b = 5.0 \text{tsf} \times \pi \left( \frac{3 \text{ft}}{2} \right)^2 = 35.343 \text{tons} \]

Skin Friction

For soil type 3, sand, skin friction is:

\[ z = 0 \text{ to } 5 \text{ ft} \]
\[ Q_s = \pi \int_0^5 (1.2)(100)zdz \]
\[ Q_s = \pi \left[ 3 \times \left( \frac{z^2}{2} \right) \right]_0^5 \]
\[ Q_s = 14137.167 \text{lbs} = 7.069 \text{tons} \]

\[ z = 5 \text{ to } 40 \text{ ft} \]
\[ Q_s = \pi \int_5^{40} (1.5 - 0.135\sqrt{z})(100)zdz \]
\[ Q_s = \pi \left[ 3 \times \left( \frac{150z - 13.5z^{3/2}}{3} \right) \right]_5^{40} \]
\[ Q_s = 615964.30 \text{lbs} - 14825.18 = 601139.12 \text{lbs} = 300.570 \text{tons} \]

Skin friction in sand layer = 7.069 tons + 300.570 tons = 307.639 tons

For soil type 4 skin friction based on McVay et al. (1992):

\[ f_{su} = \frac{1}{2} \sqrt{q_u} \sqrt{q_t} = \frac{1}{2} \sqrt{10 \text{tsf}} \sqrt{1.0 \text{tsf}} = 1.581 \text{tsf} \]
\[ Q_S = f_{su} \pi D L = 1.581 \text{tsf} \pi \times 3 \text{ft} \times 5 \text{ft} = 74.509 \text{tons} \]

Total skin friction = 307.639 tons + 74.509 tons = 382.148 tons

**Total Shaft Capacity**

Shaft Capacity 35.343 tons + 382.148 tons = 417.491 tons

**Settlement**

FHWA IGM Calculations: (Note: Must enter values for E_c, slump, and E_m)

\[ E_m = 115 \quad q_0 = 115 \times (10.0 \text{tsf}) = 1150 \text{tsf} \]

\[ \Omega = 1.14 \left( \frac{L}{D} \right)^{1/2} - 0.05 \left( \left\{ \frac{L}{D} \right\}^{1/2} - 1 \right) \log \left( \frac{E_c}{E_m} \right) - 0.44 \]

\[ \Omega = 1.14(1.667)^{1/2} - 0.05(1.667^{1/2} - 1) \log \left( \frac{288000 \text{tsf}}{1150 \text{tsf}} \right) - 0.44 = 0.99679 \]

\[ \Gamma = 0.37 \left( \frac{L}{D} \right)^{1/2} - 0.15 \left( \left\{ \frac{L}{D} \right\}^{1/2} - 1 \right) \log \left( \frac{E_c}{E_m} \right) + 0.13 \]

\[ \Gamma = 0.37(1.667)^{1/2} - 0.15(1.667^{1/2} - 1) \log \left( \frac{288000 \text{tsf}}{1150 \text{tsf}} \right) + 0.13 = 0.50282 \]

\[ \frac{\theta}{w} = \frac{E_m \Omega}{\pi L \Gamma f_{su}}; \quad f_{su} = \frac{1}{2} \sqrt{q_u \sqrt{q_t}} \]

\[ \frac{\theta}{w} = \frac{1150 \text{tsf} \times 0.99679}{\pi \times 5 \text{ft} \times 0.50282 \times (1.581 \text{tsf})} = 91.799 \text{ ft}^{-1} \]

\[ \Lambda = 0.0134 \times \frac{(\frac{L}{D})}{(\frac{L}{D} + 1)} \left( \frac{200 \left[ \sqrt{\frac{L}{D}} \Omega \right] [1 + \frac{L}{D}]^{0.67}}{\pi L \Gamma} \right) \]

\[ \Lambda = 0.0134 \times (1150 \text{tsf}) \left( \frac{1.667}{2.667} \right) \left( \frac{200 \left[ \sqrt{1.667} - 0.99769 \right] [1 + 1.667]^{0.67}}{\pi \times 5 \text{ft} \times 0.50282} \right) = 71.354 \text{tsf}^{-0.67} \]
Determine $n$ for deformation criteria (figure 4) \( q_u = \frac{10.0 \text{tsf}}{1.044272 \text{tsf}^2} = 9.576 \)

\[
\frac{E_m}{\sigma_n} = M \gamma_c Z_c; \quad \text{Since} \quad Z_c = 40 + \frac{5}{2} = 42.5 \text{ft}
\]

For a slump = 7in, $M$ (table 4) = 0.65

\[
\therefore \sigma_n = 0.65 \times 130 \text{pcf} \times 42.5 \text{ft} = 3591 \text{ psf} = 1.796 \text{tsf}
\]

\[
\therefore \frac{E_m}{\sigma_n} = \frac{1150 \text{tsf}}{1.796 \text{tsf}} = 640.312 \quad \therefore n \approx 0.4655
\]

Select values of ‘w’ for calculating

\[
Q_1 = \pi D L \theta f_{su} + \frac{\pi D^2}{4} q_b \quad \text{for} \quad \theta < n \quad ; \quad q_b = \Lambda w^{0.67}
\]

\[
Q_1 = \pi D L k f_{su} + \frac{\pi D^2}{4} q_b \quad \text{for} \quad \theta > n
\]

Let \( w = 0.036 \text{in} = 0.003 \text{ ft} \); \( \theta / w = 91.799 \text{ ft}^{-1} \),

\[
\therefore \theta = 91.799 \text{ft}^{-1} \times 0.003 \text{ft} = 0.2754 < n = 0.4655
\]

\[
Q_1 = \pi \times 3 \text{ ft} \times 5 \text{ ft} \times 0.2754 \times (1.581 \text{tsf}) + \frac{\pi \times (3 \text{ ft})^2}{4} \times 71.354 \text{tsf} \times ft^{0.67} \times (0.003 \text{ ft})^{0.67}
\]

\[
= 20.51 \text{tons} + 10.29 \text{tons}
\]

\[
= 30.808 \text{ tons}
\]

Sand Layer Above

Load Corresponding to $R = 0.1\%$ carried in skin friction:

\[
\text{For } R \leq 0.908333 \quad \frac{f_s}{f_{s\text{max}}} = -2.16R^4 + 6.34R^3 - 7.36R^2 + 4.15R
\]

\[
\frac{f_s}{f_{s\text{max}}} = -2.16(0.1)^4 + 6.34(0.1)^3 - 7.36(0.1)^2 + 4.15(0.1) = 0.3475
\]

\[
Q_s = (0.3475)307.639 \text{tons} = 106.905 \text{tons}
\]
Total load at R=0.1  
30.808 tons + 106.905 tons = 137.712 tons

Let w = 0.216 in = 0.018 ft.; θ / w = 91.799 ft⁻¹,

∴ θ = 91.799 ft⁻¹ * 0.018 ft = 1.652 > n = 0.4655

\[
k = n + \frac{(\theta - n)(1 - n)}{(\theta - 2n + 1)} = 0.4655 + \frac{(1.652 - 0.4655)(1 - 0.4655)}{(1.652 - 2(0.4655) + 1)} = 0.8334
\]

\[
Q_t = \pi * 3 ft * 5 ft * 0.8334 * (1.581 tsf) + \frac{\pi * (3 ft)^2}{4} * 71.354 tsf * ft^{-0.67} * (0.018 ft)^{0.67}
\]

= 62.091 tons + 34.18 tons

= 96.27 tons

Sand Layer Above

Load Corresponding to R = 0.6% carried in skin friction:

For \( R \leq 0.90833 \)

\[
\frac{f_s}{f_{s_{max}}} = -2.16 R^4 + 6.34 R^3 - 7.36 R^2 + 4.15 R
\]

\[
\frac{f_s}{f_{s_{max}}} = -2.16(0.6)^4 + 6.34(0.6)^3 - 7.36(0.6)^2 + 4.15(0.6) = 0.9781
\]

\[Q_s = (0.9299)307.639 tons = 286.12 tons\]

Total load at R=0.6  
96.27 tons + 286.12 tons = 382.39 tons

Let w = 0.360 in = 0.030 ft.; θ / w = 91.799 ft⁻¹,

∴ θ = 91.799 ft⁻¹ * 0.030 ft = 2.754 > n = 0.39

\[
k = n + \frac{(\theta - n)(1 - n)}{(\theta - 2n + 1)} = 0.4655 + \frac{(2.754 - 0.4655)(1 - 0.4655)}{(2.754 - 2(0.4655) + 1)} = 0.8988
\]

\[
Q_t = \pi * 3 ft * 5 ft * 0.8988 * (1.581 tsf) + \frac{\pi * (3 f)^2}{4} * 71.354 tsf * ft^{-0.67} * 0.030 ft^{0.67}
\]

= 66.96 tons + 48.13 tons

= 115.09 tons
Sand Layer Above

Load Corresponding to $R = 1.0\%$ carried in skin friction:

For $R \leq 0.908333 \quad \frac{f_s}{f_{S_{\text{max}}}} = -2.16R^4 + 6.34R^3 - 7.36R^2 + 4.15R$

\[ \frac{f_s}{f_{S_{\text{max}}}} = -2.16(1.0)^4 + 6.34(1.0)^3 - 7.36(1.0)^2 + 4.15(1.0) = 0.9781 \]

$Q_S = (0.9781)307.639\text{tons} = 300.952\text{tons}$

Total load at $R=1.0 \quad 115.09\text{tons} + 300.952\text{tons} = 416.05\text{tons}$