

Cone Penetration Test (CPT) Interpretation

Gregg uses a proprietary CPT interpretation and plotting software. The software takes the CPT data and performs basic interpretation in terms of soil behavior type (SBT) and various geotechnical parameters using current published empirical correlations based on the comprehensive review by Lunne, Robertson and Powell (1997). The interpretation is presented in tabular format using MS Excel. The interpretations are presented only as a guide for geotechnical use and should be carefully reviewed. Gregg does not warranty the correctness or the applicability of any of the geotechnical parameters interpreted by the software and does not assume any liability for any use of the results in any design or review. The user should be fully aware of the techniques and limitations of any method used in the software.

The following provides a summary of the methods used for the interpretation. Many of the empirical correlations to estimate geotechnical parameters have constants that have a range of values depending on soil type, geologic origin and other factors. The software uses 'default' values that have been selected to provide, in general, conservatively low estimates of the various geotechnical parameters.

Input:

- 1 Units for display (Imperial or metric) (atm. pressure, $p_a = 0.96$ tsf or 0.1 MPa)
- 2 Depth interval to average results (ft or m). Data are collected at either 0.02 or 0.05m and can be averaged every 1, 3 or 5 intervals.
- 3 Elevation of ground surface (ft or m)
- 4 Depth to water table, z_w (ft or m) – input required
- 5 Net area ratio for cone, a (default to 0.80)
- 6 Relative Density constant, C_{Dr} (default to 350)
- 7 Young's modulus number for sands, α (default to 5)
- 8 Small strain shear modulus number
 - a. for sands, S_G (default to 180 for SBT_n 5, 6, 7)
 - b. for clays, C_G (default to 50 for SBT_n 1, 2, 3 & 4)
- 9 Undrained shear strength cone factor for clays, N_{kt} (default to 15)
- 10 Over Consolidation ratio number, k_{ocr} (default to 0.3)
- 11 Unit weight of water, (default to $\gamma_w = 62.4$ lb/ft³ or 9.81 kN/m³)

Column

- 1 Depth, z , (m) – CPT data is collected in meters
- 2 Depth (ft)
- 3 Cone resistance, q_c (tsf or MPa)
- 4 Sleeve resistance, f_s (tsf or MPa)
- 5 Penetration pore pressure, u (psi or MPa), measured behind the cone (i.e. u_2)
- 6 Other – any additional data
- 7 Total cone resistance, q_t (tsf or MPa) $q_t = q_c + u(1-a)$

8	Friction Ratio, R_f (%)	$R_f = (f_s/q_t) \times 100\%$
9	Soil Behavior Type (non-normalized), SBT	see note
10	Unit weight, γ (pcf or kN/m^3)	based on SBT, see note
11	Total overburden stress, σ_v (tsf)	$\sigma_{vo} = \sigma z$
12	In-situ pore pressure, u_o (tsf)	$u_o = \gamma_w (z - z_w)$
13	Effective overburden stress, σ'_{vo} (tsf)	$\sigma'_{vo} = \sigma_{vo} - u_o$
14	Normalized cone resistance, Q_{tn}	$Q_{tn} = (q_t - \sigma_{vo}) / \sigma'_{vo}$
15	Normalized friction ratio, F_r (%)	$F_r = f_s / (q_t - \sigma_{vo}) \times 100\%$
16	Normalized Pore Pressure ratio, B_q	$B_q = u - u_o / (q_t - \sigma_{vo})$
17	Soil Behavior Type (normalized), SBT_n	see note
18	SBT_n Index, I_c	see note
19	Normalized Cone resistance, Q_{tn} (n varies with I_c)	see note
20	Estimated permeability, k_{SBT} (cm/sec or ft/sec)	see note
21	Equivalent SPT N_{60} , blows/ft	see note
22	Equivalent SPT $(N_1)_{60}$ blows/ft	see note
23	Estimated Relative Density, D_r , (%)	see note
24	Estimated Friction Angle, ϕ' , (degrees)	see note
25	Estimated Young's modulus, E_s (tsf)	see note
26	Estimated small strain Shear modulus, G_o (tsf)	see note
27	Estimated Undrained shear strength, s_u (tsf)	see note
28	Estimated Undrained strength ratio	s_u/σ'_v
29	Estimated Over Consolidation ratio, OCR	see note

Notes:

- 1 Soil Behavior Type (non-normalized), SBT (Lunne et al., 1997 and table below)
- 2 Unit weight, γ either constant at 119 pcf or based on Non-normalized SBT (Lunne et al., 1997 and table below)
- 3 Soil Behavior Type (Normalized), SBT_n Lunne et al. (1997)
- 4 SBT_n Index, I_c $I_c = ((3.47 - \log Q_{tn})^2 + (\log F_r + 1.22)^2)^{0.5}$
- 5 Normalized Cone resistance, Q_{tn} (n varies with I_c)

$Q_{tn} = ((q_t - \sigma_{vo})/pa) (pa/(\sigma'_{vo})^n)$ and recalculate I_c , then iterate:

When $I_c < 1.64$, $n = 0.5$ (clean sand)
 When $I_c > 3.30$, $n = 1.0$ (clays)
 When $1.64 < I_c < 3.30$, $n = (I_c - 1.64)0.3 + 0.5$
 Iterate until the change in n , $\Delta n < 0.01$

6 Estimated permeability, k_{SBT} based on Normalized SBT_n (Lunne et al., 1997 and table below)

7 Equivalent SPT N_{60} , blows/ft Lunne et al. (1997)

$$\frac{(q_t/p_a)}{N_{60}} = 8.5 \left(1 - \frac{I_c}{4.6} \right)$$

8 Equivalent SPT $(N_1)_{60}$ blows/ft $(N_1)_{60} = N_{60} C_N$
 where $C_N = (p_a/\sigma'_{vo})^{0.5}$

9 Relative Density, D_r , (%) $D_r^2 = Q_{tn} / C_{Dr}$
 Only SBT_n 5, 6, 7 & 8 Show 'N/A' in zones 1, 2, 3, 4 & 9

10 Friction Angle, ϕ' , (degrees) $\tan \phi' = \frac{1}{2.68} \left[\log \left(\frac{q_c}{\sigma'_{vo}} \right) + 0.29 \right]$
 Only SBT_n 5, 6, 7 & 8 Show 'N/A' in zones 1, 2, 3, 4 & 9

11 Young's modulus, E_s $E_s = \alpha q_t$
 Only SBT_n 5, 6, 7 & 8 Show 'N/A' in zones 1, 2, 3, 4 & 9

12 Small strain shear modulus, G_o
 a. $G_o = S_G (q_t \sigma'_{vo} p_a)^{1/3}$ For SBT_n 5, 6, 7
 b. $G_o = C_G q_t$ For SBT_n 1, 2, 3 & 4
 Show 'N/A' in zones 8 & 9

13 Undrained shear strength, s_u $s_u = (q_t - \sigma_{vo}) / N_{kt}$
 Only SBT_n 1, 2, 3, 4 & 9 Show 'N/A' in zones 5, 6, 7 & 8

14 Over Consolidation ratio, OCR $\text{OCR} = k_{ocr} Q_{t1}$
 Only SBT_n 1, 2, 3, 4 & 9 Show 'N/A' in zones 5, 6, 7 & 8

The following updated and simplified SBT descriptions have been used in the software:

SBT Zones

- 1 sensitive fine grained
- 2 organic soil
- 3 clay
- 4 clay & silty clay
- 5 clay & silty clay
- 6 sandy silt & clayey silt

SBT_n Zones

- 1 sensitive fine grained
- 2 organic soil
- 3 clay
- 4 clay & silty clay



7	silty sand & sandy silt	5	silty sand & sandy silt
8	sand & silty sand	6	sand & silty sand
9	sand		
10	sand	7	sand
11	very dense/stiff soil*	8	very dense/stiff soil*
12	very dense/stiff soil*	9	very dense/stiff soil*

*heavily overconsolidated and/or cemented

Track when soils fall with zones of same description and print that description (i.e. if soils fall only within SBT zones 4 & 5, print 'clays & silty clays')

Estimated Permeability (see Lunne et al., 1997)

SBT _n	Permeability (ft/sec)	(m/sec)
1	3×10^{-8}	1×10^{-8}
2	3×10^{-7}	1×10^{-7}
3	1×10^{-9}	3×10^{-10}
4	3×10^{-8}	1×10^{-8}
5	3×10^{-6}	1×10^{-6}
6	3×10^{-4}	1×10^{-4}
7	3×10^{-2}	1×10^{-2}
8	3×10^{-6}	1×10^{-6}
9	1×10^{-8}	3×10^{-9}

Estimated Unit Weight (see Lunne et al., 1997)

SBT	Approximate Unit Weight (lb/ft ³)	(kN/m ³)
1	111.4	17.5
2	79.6	12.5
3	111.4	17.5
4	114.6	18.0
5	114.6	18.0
6	114.6	18.0
7	117.8	18.5
8	120.9	19.0
9	124.1	19.5
10	127.3	20.0
11	130.5	20.5
12	120.9	19.0