DEEP FOUNDATIONS

Dr. Youssef Gomaa Youssef

1. CLEAN SANDS - ϕ' only

The skin friction term

(LATERAL STRESS) x FRICTION COEFFICIENT

$$f_s = (K_s \sigma'_{v_o})(\tan\delta)$$

KULHAWY (1984) – sand parameters

Pile Type	$\frac{K_s}{K_o}$	$\frac{\delta}{\phi'}$
Bored piles	0.7 to 1	1
Displacement piles		*see below*
- precast concrete	0.75 to 2	0.8 to 1
- smooth steel	0.75 to 2	0.5 to 0.7

END BEARING, f_b

Analogous to the surcharge term in bearing capacity analysis

$$f_b = (\sigma'_{vb_o})(N_q)$$

N_q for Piles in Sand

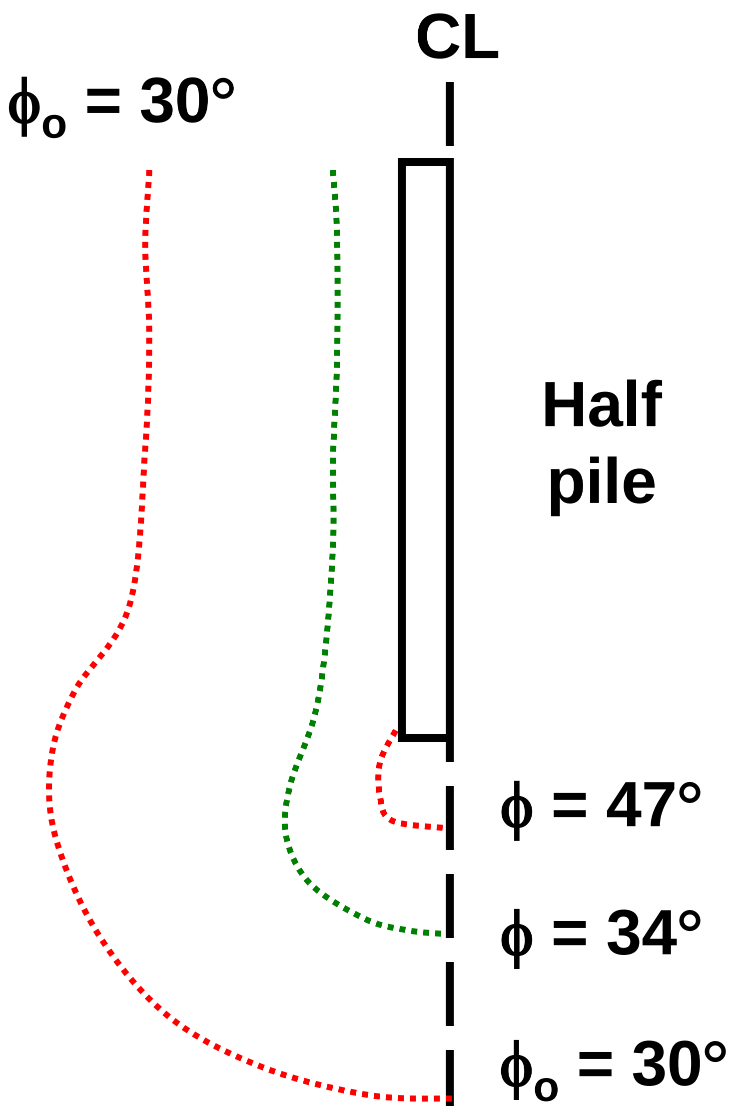
N_q = fn (density *&* method of construction)

Driven piling increases I_D and ϕ', **locally**

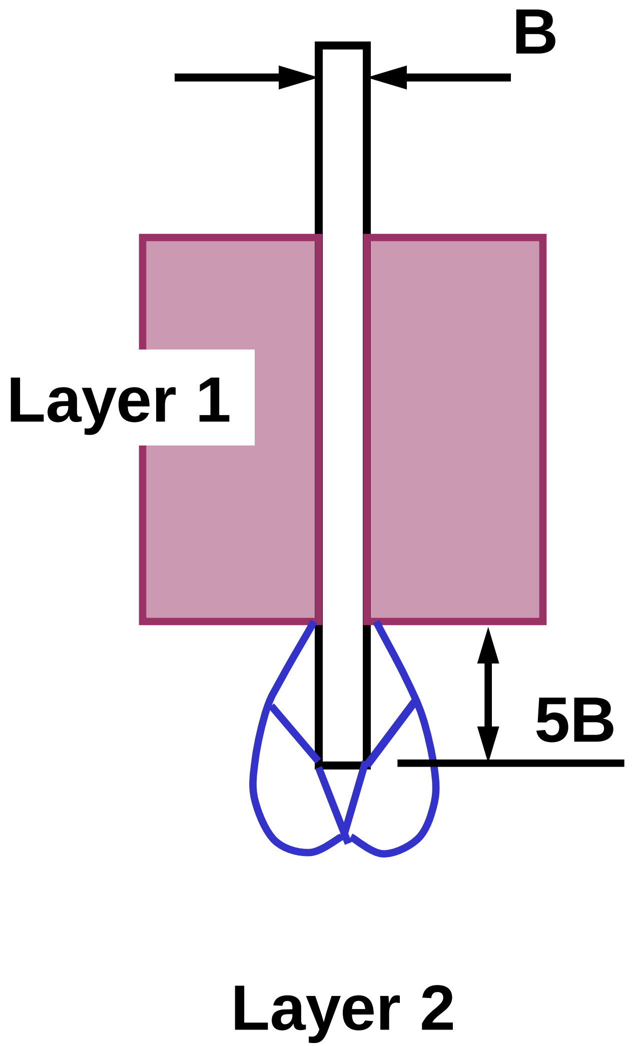
[Meyerhof 1959]

NOTE: min. penetration into bearing stratum
= 5B

Densification



5B Rule



N_q – typical values, driven piles [AS2159 (1978)]

Sand Consistency	Density Index, I_D (%)	N_q
LOOSE	20-40%	**60**
MEDIUM DENSE	40-75%	**100**
DENSE	75-90%	**180**

Limiting (maximum) values of f_s and f_b for sands

$$f_{s\ max} = 110\ kPa$$

$$f_{b\ max} = 15\ MPa$$

After Tomlinson 1995

Method Based on Standard Penetration Test

$$Q_u = 400\, N\, A_b + 2\, N_1\, A_s$$

Q_u = the ultimate pile load, *kN*

N = the average standard penetration index at the pile tip elevation, blows/300 mm

N_1 = the average standard penetration index along the pile shaft blows/300 mm with a maximum value of 50

Minimum factor of safety of 4 should be applied to Q_u.

CLAYS, SILTS

The skin friction OR side shear term…

- effective stresses and drained strength?

  BUT the pwp's are uncertain

- Total stress analysis acceptable

"Adhesion" $$f_s = F\alpha_p c_u = \alpha_p c_u$$

since F = pile flexibility factor

and F = 1 for L/B<50

<u>Generally</u>, α_p **= 1.0 for** c_u **< 40 kPa**

α_p **= 0.4 for** c_u **> 150 kPa**

Otherwise, Semple + Rigden (1984):

α_p	$\frac{(c_u)}{(\sigma'_{vo})}$
1	< 0.35
0.5	> 0.8

End Bearing Term, f_b

Total Stress Analysis of Saturated NC Clay

$$f_b = 9c_u$$

- N_c = 5.14
- $d_c N_c$ = 8.4 for infinitely deep footing
- $s_c d_c N_c$ = 9^+ for a circular or square, deep footing

PILE PARAMETERS
from CPT (field test)

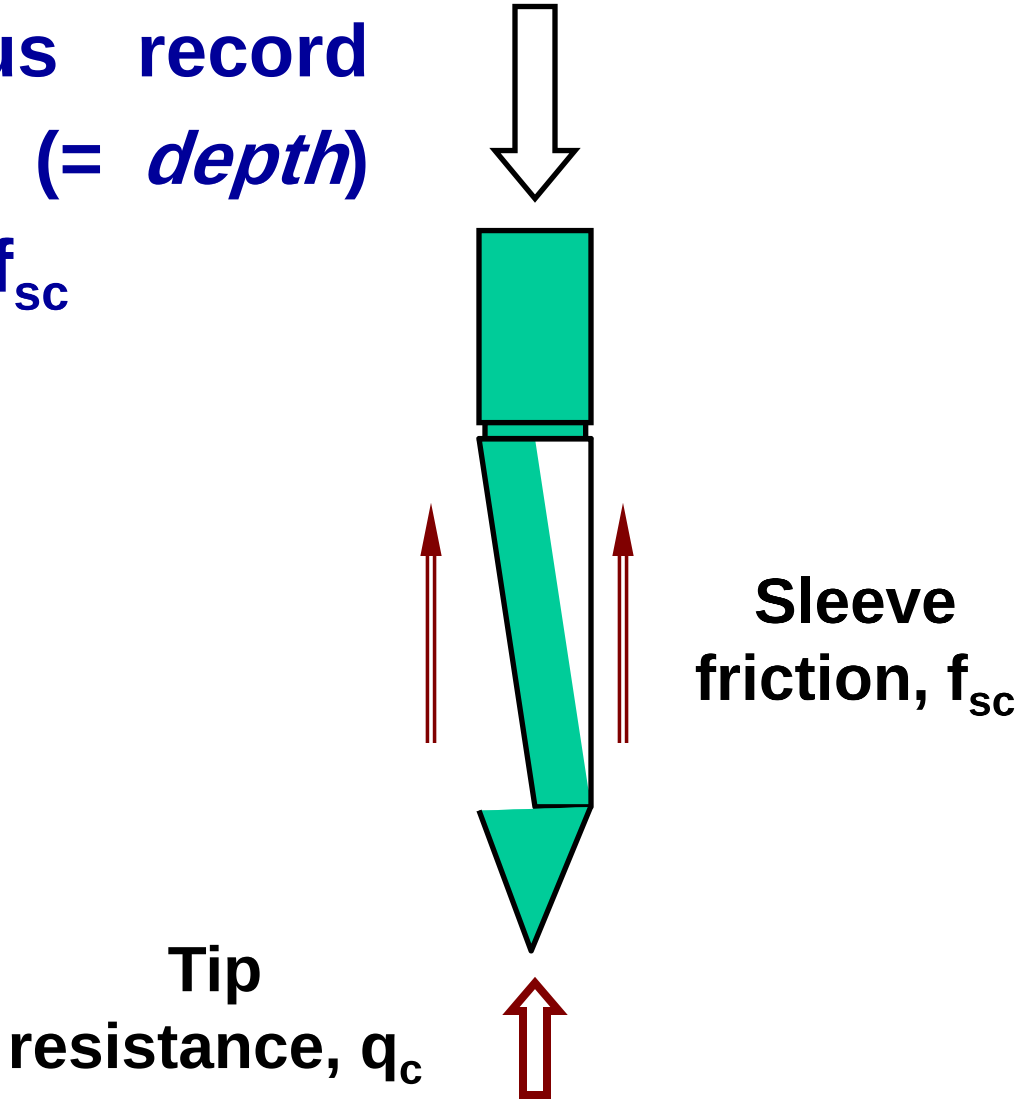
CPT = Cone Penetration Test

OR electronic friction cone

- **designed specifically for interpreting pile parameters**
- **36 mm diameter cone (60°) is pushed into the soil at 2 cm/sec**

$\Rightarrow$ **1.2 m in a minute**

CPT provides a continuous record with time (= *depth*) of q_c and f_{sc}



PILE PARAMETERS from CPT

(A) $f_s \Rightarrow f_{sc}$, directly from cone

Scale effect: small cone displaces less soil

$\Rightarrow$ conservative for sands!

CLAY SOILS……..$f_s = f_{sc}$

SANDS……………$f_s = 2f_{sc}$

(BUT $f_s = f_{sc}$ for H-piles)

PILE PARAMETERS from CPT

(B) **f_b measured directly** $\Rightarrow$ **q_c**

Interpretation of CPT for f_b

Various formulations exist, e.g.

ECP	**Av. q_c**	**6B above**
		pile base level
	AND	3**B below**

e.g. 0.4 m dia. pile founded at 10 m requires average q_c between 7.6 m and 11.2 m

Pile Capacity from CPT

For displacement piles:

$$Q_{all} = \frac{1}{3}\alpha q_c (\frac{\pi d^2}{4}) + \frac{1}{2} f_c (\pi d L)$$

α: Scale factor = 0.70

$q_c < 150 kg/cm^2$

$f_c < 1.0 kg/cm^2$

Notes:

For bored piles:

estimated values should be reduced by 0.0 to 50%

Reinforcement details of piles

- Compression loading only
- No eccentricity of loads

- As_{min} = 0.006Ag.
- Use Φ16mm as minimum diameter.
- Length of reinforcement the largest of 6m or 3d
- Spiral stirrups 8mm @ 15CM pitch

Tension Piles

Vertical tension loading:

ULTIMATE GEOTECHNICAL STRENGTH

- or capacity, P_u

$$P_u = \overline{f}_s A_s + W_p$$

Pile Subjected to Eccentric Forces

$$P_i = \frac{P_{F.L}}{n} \pm \frac{M_x}{\sum_{i=1}^{n} y^2} y_i \pm \frac{M_y}{\sum_{i=1}^{n} x^2} x_i$$

+ve : compression
-ve : tension

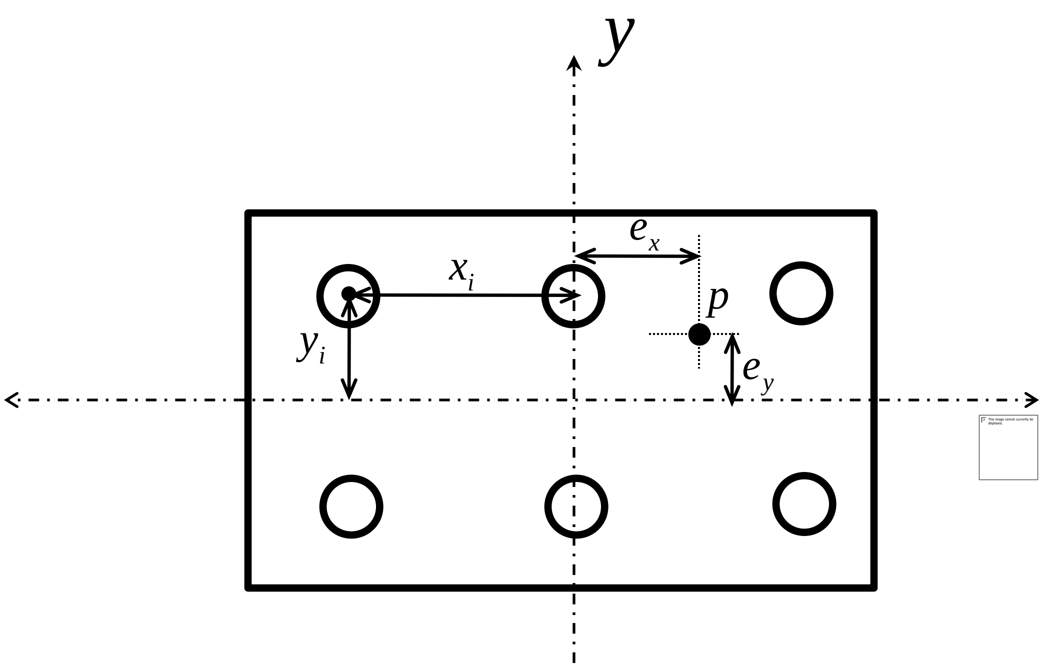
P_i : Load on Pile No. I

n : number of piles

y_i, x_i : co-ordinates of pile

$$M_x = P * e_y$$

$$M_y = P * e_x$$



Check Loads on piles:

P_i(max. comp.) < P_{all} comp.

P_i(max. ten.) < P_{all} ten.