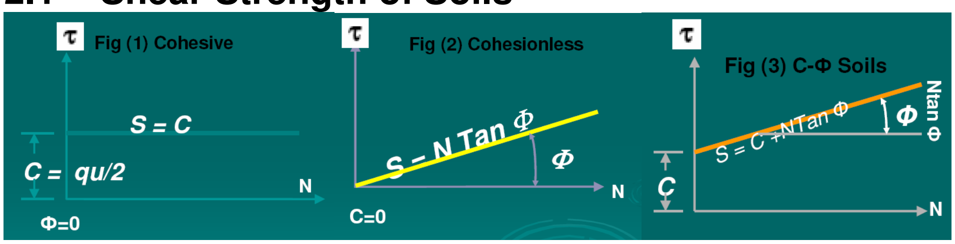
# 2. PHASE RELATIONSHIP EQUATIONS:

| Dry Unit Weight, γd | Bulk or Wet or Total Unit Weight, γm or γw or γt or γ | Saturated Unit Weight, γs or γsat |
|---|---|---|
| $\gamma_d = \dfrac{\gamma}{1+w}$ | $\dfrac{(1+w)G_s\gamma_w}{1+e}$ | $\gamma_{sat} = \dfrac{(G_s+e)\gamma_w}{1+e}$ |
| $\gamma_d = \dfrac{G_s\gamma_w}{1+e}$ | $\dfrac{(G_s+Se)\gamma_w}{1+e}$ | $\gamma_{sat} = \left(\dfrac{e}{w}\right)\left(\dfrac{1+w}{1+e}\right)\gamma_w$ |
| $\gamma_d = \dfrac{eS\gamma_w}{(1+e)w}$ | $\dfrac{(1+w)G_s\gamma_w}{1+\dfrac{wG_s}{S}}$ | $\gamma_{sat} = [(1-n)G_s+n]\gamma_w$ |
| $\gamma_d = G_s\gamma_w(1-n)$ | $G_s\gamma_w(1-n)(1+w)$ | $\gamma_{sat} = \gamma_d + \left(\dfrac{e}{1+e}\right)\gamma_w$ |

## 2.1 Shear Strength of Soils




**S = C** **S= NTanΦ** **S = C + N TanΦ**

## 2.2 Bearing Capacity of Soils

Hansen B.C. Factors:

| Ø | Nc | Nq | Nγ |
|---|---|---|---|
| 0 | 5.10 | 1.00 | 0.00 |
| 4 | 6.19 | 1.43 | 0.05 |
| 8 | 7.53 | 2.06 | 0.22 |
| 12 | 9.28 | 2.97 | 0.63 |
| 16 | 11.63 | 4.34 | 1.43 |
| 20 | 14.83 | 6.40 | 2.95 |
| 24 | 19.32 | 9.60 | 5.75 |
| 26 | 22.25 | 11.85 | 7.94 |
| 28 | 25.80 | 14.72 | 10.94 |
| 30 | 30.14 | 18.40 | 15.07 |
| 32 | 35.49 | 23.18 | 20.79 |
| 34 | 42.16 | 29.44 | 28.77 |
| 36 | 50.59 | 37.75 | 40.05 |
| 38 | 61.35 | 48.93 | 56.18 |
| 40 | 75.32 | 64.20 | 79.54 |

Terzaghi B.C. Factors

| $\phi'$ | $N_q$ | $N_c$ | $N_\gamma$ |
|---|---|---|---|
| 0 | 1.00 | 5.70 | 0.0 |
| 2 | 1.22 | 6.30 | 0.2 |
| 4 | 1.49 | 6.97 | 0.4 |
| 6 | 1.81 | 7.73 | 0.6 |
| 8 | 2.21 | 8.60 | 0.9 |
| 10 | 2.69 | 9.60 | 1.2 |
| 12 | 3.29 | 10.76 | 1.7 |
| 14 | 4.02 | 12.11 | 2.3 |
| 16 | 4.92 | 13.68 | 3.0 |
| 18 | 6.04 | 15.52 | 3.9 |
| 20 | 7.44 | 17.69 | 4.9 |
| 22 | 9.19 | 20.27 | 5.8 |
| 24 | 11.40 | 23.36 | 7.8 |
| 26 | 14.21 | 27.09 | 11.7 |
| 28 | 17.81 | 31.61 | 15.7 |
| 30 | 22.46 | 37.16 | 19.7 |
| 32 | 28.52 | 44.04 | 27.9 |
| 34 | 36.50 | 52.64 | 36.0 |
| 35 | 41.44 | 57.75 | 42.4 |
| 36 | 47.16 | 63.53 | 52.0 |
| 38 | 61.55 | 77.50 | 80.0 |
| 40 | 81.27 | 95.66 | 100.4 |
| 42 | 108.75 | 119.67 | 180.0 |
| 44 | 147.74 | 151.95 | 257.0 |
| 45 | 173.29 | 172.29 | 297.5 |

## Allowable Gross Bearing Capacity- 9 Equations

### In Cohesionless(granular) Soils

qu = γD(Nq) + 0.6γ R(N γ)--for circular footings

qu = γD(Nq) + 0.4γ B(N γ)-- for square or rectangular footings

qu = γD(Nq) + 0.5γ B(N γ)—for continuous footings

### In Cohesive (clayey) Soils

qu = 1.3 C(Nc) + γD--for circular footings

qu = CNc ( 1+ (0.3B/L) ) + γD-- for square or rectangular footings

qu = CNc + γD-—for continuous footings

### In Mixed soils (C-Φ)

qu = 1.3C(Nc) +γD(Nq) + 0.6γ R(N γ)--for circular footings

qu = CNc ( 1+ (0.3B/L) ) + γD(Nq) + 0.4 γB(N γ) - for sq/rect. footings

qu = CNc + γDNq + 0.5 γB(N γ) -—for continuous footings

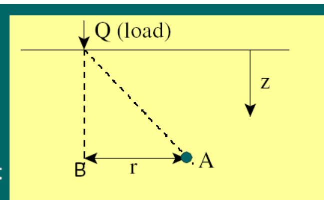
Cohesion — 1st term; Surcharge — 2nd term; Friction — 3rd term

Note: If Df/B > 1, terzaghi's B.C. factors do not apply. Use Hansen's B.C. factors. For example, if depth of footing (Df) is 3 ft but footing width (B) is 2.75 ft.

# 3. STRESSES IN SOILS

## 3.1 Various Loading Conditions:

1) Stress due to concentrated or a Point load




Δσv = (Q/Z^2) * [ 3 /( 2π[1+(r/z)^2]5/2) ] at point A

The [ second term ] is IB-Boussinesq's influence coefficient and you may Plot r/z versus IB

Δσv = 0.4775 (Q/Z^2) at point B

NOTE:

This assumes that the soil profile is isotropic, homogeneous, elastic half-spaced material. Since soil properties vary in direction, is comprised of more than one type and is layered, Boussinesq's formula is Conservative But useful for getting upper bound solution.

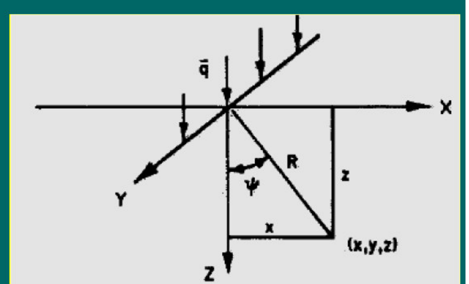
2) Stress due to a line load:

Δσv = 2q(Z^3) / π(R^4)

q = line load in k/ft or similar

R = (x^2 + z^2)^0.5

Ψ = Angle line R makes with the vertical axis




Strip

3) q = line load in ksf or similar

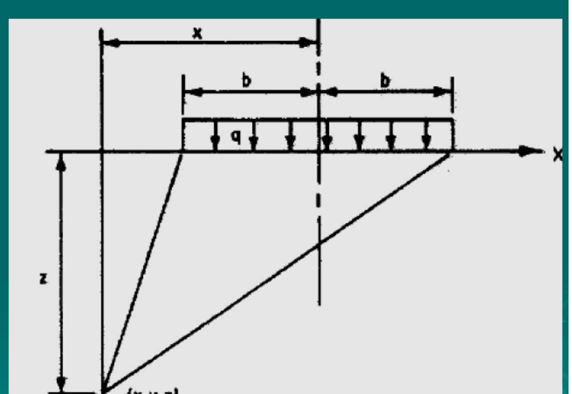
Δσv = q/π (α+ sinα(cos(α+2β)

Where:

α = Tan^-1 (x+b) / z ) - β

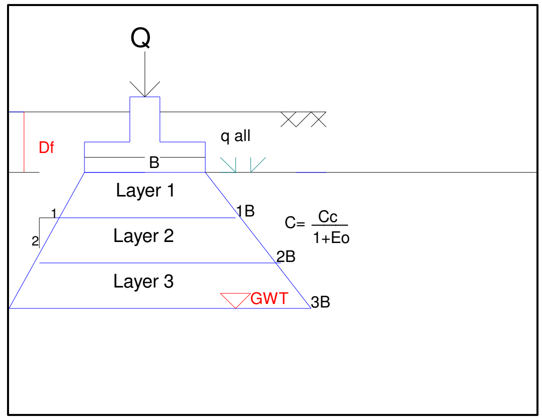
β = Tan^-1 (x-b) / z)

α & β are in Radians



# 4. SHALLOW FOUNDATIONS

## 4.1 Conventional Footings




### 4.11Geotechnical Analysis

qall = Q / Bx1 for Continuous Footings
qall = Q / BxL for Rectangular Footings
qall = Q / BxB for Square Footings
qall < qu / 3 from Bearing Capacity Calculations
e < B/6, where e=eccentricity
Df > 1.0 ft minimum
Df > frost depth
Df > setback distance for footings on slope
Df > scour depth
Df > high moisture variations depth(expansive soils)

### 4.12 Structural Design:

**Given: A Continuous footing with $\gamma m$ = 100 pcf, Df = 5 ft, qall = 4,000 psf, D.L=22 k/ft, L.L.=12 k/ft, f'c=3 ksi, fy= 60 ksi. Design the footings using the ACI code:**

1.) Effective soil pressure: Assume total depth of footing = 19 in.

Weight of footing = (19)(150)/12 = 237.5 lb./ft.$^2$
Weight of soil = (5-19/12)(100) = 341.7 lb/ft.$^2$
$q_e$ = 4000-238-342 = 3420 lb./ft.$^2$ = 3.42 k/ft.$^2$

2.) Width of footing = , **use 10 ft. footing**.

3.) Net upward pressure = $P_u$ / Area

$P_u = 1.2D + 1.6L = (1.2)(22) + (1.6)(12) = 45.6$ k/ft.
$q_u = 45.6 / (10\cdot 1) = 4.56$ k/ft.

4.) Check one-way shear: $d = 19 - 3.5 = 15.5$ in.

$$V_u = q_u\left(\frac{L}{2}-\frac{a}{2}-d\right) = 4.56\left(\frac{10}{2}-\frac{12}{2\cdot 12}-\frac{15.5}{12}\right) = 14.63 \text{ kip}$$

$$d = \frac{V_u}{\phi 2\sqrt{f_c'}b} = \frac{14.63\cdot 1000}{0.75\cdot 2\sqrt{3000}\cdot 12} = 14.8 \text{ in.} < 15.5 \text{ in.}$$

**use actual $d$ = 15.5 in.**

5.) Calculate $B.M.$ and $A_s$ :

$$M_u = \frac{q_u}{2}\left(\frac{L}{2}-\frac{a}{2}\right)^2 = \frac{4.56}{2}\left(\frac{10}{2}-\frac{12}{2\cdot 12}\right)^2 = 46.17 \text{ k.ft.}$$

, Assume $a$ =1.5 in.

$$A_s = \frac{M_u}{\phi f_y\left(d-\frac{a}{2}\right)} = \frac{46.17\cdot 12}{0.9\cdot 60\left(15.5-\frac{1.5}{2}\right)} = 0.7 \text{ in.}^2$$

$$a = \frac{A_s f_y}{0.85 f_c' b} = \frac{0.7\cdot 60}{0.85\cdot 3\cdot 12} = 1.364 \text{ in., o.k.}$$

Check
$A_{s(min)} = 0.0018bh = (0.0018)(12)(19) = 0.41$ in.$^2$ < 0.70 in.$^2$
**Use #7 bars @ 9 in.** ($A_s$ = 0.80 in.$^2$)

6.) $l_{dav}$ = available development length = (10$\cdot$ 12/2) - (12/2) - 3 = 51 in.

Required $l_d$ = 48 in. < 51 in. ($l_d$ from Table 7.2, chapter 7)

7.) Longitudinal reinforcement = $A_{s(min)}$ = 0.41 in.$^2$, **use #5 bars @ 9 in.** ($A_s$ = 0.41 in.$^2$)