4.3 Load carrying capacity of pile:

- The ultimate Load carrying capacity of pile or ultimate Load bearing resistance of pile is the maximum load which it can be carry without failure.
- The pile transfer the load in two ways
  1) Through the tip in compression is called end bearing or point bearing
  2) By shear along the surface is called as skin friction
- All type of pile behave both end bearing and skin friction

The Load carrying capacity of pile can be determined by following method

1. Dynamic Analysis
2. Static Analysis
3. Pile load test
4. Penetration test

1. Dynamic Analysis:

The load carrying capacity of a driven pile can be estimated from the resistance against penetration developed during driving operation with a hammer.

2.Static Analysis:

Sum of end bearing pile/point bearing pile and friction pile

$$Q_{up} = A_s R_f + R_p A_p$$

A_s=Surface area of pile

A_p= Area of cross section of pile

r_f=Average skin friction

r_p=end/point/tip bearing of pile

For circular Pile:

$$A_p = \frac{\pi}{4} D^2$$

$$A_s = \pi DL$$

For rectangular Pile:

$$A_p = BxD$$

$$A_s = 2(B + D)L$$

i)Cohesive soil:

$$r_f = \alpha . C \ or \ mc$$

$$r_p = C_p N_c, N_c = 9$$

$$r_p = 9C_p$$

$$Q_{up} = \alpha C A_s + 9 C_p A_p$$

Where, α=Reduction factor

$$Q_a = \frac{Q_{up}}{F}$$

$$Q_a = \frac{\alpha C A_s + 9 C_p A_p}{F}$$

ii) Cohesionless soil

$$r_f = k tan\varphi(\gamma . Z + q)$$

For circular pile:

$$rp = 0.3\gamma B N\gamma$$

For rectangular and square pile:

$$r_p = \frac{\gamma_B}{2} N_\gamma$$

Where,

r_f=average skin friction

$\gamma = density\ of\ soil.$

q= surcharge on the ground

$\varphi = angle\ of\ internal\ friction.$

Static Analysis: Problems

1.A reinforced concrete square pile of size 30x30cm and 10cm long is driven into saturated sand extending to great depth. The average effective unit weight =16KN/m^3.average FS=2.5 .Find Q_s

Given data:

square pile of size 30x30cm=0.3x0.3m

Z=10cm

$\gamma = 16KN/m^3$

F=2.5

To find:

Safe Load Q_s=?

Solution:

Assume K=1.5,N $\gamma = 25, tan\varphi = 0.6$

$$Q_{up} = A_s R_f + R_p A_p$$

cohesionless soil

$$r_f = ktan\varphi(\gamma.Z + q)$$

$$r_f = 1.5x0.6x(16x10 + 0) = 144$$

For rectangular and square pile:

$$r_p = \frac{\gamma B}{2} N_\gamma$$

$$r_p = \frac{16x0.3}{2} x25 = 60$$

$$A_p = 0.3x0.3 = 0.09m^2$$

$$A_s = bxZ = 0.3x10 = 3m^2$$

$$Q_{up} = A_s R_f + R_p A_p$$

$$Q_{up} = 0.09x60 + 144x3 = 437.4KN$$

$$Q_a = \frac{Q_{up}}{F} = \frac{437.4}{2.5} = 174.96KN$$

2. A pile is driven in a uniform clay of large depth .UCC=90KN/m^2,30 cm dia and 6m long,FS=3,α=0.7.Determine the frictional resistance.

Given data:

UCC=90KN/m^2

D=30cm=0.3m

Z=6m

F=3

α=0.7

To find :

frictional resistance=?

Soln:

$$Q_{up} = A_s R_f + R_p A_p$$

$$Q_{up} = frictional\ resistance + end/point/tip\ bearing \text{ pile}$$

$$A_sR_f = frictional\ resistance$$

$$R_pA_p = end\ bearing\ \text{pile}$$

Given clay soil therefore it is cohesive soil

For circular Pile:

$$A_s = \pi DL = \pi x0.3x6 = 5.6m^2$$

Cohesive soil:

$$r_f = \alpha.C\ or\ mc$$

UCC:

$$C = \frac{q_u}{2} = \frac{90}{2} = 45KN/m^2$$

$$R_f = 0.7x45 = 31.5$$

$$frictional\ resistance = A_sR_f = 5.6x31.5 = 176.4KN$$

$$\text{Safe frictional resistance} = \frac{A_sR_f}{F} = \frac{176.4}{3} = 58.8\text{KN}$$

3. A 30cm diameter concrete pile is driven normally consolidated clay deposit 15m thick .Estimate the safe load. Take C_u=70KN/m^2.

Given data:

Diameter D=30cm=0.3m

Clay-cohesive

Z=15m

C_u=70KN/m^2.

To find:

Safe load=?

Solution:

$$Q_{up} = A_sR_f + R_pA_p$$

For circular Pile:

$$A_p = \frac{\pi}{4}D^2$$

$$= \frac{\pi}{4}0.3^2 = 0.070m^2$$

$$A_s = \pi DL = \pi x0.3x15 = 14.13m^2$$

Cohesive soil:

Assume $\alpha = 0.9, F = 2.5$

$$r_f = \alpha.C \text{ or } mc$$

=0.9x70

=63KN/m^2

$$r_p = C_p N_c, N_c = 9$$

$$r_p = 9x70 = 630KN$$

$$Q_{up} = A_s r_f + r_p A_p$$

$$Q_{up} = 14.13x63 + 630x0.070$$

$$= 934.29KN$$

$$Q_{up} = working\ load$$

Where,α=Reduction factor

$$Q_a = \frac{934.29}{2.5} = 373.716KN$$

$$Q_a \text{ or } Q_s = safe\ load\ or\ allowable\ load$$

4.A concrete pile of 45cm dia is driven through a system of layered cohesive soil.The length of the pile=16m

1.Stiff clay=8m,C_u=30,α=0.9

2.Medium Stiff clay=6m,C_u=50,α=0.75

3.silt stratum =to creator depth ,C_u=105,α=0.5,A_s=0.159m^2.

Given data:

D=45=0.45m

Cohesive soil

Length L=16m

A_s=0.159m^2

To find:

Safe load=?

Solution:

silt stratum =to creator depth=16-(8+6)=2m

$$Q_{up} = A_s r_f + r_p A_p$$

$$r_f = \alpha.C \ or \ mc$$

=[(0.9x30x8)+(0.75x50x6)+(0.5x105x2)]=357 KN/m^2

$$r_p = C_p N_c, N_c = 9$$

$$r_p = 9x105 = 945KN$$

$$A_p = \frac{\pi}{4} D^2$$

$$= \frac{\pi}{4} 0.45^2 = 0.158m^2$$

$$Q_{up} = 0.159x357 + 945x0.158 = 202.86KN$$

$$Q_a = \frac{202.86}{2.5} = 81.144KN$$

5. A group of 9 piles with 3 piles in a row is driven into soft clay extending from ground level to a great depth. The diameter and length of piles were 30 cm and 10 cm respectively. The unconfined compression strength of clay is 70 kN/m^2. If the piles were spaced at 90cm centre to centre, compute the allowable load on the pile group on the basis of shear failure criteria for a factor of safety of 2.5, neglect bearing at thetip of piles, take m = 0.6 for shear mobilization around each pile.

Given Data:

n = 9 piles with 3 piles in a row.S= 90cm = 0.9 m c/c

D=30cm = 0.3mL=10m

q_u =70kN/m^2

$$c = \frac{q_u}{2} = \frac{70}{2} = 35KN/m^2$$

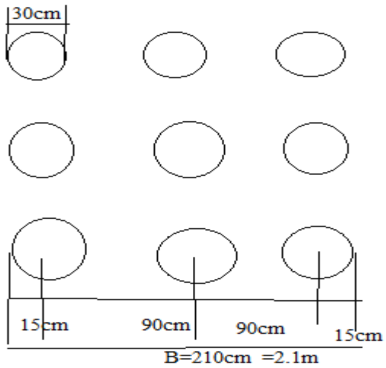
F.S. =2.5,m =0.6

To Find:

Q_a=?

Solution:

Ultimate load on pile based on individual action::



Size of pile group = BXB

=2.1m x 2.1m

$Q_{up}=A_s r_f+A_p r_p$

$A_s r_f$=Friction pile

$A_p r_p$= end/point/tip bearing

In question neglect bearing at thetip of piles,therefore

$Q_{up}=A_s r_f$

$A_s=\pi dL= \pi x0.3x10=9.42m^2$.

$r_f=\alpha C=mc=0.6x35=21$

= 9.42x21=197.82 kN

$Q_{un}=nxQ_{ug}$=9x197.82=1780.38KN

Ultimate load on pile based on group action:

$Q_{up}=A_s r_f$

A_s=4BL=4x2.1x10=84m^2

Q_{up}=84x21=1764KN

Ultimate load on pile = least = 1780.3 kN

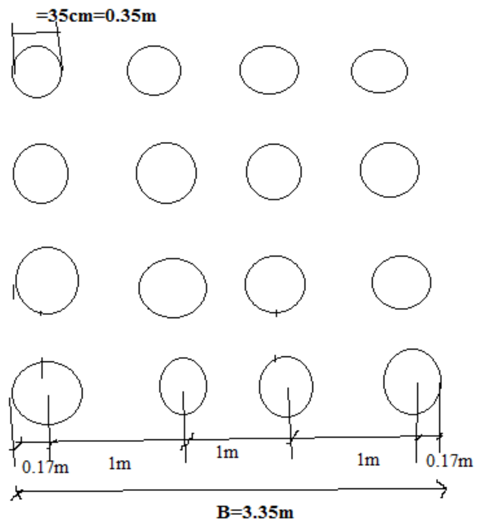
When the pile acting individually,

$$\text{Safe load on pile } = \frac{1780.3}{2.5} = 712.5\text{KN}$$

6. A group of 16 friction piles is to support a column load of 4000kN. The piles will be driven in four rows with four numbers in each column. The piles are 35 cm diameter and the c/c spacing is 1m both ways. What set value must be attained by the piles when driven by a single acting 22.5kN steam hammer with 90cm stroke so that the pile group can carry the column load? Assuming L= 10m

Solution:

Case1)i)Load carried by group action



$Q_{up}=A_s r_f + A_p r_p$

$A_s=4BL$

$=4x3.35x10$

$=134m^2$

$Q_{up}=84x21=1764KN$

$$A_p = B^2 = 3.35^2 = 11.22m^2$$

$r_p=CN_c=9C$

$r_f=\alpha C=mc=0.7xC$

In group load is 4000KN

$Q_{ug}=A_s r_f+A_p r_p$

4000=134x0.7 C+11.22x9C

$C=22KN/m^2$

ii)Load carried by individual action:

$Q_{up}=A_s r_f+ A_p r_p$

$$A_p = \frac{\pi d^2}{4} = \frac{\pi x(0.35)^2}{4} = 0.096m^2$$

$r_p=CN_c=22x9=198KN/m^2$

$r_f=\alpha C=mc=0.7x22=15.4KN/m^2$

$A_s=\pi dL=\pi x0.35x10=10.99m^2$

$Q_{up}=10.99x15.4+0.096x198=188.254KN$

$Q_{un}=nxQ_{up}$

=16x188.25

=3012.064

Individual pile fails first.

Caseii)Engineering news formula

Q_u =WH/6(S+C) for stream hammerC=0.254

2628 = [22.5 x 0.9 x 100]/ [6(S + 0254)]

2628 = 20.25/ [6S+1.524]

2628(6S + 1.524) = 20.25 x 100 (neglect the sign)

6S + 1.524 = 0.77

6S = 0.752

S = 0.125 cm

S = 1.25 mm

7. Design a friction pile group to carry a load of 3000 KN including the weight of the pile cap at a site where the soil is uniform clay to a depth of 20 m underlain by rock. Average unconfined compressive strength of the clay is 70kN/m^2. The clay may be assumed to be of normal sensitivity and normally loaded, with liquid limit of 60%. A factor safety of 3 is required against shear failure.

Given

Q_{ug} = 3000k W

C = q_u/2 =70/2 =35 kN/m^2

$$Permission\ C = \frac{c}{F}$$

Permission C = 35/3 kN/m^2

Assume,Let the length of pile =10 m

Diameter of the pile =0.5 m

Spacing of pile = 3 d =3 x 0.5 =1.5 m = 150 cm

Let the no. Of piles = n

Q_{up}=C πdL

Q_{ug} = n Q_{up}

Q_{ug} = n x 35/3 x π x 0.5 x 10

n = 16.37

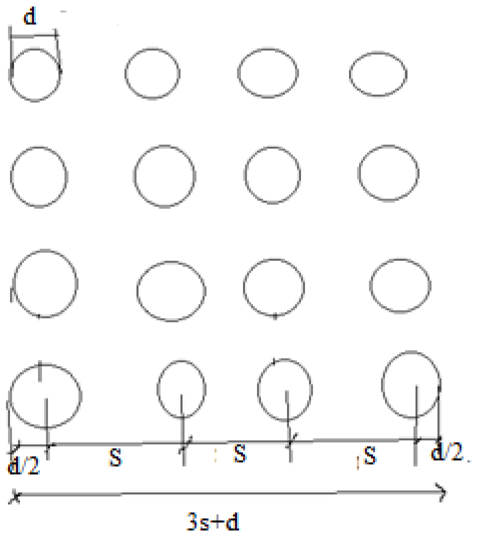
For square arrangement keep n = 16

The modified length L will then have to increase by the ratio16.37 /16

L= 10 x 16.37 /16

L =10.23L = 11 m

Check for group action



B = 3 s+d = 3 x 150 + 50 = 500 cm = 50 m

Load taken by group action

= 4 BL x C + A P. C N_c

= 4 x 5 x 11 x(35/3) + [(5 x 5) x (39/3) x 9]

=2566.7 + 2625

Q_{ug} = 5191.7 kN > 3000 KN

Hence safe,