Module 5 : Design of Deep Foundations
Lecture 23 : Piles In Sand [ Section 23.1 : Introduction ]

Objectives
In this section you will learn the following

- Introduction
\[ P_u = \int F_w F' \sigma_v' \tan \frac{\phi}{2} \, dz + A_b \sigma_v' N_q - W \]

\( \sigma_v' \) = effective vertical stress at the base of the pile.
\( N_q \) = bearing capacity factor
\( A_b \) = base area
\( \sigma_v' \) = mean effective vertical stress along the length of the pile.
\( F_w \) = correction factor for tapered pile

Fig. 5.36 Values of \( F_w \)
In this section you have learnt the following.

- Introduction
Module 5 : Design of Deep Foundations

Lecture 23 : Piles In Sand [ Section 23.2 : Vesic's method ]

Objectives

In this section you will learn the following

- Vesic's method
- Limited depth method – Vesic
- Problem
Vesic's method

\[ \sigma_v' = \frac{3}{4} \sigma_v + 10^0 \] for driven pile

\[ \sigma_v'_{AI} = 2^0 \] for bored pile

\( \sigma_v' \) = before installation

\( \sigma_v'' \) = after installation

Vesic (1967) on the basis of model tests, that the vertical effective stress reaches a limiting value at a certain (critical or limiting) depth, beyond which there is assumed to be no increase (see figure). The limiting vertical (and therefore horizontal) stress effect has been attributed to arching in the soil and particle crushing.

\( \sigma_{v0} ' \) is constant for a particular type of sand and does not depend on size of soil.

\( \sigma_v'' \) = effective vertical stress

\( \sigma_v' \) = mean effective vertical stress along the length of the pile.
Limited depth method – Vesic

Based on the test results obtained by Vesic (1967), Poulos and Davis (1980) have developed a means of estimating the critical depth, $Z_c$, in the form of the ratio $Z_c/d$ as a function of the effective angle of friction, $\phi$. This is shown in the accompanying figure. It should be noted that the value of $\phi$ used in this figure should be the value that has been adjusted to reflect the method of installation as follows. Once the value of $Z_c/d$ is known, the diameter of the pile ‘d’ and the Pile capacity can be calculated.

On the basis of Vesic’s (1967) test results, Poulos and Davis (1980) have suggested a relationship between $K \tan \phi$ and $\phi$ as shown in figure given below. The value of $\phi$ is the postdriving value. It should be noted that Vesic’s tests were conducted on steel piles, and it is likely that the values given in this figure are conservative for other (rougher) surface finishes.
Problem: Calculate the pile capacity for a concrete pile by following data.

Given data:
\[ d = 250 \text{ mm, } L = 9 \text{ meter, } k_s = 19.5 \text{ KN/m}^2, \ k_{sat} = 20 \text{ KN/m}^2, \ \phi = 38^0, \ \text{F.O.S.} = 2.0, \ K_s = 0.95, \ \tan \phi = 0.45, \ N_q = (\text{for } 38^0) = 50. \]

1. Ground water table at very large depth.
2. Ground water table at 3 m below ground level.

Solution

1. Ground water table at very large depth.

   Since in our data \( \frac{L}{d} > \frac{1}{2} \times \frac{L}{d} \),

   So select \( N_q^* \) according \( \phi \) from Upper Curve given by Mayerhaff.

   Since \( \phi = 38^0, \frac{Z_c}{d} = 16. \)

   The Critical depth (\( Z_c \)) at which Tip resistance become constant is

   \[ Z_c = 16 \times d = 16 \times 0.25 = 4.0 \text{ meter.} \]

2. Tip Resistance

   \( q_p = \sigma_{vb} \cdot N_q^* \)

   \( \sigma_{vb} = \gamma \cdot L_c = 19.5 \times 4 = 78 \text{ KN/m}^2 \)

   \( q_p = 78 \times 50 = 3900 \text{ KN/m}^2 \)

   \( q_l = 50 \times N_q^* \cdot \tan \phi \)

   \( q_l = 50 \times 50 \times \tan 38^0 \)

   \( q_l = 1953.21 \text{ KN/m}^2 < q_p \)
Module 5 : Design of Deep Foundations

Lecture 23 : Piles In Sand [ Section 23.2 : Vesic's method ]

- Skin Resistance

\[ f_s = K_s \cdot \tan \phi_a \cdot \sigma_v \]
\[ \sigma_v = \left[ \frac{\frac{1}{2} \times 78 \times 4 + (2 \times 5)}{9} \right] \]
\[ \sigma_v = 60.667 \text{ KN/m}^2 \]
\[ f_s = 0.95 \times 0.45 \times 60.667 \]
\[ f_s = 25.93 \text{ KN/m}^2 < f_1 (100 \text{ KN/m}^2) \]

here \( f_1 > f_s \)
\[ f_s = 25.93 \text{ KN/m}^2 \]

- Total Load & Allowable load

\[ P_U = q_p A_p + f_s A_s \]
\[ P_U = 1953.2 \left( \frac{\pi}{4} d^2 \right) + 25.93 \times \pi \times d \times l \]
\[ P_U = 1953.2 \left( \frac{\pi}{4} \times 0.25^2 \right) + 25.93 \times \pi \times d \times l \]
\[ P_U = 279.2 \]
\[ P_{allow} = \frac{279.2}{2} = 139.6 \text{ KN} \]
2. When ground table below 3 m.

Since \( \phi = 38^\circ \),

\[
\frac{Z_c}{d} = 16.
\]

The Critical depth \( Z_c \) at which Tip resistance become constant is

\[
Z_c = 16 \times d = 16 \times 0.25 = 4.0 \text{ meter.}
\]

\[
\sigma_{vb} = \gamma .L_c = 19.5 \times 3 + (20 - 9.81) \times 1
\]

\[
\sigma_{vb} = 58.5 + 10.19
\]

\[
\sigma_{vb} = 68.69 \quad \text{KN/m}^2
\]

\[
q_p = \sigma_{vb} . N_q^* = 68.69 \times 50
\]

\[
q_p = 3434.5 \quad \text{KN/m}^2
\]

\[
q_l = 50 \times N_q^* \cdot \tan \phi
\]

\[
q_l = 50 \times 50 \times \tan 38^\circ
\]

\[
q_l = 1953.21 \quad \text{KN/m}^2 < q_p
\]

\[
f_s = K_s \cdot \tan \phi_s, \sigma_v
\]

\[
\sigma_v = \left[ \frac{(\frac{1}{2} \times 58.3 \times 3) + (58.5 + 68.69) \times 1 + (5 \times 68.69)}{2} \right]
\]

\[
\sigma_v = 54.977 \quad \text{KN/m}^2
\]
\[ \sigma'_v = \left( \frac{9}{2} \times \frac{58.3 \times 3 + (58.3 + 68.69) \times 1 + (5 \times 68.69)}{2} \right) \]

\[ \sigma'_v = 54.977 \text{ KN/m}^2 \]

\[ f_s = 0.95 \times 0.45 \times 54.977 \]

\[ f_s = 23.50 \text{ KN/m}^2 < f_l (100 \text{ KN/m}^2) \]

Here \[ f_l > f_s \]

\[ f_s = 23.50 \text{ KN/m}^2 \]

\[ P_U = q_p A_p + f_s A_s \]

\[ P_U = 1953.2 (\frac{3}{4} \times d^2) + 23.5 \times \pi \times d \times l \]

\[ P_U = 1953.2 (\frac{3}{4} \times 0.25^2) + 25.93 \times \pi \times 0.25 \times 5 \]

\[ P_U = 261.99 \text{ KN} \]

\[ P_{allow} = \frac{261.99}{F.O.S.} = \frac{261.99}{2} = 130.99 \text{ KN} \]
Recap

In this section you have learnt the following.

- Vesic's method
- Limited depth method – Vesic
- Problem
Module 5: Design of Deep Foundations
Lecture 23: Piles In Sand [ Section 23.3 : Computation of the Pull out resistance of pile ]

Objectives

In this section you will learn the following

- Computation of the Pull out resistance of pile
Computation of the Pull out resistance of pile

Structures such as tall chimneys, transmission towers and jetties can be subject to large overturning moments and so piles are often used to resist the resulting uplift forces at the foundations. In such cases the resulting forces are transmitted to the soil along the embedded length of the pile. The resisting force can be increased in the case of bored piles by under-reaming. In the design of tension piles the effect of radial contraction of the pile must be taken into account as this can cause about a 10% - 20% reduction in shaft resistance. Only skin friction guided the pullout of pile. No bearing is there, so tip resistance is zero.

\[ P_{bu} = 0 \]

So \[ P_U = P_{su} \]

\[ T_U = T_{UN} + W \]

\[ T_{UN} = L \cdot P \cdot \alpha' \cdot C_U \]

Here \( P \) = Perimeter,

For Cast In-Situ Concrete Pile.

\( \alpha' = 0.9 \) to \( 0.00625 \) & \( C_u < 80 \text{kPa} \).

In Sands Pullout Resistance

\[ T_{UN} = \int_{0}^{L} f_n \cdot P \cdot dz \quad (P = \text{Perimeter}) \]

\[ f_n = K_U \cdot \sigma_v \cdot \tan \delta \]

F.S. = 2 to 3
Recap

In this section you have learnt the following.

- Computation of the Pull out resistance of pile

Congratulations, you have finished Lecture 23. To view the next lecture select it from the left hand side menu of the page.