Helical Pile Design: Special Topics

Questions & Answers

1. In column buckling analysis, what does the critical buckling load depend on?

   Ans: *The critical buckling load depends on the stiffness of the shaft (EI) and the square of the effective length (kl), and it is a condition of elastic stability.*

2. A 2-7/8” O.D helical pile shaft, with 0.276” wall thickness, was installed to a depth of 30 feet. The pile head is assumed to be at the ground surface. The top 5 feet of soil is clay with blow count N=3. The rest of the soil profile consists of clayey soil with blow count, N, larger than 5. What is the critical buckling resistance using buckling analysis prescribed by IBC code and the buckling equation given by AISC? Use E = 30,000 Ksi and Fy = 50,000 psi, effective length factor k = 0.8

Ans:

Here, we have 5 feet of soft soil with firm soil beneath it. The unbraced length is 10 ft. K=0.8, Fy = 50,000 psi and E = 30,000 Ksi. Using the formula for $\lambda_{c,,}$ and the design shaft wall thickness, we get a value 0f 1.52 ≥1.5. So $F_{cr} = (0.877/ \lambda_c^2) F_y$= 19,000 lb. Ag = 2.113 in^2. So, the nominal compressive buckling strength is: P = 2.113 19,000 = 40,000 KIPS.*

3. A 1.5" solid square helical pile shaft was installed to a depth of 25 feet. The top 10 feet of soil consists of soft clay. The rest of the soil profile below 10 feet is categorized as stiff clay. What is the critical buckling load using Davisson's method? Assume U_{cr} = 2.0. The modulus of subgrade reaction is 20 lb/in^3. E = 30,000 Ksi.

   Ans:

   U_{cr} = 2.0 ; E = 30,000,000 psi ; K_h = 20lb/in^3 , I = 0.42 in^4

   $R^4 = \frac{30{,}000000*0.42}{20*1.5}$ = 420,000, R^2 = 648

   *P_{cr} = (2.0 * 30,000,000*0.42)/648 = <u>39 Kips</u>*

4. A 3.5” O.D helical pile shaft, with 0.3” wall thickness, was installed to a depth of 30 feet. The top 20 feet of soil is very soft clay with SPT blow count N value of 2 to 3, while the soil below the 20 feet depth has an SPT N-value of 5 or greater. Using the Davisson method, determine the critical buckling load and the allowable design load using a safety factor of 2.0? assume U_{cr} = 2. E = 29,000 Ksi. Modulus of subgrade reaction, k_h = 10 lb/in³.

Ans:

$U_{cr} = 2.0$; $E = 29{,}000{,}000$ psi ; $K_h = 10\ lb/in^3$; $I = 3.9\ in^4$

$R^4 = \frac{29{,}000{,}000 * 3.9}{10 * 3.5} = 3{,}231{,}430;\quad R^2 = 1{,}797$

$P_{cr} = (2.0 * 29{,}000{,}000 * 3.9)/1{,}797 = \underline{126\ Kips}$

$P_{all} = 126/2 = 63\ Kips$

5. From your understanding of buckling analysis, what is the main difference between Davisson method and the one prescribed by IBC and AISC?

Ans:

The IBC and AISC clearly define the unbraced length of the pile shaft based on soil conditions and uses a converted Euler equation to determine the buckling load. In Davisson's method, the unbraced length is not well defined, and the modulus of subgrade reaction is assumed constant with depth, which is not generally the case.

6. A 3.5" O.D helical pile shaft with 0.276" wall thickness was installed to 30 feet deep with a final termination torque of 10,000 ft-lb. The torque correlation factor for this shaft is $K_t = 7$. The soil profile is as follows: the top 5 feet of soil is very soft clay with an SPT blow count N values of 2 to 3. The soil below 5 feet consists of clay that ranges from stiff, medium stiff to very stiff. The top of the pile is 4 feet above the ground. What is the compression allowable capacity of this pile assuming a safety factor of 2? Assume E = 29,000 Ksi. F_y = 50 Ksi. Effective length factor, k = 0.8.

Ans:

Based on torque, the pile soil capacity is : Q = Kt T = 7*10,000 = 70 Kips. Now let check to see if buckling controls. The unbraced length is 4' + 5' + 5' = 14'. From the formula, we get* $\lambda_c = 1.9 > 1.5$.

$F_{cr} = (0.877/1.9^2)* 50,000 =$ *12,146 LBS. So, the nominal compressive buckling strength is : P = 2.8* 12,146 = 34 Kips. Using a resisting factor of 0.85, the buckling load is 30 Kips, which is less than 70 Kips. So, the allowable capacity is 30/2 = 15 kips.*

7. Two construction sites were considered for a project. Both sites consist of clayey soil. Site A consists of clayey soil with kaolinite as its dominant mineral. Site B consists of clay with montmorillonite as its dominant mineral. Helical pile foundations were recommended for both sites. Which site will you most likely consider expansive soil in your design and why?

Ans:

Site B because of the clay mineral montmorillonite.

8. Helical piles in compression were recommended for a construction site with expansive soil. The depth of the active zone is 20 feet. The vertical swell pressure is 15,000 psf. A 2-7/8" O.D helical pile shaft is used for this project. This shaft has a torque correlation factor of K_t=9. What minimum depth should the bearing plates be installed to in this case? Based on the capacity-torque correlation, and using a safety factor of 2 against heaving, what is the minimum installation torque required in this case? Assume a shaft adhesion coefficient of 0.1 and permanent dead load is zero.

Ans:

Since the active zone is 20 feet, the bearing plates should be installed to a depth higher than 20 feet. The upper most helix should be 3D to 5D below the active zone. D is the diameter of the upper most helix. The swelling pressure is 15,000 psf = 104 psi. So, the heaving force is: $\pi * d_{eff} * d_w * \alpha_0 * P_s$ *= 3.14*2.875*20*12*0.1*104 = 22,530 lbs. for a safety factor of 2, the required pile pullout resistance should be 22,530*

** 2 = 45,000 lbs. from Q = K_t * T, we get T = Q/K_t = 45,000/9 = <u>5,000 ft-lb</u>.*

9. An 8-5/8" O.D helical pile shaft was installed 10 feet deep in sand with friction angle of 34 degree and a unit weight of 115 lb/ft^3. What is the lateral resistance of this pile assuming the applied load at the tip of the pile is 1 foot above the ground?

   <u>Ans:</u>

   Here we have L = 10 ft ; e = 1 ft ; $\gamma = 115\ lb/ft^3$; $d = 8.625\ in = 0.719\ ft$; $K_p = \tan^2(45^o + 34^o/2) = 3.0$

   $$PL = \frac{115*0.719*1000*3}{2(1+10)} = \underline{11.3\ Kips}$$

10. Explain why corrosion is generally considered not problematic for helical piles? What are the most common types of corrosion protective coating of helical piles?

Ans:

Helical piles are installed in a way that soil disturbance is minimized, and therefore reduces potential of corrosion. In addition, helical piles are first designed to resist torque, which requires way more material (shaft thickness) than what is required to resist tension or compression loads.

The most common types of corrosion protective coating of helical piles are Hot-dipped galvanization or epoxy.

References

1. Buckling

Euler Buckling equation: $P_{cr} = \frac{\pi 2EI}{(kl)2}$

IBC Code and AISC:

$$P_n = A_g F_{cr}$$

For $\lambda_c \leq 1.5$ $\quad F_{cr} = (0.685\ \lambda_c^2)\ F_y$

For $\lambda c > 1.5$ $\quad F_{cr} = \left[\frac{0.877}{\lambda c2}\right] F_y$

$$\lambda_c = \frac{kl}{r\pi}\sqrt{\frac{Fy}{E}}$$

Where:

A_g : Gross cross section area of pile shaft

F_{cr} : Critical buckling stress

F_y : yield strength of pile shaft

r : Radius of gyration of pile shaft

k : Effective length factor

E : Modulus of elasticity of pile shaft

<u>Davisson Method</u>:

$$P_{cr} = U_{cr} \times (EI/R^2)$$

Where:

U_{cr} : Dimensionless factor

$R^4 = \frac{EI}{kh \ x \ d}$

K_h : Modulus of subgrade reaction

d : Pile diameter

2. Lateral capacity:

<u>Broms equations for fined grained soil</u>:

$P_L = 9cdf$

M_{max} = 9cd(g/2)2

M_{max} = PL (e +1.5d +0.5f)

L = 1.5d + f + g

<u>Broms equation for coarse grained soil:</u>

$$P_L = \frac{\gamma d l^3 K_p}{2(e+L)}$$

3. Expansive soil

$$P_u = \pi d_{eff} d_w\ \alpha_0 P_s - P_{dead}$$