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1. What are the four methods used to determine the soil axial capacity of a helical pile? Explain how each method differs from the others.

The four methods used to determine the soil axial capacity of a helical pile are:
1. Individual Bearing Plate Method
2. Cylindrical Shear Method
3. Capacity-Torque Correlation Method
4. Load Test

The failure mechanism in the individual bearing plate method assumes that each individual helical plate displaces the soil in a characteristic deep bearing capacity failure mode. The ultimate bearing capacity of the pile is then the sum of the individual bearing capacities of all the helical plates, which are acting separately from each other. the individual bearing plate method uses traditional soil mechanics (Terzaghi's bearing capacity equation) to compute the soil pile capacity.
The cylindrical shear method assumes that the entire volume of soil between the upper and lower helices is mobilized. The ultimate capacity of the pile is then equal to the sum of the shear forces along the soil cylinder encompassed between the upper and lower helical plates plus the bearing capacity of the upper helix.
The capacity-torque correlation is an empirical method based on test result analysis. it basically relates the final installation torque to the ultimate pile capacity via a parameter Kt that has become known as the capacity -to-torque ratio. The parameter Kt used in the helical pile industry is based on the pile shaft size only. new researches have shown that factors such as installation torque, helix configuration, axial load direction , soil type can have an effect on the Kt parameter.
For helical piles, load tests used are usually the ASTM D1143 (compression) and ASTM D3689 (tension). From the load deflection curve, the ultimate capacity of the pile is determined based on some criteria. In the helical pile industry, the 10% net deflection criteria is usually used, as described in AC358.

2. The capacity-torque correlation method usually results in a more accurate prediction of the pile capacity in tension rather than in compression. Why?

During the installation of the pile, the torque is measured up to the final depth of the pile. The lead helix (bottom helix) rests on relatively undisturbed soil. we do not know what the torque is beneath the bottom helix. In tension application, the torque is measured up to the final depth of the pile and using the capacity torque relationship will result in more accurate prediction than in compression application, because the torque below the bottom helix is basically unknown.

3. One of the most significant attributes of helical piles is the relationship between pile capacity and installation torque. What does the correlation factor, Kt, depend on?How is it determined?

Currently, in the helical pile industry, the used correlation factor, Kt, is dependent only on the shaft diameter. This is also stated in the acceptance criteria AC358 published by ICC-ES. New researches (see Moncef 2019) have shown that the correlation factor, Kt, depends on the shaft diameter, final installation torque, helix configuration axial load direction (compression or tension), and soil type.
The correlation factor, Kt, is usually determined by load testing.

A helical pile, comprised of a 2-7 /8" O.D. shaft with a single 14" helix, was installed to a final depth of 30 ft. What is the allowable axial compression capacity of this pile using a safety factor of 2.5?

The single 14" helix is installed at 30 feet deep in sand. The blow count, N, at this depth is 15. Using the empirical relationship between N and friction angle, we get:
friction angle = 0.36*15 +27 = 32.4. Using the correlation between Nq and friction angle, we get Nq = 17.9
assuming c =0, ultimate capacity = A*q*Nq, where A = projected area of the helix, q = over burden pressure at the helix depth and Nq is the bearing capacity factor. The projected area is the area of the helical plate in contact with the soil minus the cross sectional area of the shaft. For a single 14" helix welded to a 2-7/8" O.D shaft, A = 1.02 square feet. The overburden pressure at 30 ft deep = 5*70 + 10*90 +10*115 = 2,400 lbs/sq ft.
The ultimate capacity = A*q*Nq = 1.02*2,400*17.9 = 43,820 lbs.
Using a safety factor of 2.5, the allowable axial compression capacity is: 43,800/2.5 = 17,530 lbs.

5. A helical pile comprised of a 3.5" O.D. shaft with 1 0", 12" & 14" helices was installed to a final termination torque of 10,000 ft-lb. The pile was then tested in tension. The test was stopped when the total pile deflection reached 1.0". The measured ultimate capacity at 1.0" total deflection was 63,000 Lbs. The

owner complained that he thought the traditional Kt value for the 3.5" O.D. shaft was 7.0, but he got only 6.3. Which answer is correct? Explain.

This is more of a trick question. First, the correlation factor Kt is defined as the ultimate capacity, Q, divided by the final installation torque. In this case, we have the final installation (termination) torque. We need the ultimate capacity,Q, to be able to determine Kt. We need to remember that Q, used in the determination of Kt, is defined as the ultimate capacity of the pile corresponding to a net deflection equal to 10% of the average helix diameters. This is the standard used in the helical pile industry and clearly stated in AC358. The helix configuration consists of 10", 12" & 14". the average is 12". 10% of the average diameters is 1.2". In our case here, the test was stopped at a total deflection of 1.0", way before the net deflection of 1.2". Depending on the length of the pile, the test must go beyond 1.2" total deflection so that we can get 1.2" net deflection when we subtract the elastic lengthening of the pile. From the standard definition of ultimate capacity (at net deflection equal to 10% of average helix diameters), the owner's Kt factor of 6.3 is incorrect. Since the test was stopped early (way before a net deflection of 1.2"), we don't know what Kt value we will obtain. but the standard Kt value for a 3.5" O.D shaft is 7.

The design working load is given as 27 Kips in compression and the safety factor is 2. The pile consists of a 2-7 /8" O.D. shaft. The helices available are 8", 1 O", 12" and 14". The helical pile final installation depth will be in the very stiff clay layer. What is the helix configuration needed to support the working design load? Assume spacing between helices is 3D.

Given the safety factor = 2 and the design working load = 27 Kips, the ultimate load will be = 27 * 2 = 54 Kips. Spacing between helices is 3D, which means individual bearing plate method will be used. Since friction angle is zero, the qNq term will be zero. Therefore, the ultimate capacity will be, Q = A*c*Nc. Assume Nc =9. c is given as 3,000 lb/sq ft.
let's try 10', 12' & 14". The projected area of each helix is 0.5, 0.74 & 1.02 sq ft respectively. the total area of the helices is 2.26 sq ft. The ultimate capacity of this helix configuration is: Qult = 2.26*3,000*9 = 61,000 lbs = 61 Kips which is larger than 54 Kips. Therefore, the 10", 12", & 14" helix configuration is valid to support the given design working load.
Other helix configurations are possible.

The design working load is 40 Kips in compression and the safety factor is 2. The pile consists of a 3.5" O.D. shaft. The helices available are 8", 1 0", 12" and 14". The helical pile final installation depth will be in the dense sand. What is the helix configuration needed to support the working design load? Assume spacing between helices is 3D.

As in the previous problem, given the spacing of helices of 3D, the individual bearing plate method will be used. Given c = 0, therefore the cNc term will be zero. The ultimate pile capacity will be equal to Q = A*q*Nq. The design working load is given as 40 Kips and safety factor as 2. This requires an ultimate load = 2*40 = 80 Kips. The friction angle is given as 38 degrees. This gives us an Nq = 37. Let's start with an 8", 10" & 12" helix configuration.The projected area for each helix is 0.28, 0.48, & 0.72 sq ft respectively. let's calculate the effective overburden pressure for each helix. Assume the pile depth is 20 feet.
q8" = 5*110 + 5*115 + 3*(125-62.4) + 7* (130-62.4) = 1,786 lb/sq ft
q10" = 5*110 + 5*115 + 3*(125-62.4) + 5*(130-62.4) = 1, 650 lb/sq ft
q12" = 5*110 + 5*115 + 3*(125-62.4) + 2.5*(130-62.4) = 1,481 lb/sq ft
The ultimate capacity is then equal to, Qult = 0.28*1,786*37 + 0.48*1,650*37 + 0.72*1,481*37 = 87,260 lbs = 87.26 Kips which is larger than 80 Kips. Therefore, 8", 10" & 12" helix configuration is valid to support the given design working load of 40 Kips.
Other helix configurations are possible.

What is the measured capacity-to-torque ratio, Kt? What is the deflection at the working load assuming a safety factor of 2?

The ultimate capacity is defined as the applied load that causes a net deflection equal to 10% of the average helix diameters. Here, we have an 8",10", 12" helix configuration. The average diameter is 10". The net deflection at 10% is equal to 1". Net deflection (red line on the curve above) is defined as the measured total deflection (blue line on the curve above) minus the elastic shortening (compression) or lengthening (tension) of the pile. From the curve above, at 1" net deflection, the applied load is about 35,000 lbs. The capacity-torque ratio, Kt, is defined as the ultimate capacity at 10% net deflection divided by the final installation torque. In our case here, Kt is equal to 35,000/ 3,300 =10.6.
The ultimate capacity is found to be 35,000 lbs. With safety factor of 2, the working design load is 17,500 lbs. From the load-deflection curve above, the total deflection at an applied load of 17,500 lbs is found to be about 0.28".

9. Using the modified Kt by Moncef (2019), what is the ultimate capacity of the installed pile in question 8?

This is a Round shaft (2-7/8" O.D) with multi-helix configuration and tested in tension. This falls under RMHT. At 3,300 ft-lb torque, and using Moncef's modified Kt, the ultimate capacity of the pile is found to be 31,350 lbs.

Assuming a spacing of 3D between the helices, what is the ultimate tension capacity of this pile using the Individual Bearing Method? Assuming a spacing of 1.5D between the helices, what is the ultimate tension capacity of the pile using the Cylindrical Shear Method? Assume Ko = 1- sinΦ.

1. Individual Bearing Plate Method:
For the 3.5" O.D shaft, the areas of the 8", 10", & 12" are 0.28 sq ft, 0.48 sq ft & 0.72 sq ft, respectively. For a friction angle of 36 degrees, Nq is 28.6. The depth of the helices are: 8" helix is at 20 ft, 10" helix is at 18 ft (20' - 3*8") & the 12" helix is at 15.5 ft (18' -3*10"). since we are not given soil density above 15 ft deep, assume that the soil from ground surface to 15 ft is loose to medium sand with an average density = 110 lb.cu ft. So the ultimate capacity of each helix are:
8" helix: qult = A*q*Nq = 0.28* (15'*110 + 5' * 120) * 28.6 = 18,000 lbs
10" helix : qult = A*q*Nq = 0.48 * (15'*110 + 3'*120)*28.6 = 27,600 lbs
12" helix: qult = A*q*Nq = 0.72*(15'*110 + 0.5*120)*28.6 = 35,200 lb
The ultimate tension capacity of the pile is Qult = 18,000 + 27,600 + 35,200 = 80,800 lbs.
2. Cylindrical Shear Method:
Assume the cylinder encompassed between the upper and lower helix has a 10" diameter which is the average of the 3 helices. the height of the cylinder is 27" (1.5*8 + 1.5*10). For dry dense sand, Ko is about 0.5. The ultimate tension capacity of the pile is the sum of the shear strength along the cylinder of the soil between the helices and the bearing capacity of the upper helix. The bearing capacity of the upper helix (12" helix) is already determined as 35,200 lbs. The shear strength along the cylinder is computed as follows: the overburden pressure q is computed at the mid-height of the cylinder, that is at 18.875 ft depth. Therefore, q = 15'* 110 + 3.875 *120 = 2,115 lb/sqft. D = 10"/12 = 0.833 ft. H= 27"/12=2.25 ft. The tangent of 36 degrees is 0.726. Using the cylindrical shear formula for the ultimate capacity, we find:
Qult = 3.14*0.833*2.25*(0.5*2,115*0.726) + 35,200 = 39,700 lbs.