Step 4 – Bearing Capacity

Calculating Helical Screw Foundation Capacity

The capacity of a helical screw foundation is dependent on the strength of the soil. The soil strength can be evaluated by use of various techniques and theories [Clemence (1985)]. The approach taken herein will be to assume that the soil failure mechanism will follow the theory of general bearing capacity failure and that the behavior will be as a deep foundation, i.e. installation depth below grade greater than 5 times the diameter of the largest helix. Following is Terzaghi's general bearing capacity equation which allows determination of the ultimate capacity of the soil. This equation and its use will be discussed in this section.

$$Q_{ult} = A_h \left(cN_c + q'N_q + 0.5\gamma'BN_\gamma \right)$$

 $\begin{array}{ll} \mbox{Where:} & Q_{ult} = \mbox{Ultimate Capacity of the Soil} \\ A_h = \mbox{Projected Helix Area} \\ c = \mbox{Soil Cohesion} \\ q' = \mbox{Effective Overburden Pressure} \\ \gamma' = \mbox{Effective Unit Weight of the Soil} \\ B = \mbox{Footing Width (Base Width)} \\ \mbox{and } N_c, N_q, \mbox{ and } N_\gamma \mbox{ are Bearing Capacity Factors} \end{array}$

Following is quoted from Bowles (1988) concerning Equation 4.1 where the various terms of the bearing capacity equation are distinguished.

- "1. The cohesion term predominates in cohesive soil.
- 2. The depth term $(q'N_q)$ predominates in cohesionless soil. Only a small D [vertical depth to footing or helix plate] increases Q_{ult} substantially.
- 3. The base width term $0.5\gamma'BN_{\gamma}$ provides some increase in bearing capacity for both cohesive and cohesionless soils. In cases where B < 3 to 4 m this term could be neglected with little error."

The base width term of the bearing capacity equation is not used when dealing with the helical screw foundation because as Bowles indicates, the resulting value of that term is quite small.

Note: The effective overburden pressure (q', of consequence for cohesionless soils) is the product of depth and the effective unit weight of the soil. The water table location may cause a reduction in the soil bearing capacity. The effective unit weight of the soil is its insitu unit weight when it is above the water table. However, the effective unit weight of soil below the water table is its in-situ unit weight less the unit weight of water.

Concern can develop when a helical screw foundation installation is terminated above the water table with the likelihood that the water table will rise with time to be above the helix plates. In this situation, the helical screw foundation lead section configuration and depth should be determined with the water at its highest anticipated level. Then the capacity of the same helical screw foundation should be determined in the same soil with the water level below the helical screw foundation, which will typically produce higher load capacities and a more difficult installation, i.e. it will require more installation torque. It is sometimes the case that a larger helical screw foundation family, i.e. one with greater torque capacity, must be used in order to facilitate installation into the dry conditions.

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(Equation 4.1)

Provided that helix spacing on the helical screw foundation shaft is \geq 3 helix diameters, the capacity of individual helices on a multi-helix screw foundation may be summed to obtain the total ultimate capacity of a specific helical screw foundation thusly:

$$Q_t = \sum Q_h$$
 (Equation 4.2)

Where: 0

 Q_t = Total Ultimate Multi-Helix Screw Foundation Capacity Q_h = Individual Helix Capacity

The ultimate capacity of an individual helix may be evaluated as per the following equation. An upper limit for this capacity is based on helix strength that can be obtained from the manufacturer. See Chart 8.3 for helix strengths.

$$Q_{h} = A_{h} (cN_{c} + q'N_{q}) \le Q_{s}$$
 (Equation 4.3)

 $\begin{array}{ll} \mbox{Where:} & A_h = \mbox{Projected Helix Area} \\ & Q_s = \mbox{Capacity Upper Limit, determined by Helix Strength} \end{array}$

Non-Cohesive Soil

Determination of helix capacity in a non-cohesive or granular soil can be accomplished with the following equation in which the cohesion term has been eliminated.

$$Q_h = A_h q' N_q = A_h \gamma' D N_q$$

Where:

 A_h = Projected Helix Area γ' = Effective Unit Weight of the Soil P_{i} = Vertical Depth to Helix Plate

D = Vertical Depth to Helix Plate

 N_q = Bearing Capacity Factor for Non-Cohesive Component of Soil

The bearing capacity factor N_q is dependent on the angle of internal friction (ϕ) of the cohesionless soil. When a value is provided for the friction angle, Figure 4.1 (N_q vs. ϕ Graph) may be used to determine the value for N_q .

When the angle of internal friction is not known, it may be estimated using blow counts obtained from the Standard Penetration Test per ASTM D 1586. Following is an equation that allows an estimate of the angle of internal friction. This equation is based on empirical data given by Bowles(1968) and its results should be used with caution.



(Equation 4.4)



 $\phi = 0.28 \text{ N} + 27.4$

(Equation 4.5)

The graph in Figure 4.1 allows the determination of N_q for a specific angle of internal friction when measured in degrees. This curve was adapted from work by Meyerhof (1976). Equation 4.6 was written for the curve shown in Figure 4.1, which is Myerhof's N_q values divided by 2 for long term applications.

$$N_q = 0.5 (12 \text{ x } \text{ø})^{\text{ø}54}$$
 (Equation 4.6)

 $\begin{array}{lll} \mbox{Where}: & N_q = \mbox{Bearing Capacity Factor for Non-Cohesive Component of Soil} \\ & \ensuremath{ \phi = Angle of Internal Friction} \end{array}$

Cohesive Soil

Determination of helix capacity in a cohesive or fine-grained soil can be accomplished with Equation 4.3 with the second term eliminated. When this equation is applied to helical screw foundations, the N_c factor is taken to be 9, as it is in other deep applications.

$$Q_h = A_h c N_c = A_h c 9 \qquad (Equation 4.7)$$

 $\begin{array}{ll} \mbox{Where:} & A_h = \mbox{Projected Helix Area} \\ c = \mbox{Cohesion} \\ N_c = \mbox{Bearing Capacity Factor for Cohesive Component of Soil} = 9 \end{array}$

In the event that cohesion values are not available, the following equation can be used to obtain estimated values when blow counts from ASTM D 1586 Standard Penetration Tests are available. This equation is based on empirical values and is offered only as a guide when cohesion values are otherwise not available. It is suggested that results be used with caution. The reader is urged to seek cohesion values obtained by other means.

c (ksf) = N / 8 (Equation 4.8)

Where:c = CohesionN = Blow Count Value per ASTM D1586 Standard Penetration Test

Mixed or c - ø Soil

The determination of the bearing capacity of a mixed soil, one that exhibits both cohesion and friction properties, is accomplished by use of equation 4.3. This is fairly uncomplicated when accurate values are available for both the cohesion and friction terms of the equation. Unless the designer is quite familiar with the project soil conditions, it is recommended that another approach be taken when accurate values are not available for both terms of the equation.

One suggestion is to first consider the soil as cohesive and determine capacity. Then consider the same soil as cohesionless and determine capacity. Finally, take the lower of the two results and use that as the soil bearing capacity and apply appropriate safety factors, etc.



Reasonability Check

Consideration should be given to the validity of the values obtained when determining the bearing capacity of the soil. The calculated theoretical ultimate capacity is no better than the data used to obtain that value. Data from boring logs, the water table depth, and load information may not accurately represent actual conditions where the helical screw foundation must function. Empirical values that are used and estimates of strength parameters, etc. that must be made because of lack of data affect the calculated bearing capacity value.

An important step in the process of determining the capacity of a helical screw foundation is to conduct a reasonability check. One should use the best engineering judgment that they possess to perform the reasonability check. This should be based on experience, historical test data and consulting colleagues. This is easily overlooked but must be performed by the designer or by others.

Once the capacity of the helical screw foundation is determined, concern may turn to location of the foundation element with respect to the structure and to other screw foundations. It is recommended that the spacing between adjacent screw foundations be no less than five times the diameter of the largest helix from center to center. The minimum spacing is three diameters. This latter spacing should be used only when the job can be accomplished no other way and should involve special care during installation to insure that the spacing does not decrease with depth. Minimum spacing requirements apply only to the helix bearing plate(s), i.e. the screw foundation shaft can be battered to achieve minimum spacing. Spacing between the helical screw foundation and other foundation elements, either existing or future, requires special consideration and is beyond the scope of this section.

Factor of Safety

The discussed equations are used to obtain the ultimate capacity of a helical screw foundation. An appropriate safety factor must be applied to reduce the ultimate capacity to an acceptable design (or working) capacity. The designer determines the safety factor to be used. In general, a minimum safety factor of 2 is recommended.

HeliCAP[™] Engineering Software

The various equations, factors, empirical values, etc. presented herein are the very algorithms used in a computer program $\operatorname{HeliCAP}^{\mathbb{M}}$ Engineering Software. This program makes the selection of a helical screw foundation quicker than making hand calculations. The program allows the opportunity to quickly make calculations while varying the different parameters to arrive at the most appropriate solution.

The computer program will assist in determining an appropriate helical lead configuration and overall screw foundation length. It also provides an estimate of the installation torque. The helical lead configuration can vary by the number and sizes of helix plates required to develop adequate capacity. Helical screw foundation length may vary due to the combined effects of the lead configuration and soil strength. Generally speaking, the smaller the lead section for a given load, the better the performance will be in regard to deflection under load.

Following are various screens from the ${\rm HeliCAP}^{{}^{\rm TM}}$ program that illustrate the progression of program use.



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Screen 1 shows first program screen that opens after an application button (Compress, Tension, Tieback, or Soil Nail) button has been clicked and a file name has been entered.



Screen 2 gives view with job name, boring, installation angle, datum depth, and anchor length values in appropriate locations.





Screen 3 shows the pull down chart that allows input and modification of soil profile parameters. The "Profile" button allows access to this chart.



Screen 4 gives a picture of the soil data presented graphically. This is accomplished by clicking on the "Profile" button again.





Screen 5

By clicking on the "Family" button, a pull down menu is displayed that allows choice of anchor family and lead section configuration.



Screen 6

A lead section configuration has been chosen and input. The program now contains enough information to make a run.





Screen 7

Pushing the run button produces this graphical representation of depth vs. load and depth vs. torque.



Screen 8 shows the chart giving anchor capacity at the input depth, etc. This is displayed by clicking the "Table" button.





This sheet is a printout of the job input data and the anchor capacity.

			HeliC	AP SUMN	IARY REF	PORT	
Job Name: Sample Job					C:\Documents and Settings\jlgoen\My Documents\ 1/29/2003		
Job Number:							
Boring No: B-1							
Anchor Use: Co	ompression						
Capacity Summary							
Anchor Number	Anchor Family	H D (fi	elix epth t)	Helix Capacity (kips)	Total Anchor Capacity (kips)	Recommended Ultimate Capacity (kips)	Torque (ft-lbs)
Anchor 1	Angle: 90 Datum Dep Length: 20	oth: 0					
14" helix	SS 5	12		18.4t			
12" helix	SS 5	15	5	14.7t 17.3c 12.7t	E A 1+		
10" helix	SS 5	17	7.5				EE01
8" helix	SS 5	19.5		8.2t 8.4c	54.11 58.6c	54.11 58.6c	5561
				Soil Pr	ofile		
Top of Layer Depth	Soil Type	Cohesior (lb/ft2)	n N	Angl Inter Frict	e of nal ion	Unit Weight (Ib/ft3)	
(π) 0 5 10 15 20 25 30	Clay Sand Clay Mixed Sand Clay Clay	500 0 2125 200 0 2000 2875	0 15 17 0 0 0 23	(Deg 0 31.6 0 31 32 0 0	jrees)	80 105 114 0 60 106 120	

The HeliCAP^{$^{\text{M}}$} Engineering Software program calculates ultimate capacity and must have an appropriate safety factory applied. The program has additional features that allow its use for other applications. It is beyond the scope of this introduction to present all facets of the program.

For additional assistance, please refer to the Help screen or call Hubbell/Chance applications engineers.

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