[1] Experience has shown that in most cases the footing and stem wall foundation system that will withstand a given long term working load will withstand a pier installation force of up to 1.5 times that long term working load. If footing damage occurs during installation, the free span between piers ($L_{P\,MAX}$) may be excessive.

[2] It is recommended that $\mathbf{R}_{\mathbf{h\,MAX}}$ not exceed ($\mathbf{R}_{\mathbf{h\,ULT}}$ / 2) x 1.65 during installation without engineering approval.

Additional Notes:

Current practice by CHANCE® Civil Construction is to limit the unsupported pier pipe exposure to a maximum of 2 feet at the published working loads for the standard pier systems. The soil must have a SPT “N” of greater than 4. The pier pipe must be sleeved for pier pipe exposures greater than 2 feet and up to 6 feet and/or through the depths where the SPT value “N” is 4 or less. Sleeve must extend at least 36” beyond the unsupported exposure and/or the area of weak soil. If the anticipated lift is to exceed 4”, then the Atlas Resistance® Continuous Lift Pier System should be used.

Atlas Resistance® Piers can be located as close as 12" (305 mm) between adjacent piers to develop a "cluster" of load bearing elements.

CHANCE® HELICAL ANCHOR/PILE BEARING CAPACITY

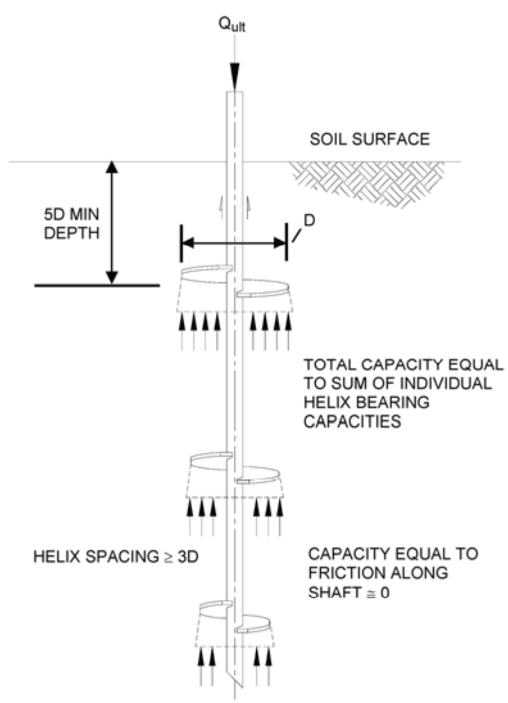


Plate Bearing Capacity Model (Compression)
Figure 5-3

The capacity of a helical anchor/pile is dependent on the strength of the soil, the projected area of the helix plate(s), and the depth of the helix plate(s) below grade. The soil strength can be evaluated by use of various techniques and theories (Clemence, 1985). The projected area is controlled by the size and number of helix plates. For helix depth, two modes of soil failure may occur: shallow and deep failure. The terms “shallow” and “deep” refer to the location of the bearing plate with respect to the earth’s surface. By definition, “shallow” foundations in tension exhibit a brittle failure mode with general eruption of soil all the way to the surface and a sudden drop in load resistance to almost zero. With “deep” foundations in tension, the soil fails progressively, maintaining significant post-ultimate load resistance, and exhibits little or no surface deformation. The dividing line between shallow and deep foundations has been reported by various researchers to be between three and eight times the foundation diameter. CHANCE® Civil Construction uses five diameters (5D) as the break between shallow and deep helical anchors/piles. The 5D depth is the vertical distance from the surface to the top-most helix. Whenever a Chance® Helical Anchor/Pile is considered for a project, it should be applied as a deep foundation for the following reasons:

1. A deep bearing plate provides an increased ultimate capacity in uplift or compression.
2. The failure at ultimate capacity will be progressive with no sudden decrease in load resistance after the ultimate capacity has been achieved.

The approach taken herein assumes that the soil failure mechanism will follow the theory of general bearing capacity failure. This theory suggests that the capacity of a helical anchor/pile is equal to the sum of the capacities of the individual helix plates. The helix capacity is determined by calculating the unit bearing capacity of the soil at each helix and then multiplying the result by the individual helix's projected area. Friction along the central shaft is typically not used to determine capacity, but may be included when the central shaft is round and at least 3-1/2" (89 mm) in diameter. Refer to *Calculating Helical Pile Frictional Capacity* later in this section. A necessary condition for this method to work is that the helix plates be spaced far enough apart to avoid overlapping of their individual "pressure bulbs", i.e., stress zones in the soil. This will prevent one helix from significantly influencing the performance of another. CHANCE® Civil Construction has determined that the optimum spacing between any two helical plates on a helical anchor/pile is three times the diameter of the lower helix. This is consistent with the findings of others (Bassett, 1977) for multi-belled concrete piers. For example, the distance between a 10 inch (254 mm) and 12 inch (305 mm) helix is three times the diameter of the lower helix, or 10 x 3 = 30 inches (762 mm).

The 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, as it forms the basis of determining helix capacity in soil.

$$Q_{ult} = A_h (cN_c + q'N_q + 0.5 \gamma ' B N \gamma) \quad \text{(Equation 5-6)}$$

where:
- Q_{ult} = Ultimate capacity of the soil
- A_h = Projected helix area
- c = Soil cohesion
- q' = Effective overburden pressure
- B = Footing width (base width)
- $\gamma '$ = Effective unit weight of the soil

and N_C, N_q, and $N\gamma$ are bearing capacity factors

Following is quoted from Bowles (1988) concerning *Equation 5-6* 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 $0.5\gamma ' B N_\gamma$ 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 anchors/piles 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 in-situ 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 anchor/pile 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 anchor/pile lead section configuration and depth should be determined with the water at its highest anticipated level. Then the capacity of the same helical anchor/pile should be determined in the same soil with the water level below the helical anchor/pile, 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 anchor/pile product series, i.e., one with greater torque capacity, must be used in order to facilitate installation into the dry conditions.

Provided that helix spacing on the helical anchor/pile shaft is ≥ 3 helix diameters, the capacity of individual helices on a multi-helix anchor/pile may be summed to obtain the total ultimate capacity of a specific helical anchor/pile thusly:

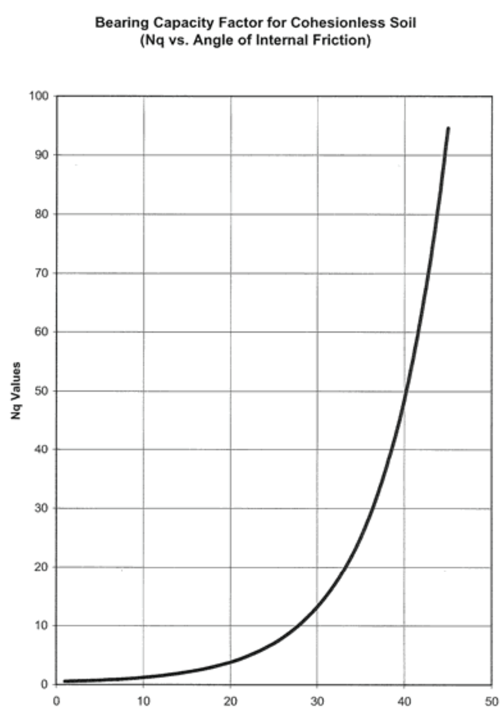
$$Q_t = \sum Q_h \qquad \text{(Equation 5-7)}$$

where: Q_t = Total ultimate multi-helix anchor/pile 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 *Tables 7-5 and 7-7* in *Section 7* of this Technical Design Manual for the mechanical strengths of helices.

$$Q_h = A_h\,(cN_c + q'N_q) \le Q_s \qquad \text{(Equation 5-8)}$$

where: A_h = Projected helix area
Q_s = Capacity upper limit, determined by the helix mechanical strength



Angle of Internal Friction (Degrees)
Figure 5-4

Non-Cohesive Soil

Determination of helix capacity in a non-cohesive or granular soil can be accomplished with *Equation 5-9* in which the cohesion term has been eliminated.

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 5-4* (Nq vs ϕ) may be used to determine the value for Nq.

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. *Equation 5-10* 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.

The graph in *Figure 5-4* 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 5-11* was written for the curve shown in *Figure 5-4*, which is Myerhof's N_q values divided by 2 for long term applications.

$$Q_h = A_h q' N_q = A_h \gamma' D N_q \quad \text{(Equation 5-9)}$$

where:
- A_h = Projected helix area
- D = Vertical depth to helix plate
- N_q = Bearing capacity factor for non-cohesive component of soil
- γ' = Effective unit weight of the soil

$$\phi = 0.28\,N + 27.4 \quad \text{(Equation 5-10)}$$

where:
- ϕ = Angle of internal friction
- N = Blow count per ASTM D 1586 Standard Penetration Test

$$N_q = 0.5\,(12 \times \phi)^{\phi/54} \quad \text{(Equation 5-11)}$$

where:
- N_q = Bearing capacity factor for non-cohesive component of soil
- ϕ = Angle of internal friction

Cohesive Soil

Determination of helix capacity in a cohesive or fine-grained soil can be accomplished with *Equation 5-8* with the second term eliminated. When this equation is applied to helical anchors/piles, the N_c factor is taken to be 9, as it is in other deep applications, provided the installation depth below grade is greater than five times the diameter of the top most helix.

$$Q_h = A_h c N_c = A_h c 9 \quad \text{(Equation 5-12)}$$

where:
- A_h = Projected helix area
- c = Cohesion
- N_c = Bearing capacity factor for cohesive component of soil = 9

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.

$$c\,(\text{ksf}) = N / 8 \quad \text{(Equation 5-13)}$$

where:
- c = Cohesion
- N = Blow count value per ASTM D 1586 Standard Penetration Test

Mixed or c - ϕ 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 5-8*. 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 Factors of Safety, 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 anchor/pile 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. In those situations where soil data is insufficient or not available, a helical trial probe pile can help determine such items as, location of bearing strata, location of soft/loose soil, and the presence of obstructions, such as, cobbles, boulders, and debris.

An important step in the process of determining the capacity of a helical anchor/pile 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.

Helical Anchor/Pile Spacing

Once the capacity of the helical anchor/pile is determined, concern may turn to location of the foundation element with respect to the structure and to other helical anchors/piles. It is recommended that the center-to-center spacing between adjacent anchors/piles be no less than five times the diameter of the largest helix. The minimum spacing is three feet (0.91 m). This latter spacing should be used only when the job can be accomplished no other way and should involve special care during installation to ensure that the spacing does not decrease with depth. Minimum spacing requirements apply only to the helix bearing plate(s), i.e., the anchor/pile shaft can be battered to achieve minimum spacing. Spacing between the helical anchors/piles and other foundation elements, either existing or future, requires special consideration and is beyond the scope of this section.

Group effect, or the reduction of capacity due to close spacing, has never been accurately measured with helical piles. However, bearing capacity theory would indicate that capacity reduction due to group effect is possible, so it's considered good practice to install helical piles into dense bearing stratum when center-to center spacing is less than 4 feet (1.2 m).

FACTOR of SAFETY

The equations discussed above are used to obtain the ultimate capacity of a helical anchor/pile. An appropriate Factor of Safety must be applied to reduce the ultimate capacity to an acceptable design (or working) capacity. The designer determines the Factor of Safety to be used. In general, a minimum Factor of Safety of 2 is recommended. For tieback applications, the Factor of Safety typically ranges between 1.25 and 2.

Design or working loads are sometimes referred to as *unfactored loads* and ***do not include any Factor of Safety***. They may arise from dead loads, live loads, snow loads and/or earthquake loads for bearing (compression) loading conditions; from dead loads, live loads, snow loads and/or wind loads for anchor loading conditions; and earth pressure, water pressure and surcharge loads (from buildings, etc.) for helical tieback or Soil Screw® earth retention conditions.

Ultimate loads, sometimes referred to as *fully factored loads*, already fully incorporate a Factor of Safety for the loading conditions described above. CHANCE® Civil Construction recommends a minimum Factor of Safety of 2.0 for permanent loading conditions and 1.5 for temporary loading conditions. This Factor of Safety is applied to the design or working loads as defined above to achieve the ultimate load requirement. National and local building code regulations may require more stringent Factors of Safety on certain projects.