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GroundED

THE SUPPORTWORKS NEWSLETTER FOR DESIGN PROFESSIONALS

Bearing Capacity Factors for Helical Pile Design

Helical Pile Capacity: It has been our experience that most design professionals utilize the individual bearing method in calculating the end bearing capacity of a helical pile. That is also certainly true for the engineers at Supportworks. The individual bearing method states that the ultimate pile capacity is equal to the sum of the individual helix plate capacities, using the helix plate area and cohesive strength and overburden pressure parameters multiplied by dimensionless bearing capacity factors. The simplified form of the individual bearing method is:

$$Q_u = \sum A_h(cN_c + q'N_q)$$

Where,

Q_u = Ultimate Pile Capacity (lb)

c = Cohesion at Helix Depth (lb/ft^2)

q' = Effective Vertical Overburden Stress at Helix Depth (lb/ft^2)

A_h = Area of Helix Plate (ft^2)

N_c, N_q = Dimensionless Bearing Capacity Factors

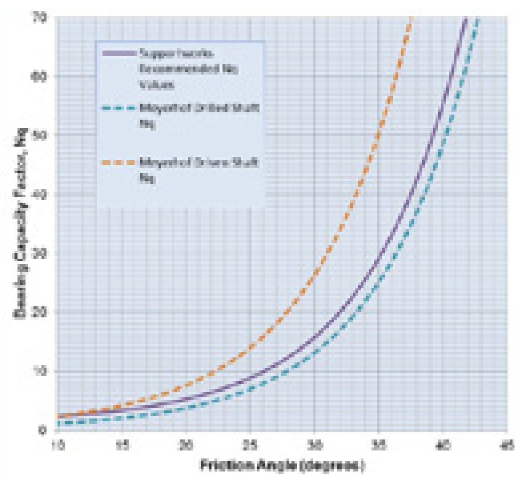
The equation was first introduced by Karl Terzaghi in 1943 for shallow foundations with bearing capacity factors for cohesion (N_c) and overburden pressure (N_q) dependent upon the soil friction angle (ϕ). Later research has shown that these bearing capacity factors may not only be a function of the soil friction angle, but also pile embedment depth, pile type, pile geometry and installation method.

Bearing Capacity Factor N_q: Open up any foundation design textbook and you'll likely find tables listing a wide range of N_q factors based on several researchers' methods. These N_q values are typically based on specific pile types and installation methodologies that may not be representative of helical pile foundations. So what would be considered appropriate?

There has been little research to determine how N_q might vary for helical piles. However, since helical piles are generally considered low displacement piles, due to the lack of spoils during installation, it would seem appropriate to consider N_q values for driven piles with a reduction to account for soil disturbance created by the helix plates. A research paper written by George Meyerhof in 1976 provides a comprehensive analysis of the N_q bearing capacity factors for driven piles and a recommendation for a 50% reduction of N_q values for drilled shaft piles versus driven piles. Taking Meyerhof's work into account, Supportworks recommends using the following equation to determine N_q:

$$N_q = 1 + 0.56(12\phi)^{\phi/54}$$

Figure 1



The N_q values recommended by Supportworks are between the values proposed by Meyerhof for drilled and driven shafts (Figure 1).

Bearing Capacity Factor N_c: There is general agreement in the geotechnical community that, for driven or bored deep foundations with a tip depth of at least five diameters, N_c is equal to nine for saturated cohesive soil if the soil friction angle is equal to zero.

$$N_c = 9, \text{ when } \phi = 0$$

For mixed soils (soils with cohesion and friction angle) the Terzaghi equation for N_c (shown below) is commonly used. It should be noted that since this equation is dependent upon the modified N_q values discussed above, the results will be more conservative than Terzaghi's original N_c values.

$$N_c = (N_q - 1)\cot\phi \geq 9$$

Supportworks has provided helical pile designs for thousands of successful projects using the individual bearing method and the recommended bearing capacity factor equations discussed in this article. For more information related to the use of the individual bearing method to determine helical pile capacity, please see Section 1.7.1 of the 2017 Supportworks Technical Manual.

DONALD A. DEARDORFF, P.E., SENIOR APPLICATION ENGINEER

Project: Strip Mall Renovation
Location: Twin Oaks, MO
Pile Installer: Foundation Supportworks® by Woods

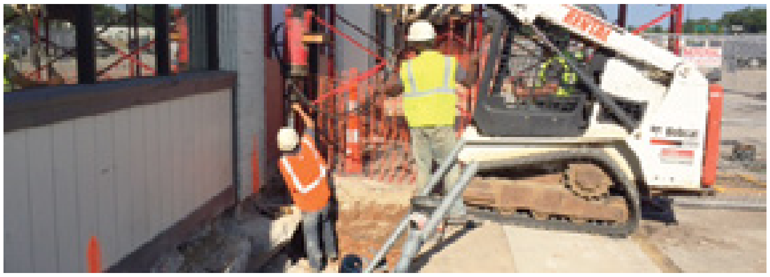
Challenge: The "Villages of Twin Oaks" development project was planned southeast of the Big Bend Road and Missouri State Route 141 interchange. The new development would include buildings for residential apartments and retail sales and the renovation of the storefront of an existing strip mall. The renovation would include five wall bump outs extending nine feet north of the north wall line with lengths ranging from 37 to 85 feet. The façade in the remaining areas of the 386 feet of front wall would also be updated. This work would be completed while allowing uninterrupted access to the businesses occupying the strip mall.

Nine test borings were completed for the proposed new buildings northwest of the strip mall. Three borings closest to the strip mall indicated a general subsurface profile consisting of approximately three feet of clay fill over nine to 19 feet of medium stiff to stiff clay over very stiff clay (weathered bedrock) to the termination of the test borings.

Deep foundations were proposed to support the additional load that will be placed on or immediately adjacent to the footings along the existing north wall line. The new pile caps and grade beams would be doweled into the existing footings to prevent differential movement between the additions and existing building. The proposed columns nine feet north of the north wall line would be supported on spread footings.

Solution: Helical piles were considered the ideal deep foundation option given the soil conditions, required capacities, anticipated pile production rate and the smaller installation equipment that could be used to access and maneuver within the tight working space. The helical pile design consisted of the Model 288 (2.875-inch OD by 0.276-inch wall) hollow round shaft with 8"-10" double-helix lead sections to support the design working compression load of 15 kips. Twelve piles were installed to depths of about 14 to 17 feet to exceed the target installation torque of 3,400 ft-lb. The torque-correlated ultimate capacities then exceeded the design working load by factors greater than 2.0 (FOS > 2). The piles were either advanced to depth to set the top of pile elevation, or the completed piles were cut off at the design elevation. New construction brackets were set on the tops of the piles to be cast into concrete. The 12 helical piles were installed within one day.

Connecting drive head to helical lead section



Tracked skid steer maneuvers easily within construction area

Advancing helical extension

Completed piles with new construction brackets

Completed piles with new construction brackets

Upcoming Webinar Opportunities

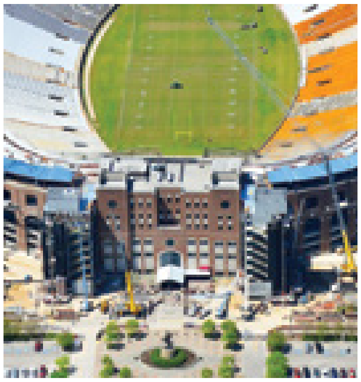
- **An Introduction to Helical Foundation Systems**
  1^{st} Wednesday of every month 11:30 am (CT) and 1:30 pm (CT)
- **An Introduction to Polyurethane Foam Injection**
  2^{nd} Wednesday of every month 11:30 am (CT) and 1:30 pm (CT)
- **An Introduction to Hydraulically Driven Push Pier Systems**
  3^{rd} Wednesday of every month 11:30 am (CT) and 1:30 pm (CT)

Compression load test

Advancing helical pile lead section

Installing helical piles within stadium

Piles installed and fitted with new construction brackets



Construction underway on south end of stadium (Image courtesy of Aero Photo)

Project: FSU Doak Campbell Stadium
Location: Tallahassee, FL
Pier Installer: Alpha Foundations

Challenge: Florida State University planned to enclose the south end of Doak Campbell Stadium to create the Champions Club Level which will offer over 5,000 premium seats, a 70,000-square-foot, air-conditioned club and 34,000 square feet of shaded rooftop terraces. The renovations would include additional foundation support to 14 existing column locations. Designers originally considered installing two auger-cast piles at each column to provide the additional support; however, low overhead clearance and narrow access points at some of the column locations made it too difficult to use standard auger-cast equipment. A geotechnical investigation identified highly variable soil conditions containing sands, clays, silts and organic material, also making it difficult to predetermine target depths for the auger-cast piles.

Solution: Helical piles can be installed quickly with relatively small equipment, making them the obvious choice to provide the additional column support. A load test was performed to verify pile capacity and depth. Each existing column location would include pile cap extensions supported by four helical piles. Each pile would support a design working load of 25 kips. The pile configuration consisted of Model 288 (2.875-inch OD by 0.276-inch wall) hollow round shaft with a 10"–12"–14" triple-helix lead section.

Standard extensions advanced the piles to depths from 14 to 21 feet to achieve torque-correlated ultimate capacities of at least twice the design working load (FOS ≥ 2). The piles were fitted with standard new construction brackets to be cast within the pile caps. Despite tight access and working conditions, 56 helical piles were installed within just four days.

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- Name of the firm
- Location of firm
- Approximate number of engineers/architects/GCs that will be in attendance

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What's inside

Bearing Capacity Factors for Helical Pile Design

Featured Case Studies:

- Strip Mall Renovation – Twin Oaks, MO
  Foundation Supportworks® by Woods
- FSU Doak Campbell Stadium – Tallahassee, FL
  Alpha Foundations

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