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Ideal Soil Profiles for Push Piers and Helical Piles

As a helical pile and push pier designer, I long for that soil profile that is "ideal" for the project. You may be wondering what I mean by an ideal soil profile; it is one that avoids having to design for adverse soil conditions. The ideal soil profile would vary between the two systems since push piers are typically compression-only systems, and helical piles may have compression and tension loading. So, let's start by first identifying some of the more common soil conditions that present challenges or require special design consideration for any deep foundation system and then get into the specifics of the ideal soil profile for helical piles and push piers.

Fluid Soils

In accordance with the International Building Code, buckling needs to be evaluated for compression-loaded piles in "fluid" soils. Fluid soils may be defined as any soil with a Standard Penetration Test (SPT) blow count of zero. The SPT is a common method of retrieving soil samples in the field during drilling operations while also providing correlations to several soil strength parameters. The SPT uses a specific amount of energy to drive a 2-inch O.D. split-barrel sampler a distance of 18-inches. The number of blows required to drive the sampler the final 12 inches is recorded as the standard penetration number, or N-value. So fluid soils may be identified as having an N-value of zero blows per foot (bpf). Fluid soils can occur naturally or be created by liquefaction during a seismic event. Earthquake-prone regions will often require a liquefaction analysis as part of the standard geotechnical report.

Expansive Soils

Many regions of the United States have highly expansive soils that can expand or contract with changes in moisture content (Figure 1). Foundations placed on expansive soils can experience settlement or heave during periods of moisture fluctuation. The geotechnical engineer should consider the depth of wetting in the soil profile, which is the zone that undergoes seasonal moisture fluctuations. Typically, expansive soils below the depth of wetting will have stable moisture and are not susceptible to volume changes. Deep foundations should bear below the depth of wetting to minimize pile movement due to swelling or expansion of the bearing soil. Piles may also need to be designed to resist any uplift forces that may occur from expansive soils in the zone of seasonal moisture fluctuation.

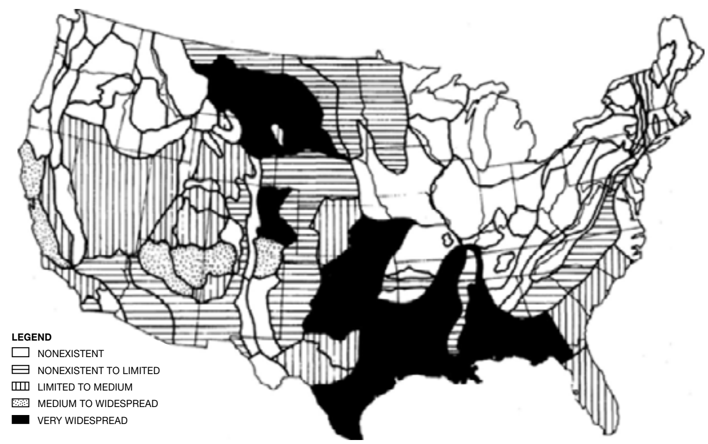

Figure 1: Expansive soil regions of the United States (from Witzcak, 1972)

Fill Soils

Most fill soils are placed with little or no compactive effort and may contain material not suitable for foundation bearing. The presence of building debris or cobbly material may require predrilling to facilitate the installation of a deep foundation system. Newly placed fill can also create consolidation of very soft soil layers below the fill. This can create a phenomenon called downdrag, which is an additional compression force created from the downward movement of these soils that needs to be considered in the pile design.

Layered Soil Profiles

Highly variable soil profiles can create design problems for deep foundations. For example, bearing in a dense stratum that is directly above softer strata can result in excessive settlement upon loading if the dense layer below the bearing depth is not thick enough. A very soft layer directly above a very dense layer is an issue for piles loaded in tension. The dense layer may restrict pile penetration and require bearing for uplift in the softer zone, significantly reducing tension capacity.

Loess Soils

Loess soils are wind deposited silts with a loose structure that may have high collapse potential upon wetting. One of the largest loess deposits in the United States is in the Midwest and Mississippi River Valley, as shown on the map below (Figure 2). When loess soils are present, the geotechnical engineer needs to evaluate specific soil parameters such as moisture content, unconfined compressive strength and soil unit weight to determine the suitability for pile bearing capacity. Loess soils can also be highly frost susceptible.

Figure 2

Now that we understand some of the soil conditions that can present challenges, let's discuss what we would like to see in our ideal soil profile for helical piles and push piers.

Push Piers

Push piers are advanced into the ground with hydraulic equipment exerting a steady downward force at the top of the pier. In order to provide competent bearing and minimize the potential for the push pier to punch through a seemingly competent but thin layer of soil, a minimum thickness of 10 to 15 feet of hard/dense material should be identified or known to exist. This material may consist of hard clays, dense to very dense sands, or competent bedrock. The required thickness and strength of this layer would increase with an increase in the required pier capacity. Typically, SPT N-values of 35 to 40 bpf for clay soils and 30 to 35 bpf for sand are required to provide end-bearing resistance for push piers. When laboratory tests are available, such as unconfined compression tests, undrained shear strengths in excess of 4,000 pounds per square foot (psf) are typically required to provide end-bearing resistance for push piers.

Helical Piles

Helical piles and anchors are advanced into the ground by the application of torque and downward force (crowd). Helical piles are best suited for medium dense sands and stiff to very stiff clay soils, although they can be effectively designed for bearing in very dense sands and hard clay. With proper design and installation techniques, helical piles may also be considered for bearing on or within soft or weathered bedrock. Additional helix plates are often needed along the shaft as the required pile capacity increases. Therefore, with higher pile capacities, the required thickness of the bearing zone increases. The soil profile should not only have sufficient soil strength surrounding the helix plates at the bearing depth, but there should also be suitable soil strength above the upper helix plate for tension loading and below the bottom helix plate for compression loading. Typically, N-values of 15 to 30 bpf for clay soils and 10 to 25 bpf foot for sand are preferred for providing the necessary end-bearing resistance for helical piles. When laboratory unconfined compression strength tests are available, undrained shear strengths ranging from 1,500 psf to 4,000 psf are preferred for the use of helical piles. However, higher or lower values may also be considered.

The good news is that the soil profile does not need to be "ideal." Helical piles and push piers are used successfully even when a project's soil profile presents some of the challenges discussed in this article. If you are considering either of these systems for your upcoming project, feel free to contact the Foundation Supportworks engineering team for preliminary design assistance.

DON DEARDORFF, P.E.

Project: **Central States Manufacturing**
Location: **St. Peters, MO**
Pile Installer: **Woods Commercial Division**

Challenge: A 53,600 square-foot structure for the manufacture of metal roofing and siding was planned for construction in St. Peters, Missouri. Approximately 18,000 square feet would be dedicated for the movement and storage of steel coils used in the manufacturing process. The original foundation design included shallow spread footings for all areas of the plant. However, during construction, it was determined that the coil rack storage areas could not be supported with shallow footings given the near-surface soil conditions. The construction of the building progressed while alternative deep foundation solutions were considered for the coil rack slab areas. These deep foundations would be installed after most of the building had been constructed, requiring smaller installation equipment for the limited access conditions. The deep foundations would also have to be installed with care around new interior column footings and shallow utilities. The final design called for five coil rack systems, with support slab areas ranging from 162 to 696 square feet. The slabs included a total of 110 piles with service compression loads of 60 kips/pile. The deepest boring advanced in the area showed stiff to hard fat clay to a depth of about 18 feet, where it became very soft clay to the termination depth of boring at 40 feet. Based on local experience, competent bedrock was believed to be present at a depth of about 60 feet, which served as the basis for the pile design.

Solution: Helical piles were selected as the preferred deep foundation alternative since the piles could be installed in the limited access areas, near existing foundations and utilities, and without concern of damage to the existing structure due to vibration. The helical piles could also be installed with smaller equipment than what would have been required for other deep foundation systems. Woods Commercial Division was contracted to install 110 helical piles for the five rack slab foundations. The helical pile design consisted of the Model 350 (3.5-inch OD by 0.340-inch wall) hollow round shaft with a 10” -12” -14” helix plate configuration. The helical piles were installed to lengths ranging from 52 to 57 feet after achieving torque-correlated ultimate capacities of at least twice the design working load of 60 kips. Phase 1 included the installation of 10 piles for the smallest of the coil rack slab areas. This work was completed as the design for the other areas was being finalized. The remaining 100 piles were installed in Phase 2 over a period of 10 days.

Building shell erected

Phase 1 helical piles being installed

Phase 2 area prepared for pile installation around spread footings

Installing helical piles around existing utilities (Phase 2)

Phase 1 coil rack foundation in service

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