



ACCELERATED BRIDGE CONSTRUCTION  
UNIVERSITY TRANSPORTATION CENTER

## ABC-UTC GUIDE FOR:

# HELICAL PILE FOUNDATION IMPLEMENTATION

**July 2021**

**End Date:** June 30, 2021

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### **ABSTRACT**

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This document summarizes the work activities undertaken in this Phase I study and provides a brief Guide for Helical Pile Foundation Implementation projects. The information will be of interest to designers, agencies, and contractors engaged on helical pile foundation accelerated bridge construction (ABC) projects.

Decision making tools were developed for the owner and/or engineer in the form of a flowchart and a table matrix. Together, these tools help direct decision making with respect to the suitability of helical piles as a deep foundation option. A series of questions was produced to draw attention to the particular points of emphasis to consider in choosing helical piles.

### **ACKNOWLEDGMENTS**

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The research study resulting in development of this guideline was supported by the US Department of Transportation through the Accelerated Bridge Construction University Transportation Center (ABC-UTC).



## 1. BACKGROUND AND INTRODUCTION

The number of current standard foundation options for bridge substructures is limited, thus reducing the potential time savings afforded through newer, less-common technologies. Although acceleration of bridge construction projects has greatly progressed, the potential for additional time savings still exists through the use of other methods, such as helical piles.

In addition to relatively rapid installation, the use of helical piles offers immediate capacity determination by using torque ratios upon installation and small maneuverable equipment. The required equipment for installation (skid steer, backhoe, or excavator) lends itself to quick deployment and being an economical solution (i.e., excavator vs. crane), which is an advantage for any bridge construction project, but particularly for low-volume roads where budgetary considerations tend to be a specific priority.

Simply stated, the ability for helical piles to support loads and be installed in areas that are otherwise difficult for other foundation technology installations has become attractive to engineers and owners of all types of projects. The continued use of helical piles is predictably high and the knowledge base is continually growing.

## 2. PROBLEM STATEMENT

Helical pile foundations have become commonplace in new commercial building construction and foundation repair applications with many foundation installers now offering this technology as one of their services. However, few bridge projects have been completed using helical piles despite their high capacities and speed of installation.

## 3. DECISION MAKING FRAMEWORK

Several deep foundation options exist from which engineers can select. It is likely one or two options have been the most commonly selected based on historical use and proven functionality. Introducing another option can introduce uncertainty if a suitable decision making framework is not available to the engineer. In such cases, the default will be to consider previously used deep foundation options.

Two tools to help direct the decision in consideration of helical piles were developed and are presented in this guide. First, the flowchart (Figure 1) provides a systematic step-through of questions and instructions to conclude whether the use of helical piles or another deep foundation system is most suitable.

Second, a matrix of questions (Table 1) is provided to help direct the engineer toward a decision of helical pile suitability. The questions are categorized by 1) Site and Constructability, 2) Geotechnical, and 3) Design Considerations. A response of Yes, No, Maybe, or N/A should be provided for each question.

Any questions answered as other than Yes do not discount helical piles from being used. Rather, additional considerations should be evaluated before a final decision is made. The commentary provided for each question provides additional information and instruction to assist the user in their decision.

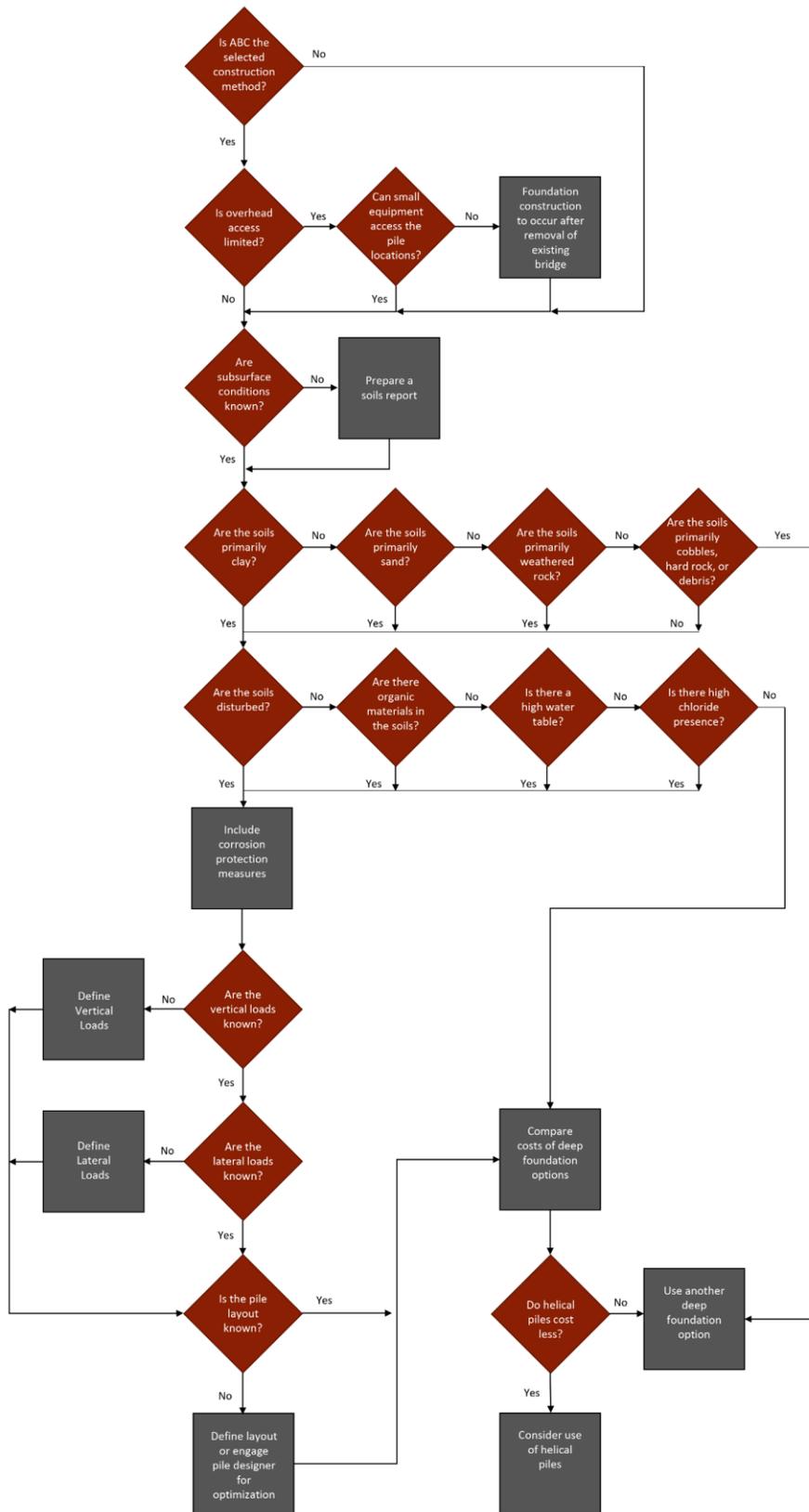


Figure 1. Flowchart for use of helical piles or another deep foundation system


**Table 1. Questions for helical pile suitability**

Question	Yes	No	Maybe	N/A	Commentary
<b>Site and Constructability</b>					
Does the site topography allow access for multiple types of smaller equipment? (mini-excavator, rubber-tired backhoe, small-tracked machine)					Helical piles can be and are most often installed without the use of larger equipment—an advantage to using helical piles if site access for larger equipment is difficult.
Does the schedule require accelerated construction of deep foundations?					Helical pile installation can be completed more quickly than more traditional deep foundation options.
Are there overhead obstructions?					Overhead obstructions may limit or prohibit the use of larger equipment. Helical piles can be installed in low-overhead-clearance conditions.
Can welding and torch cutting be safely conducted on site?					Welding and/or torch cutting may be necessary to complete helical pile installation and should be considered if these activities can be safely completed.
Can large equipment access the site? (excavator)					In some instances of high-capacity helical piles, a larger excavator may be required for installation.
<b>Geotechnical</b>					
Are the subsurface conditions known?					A soils report will provide the necessary information for helical pile design. Unknown subsurface conditions do not necessarily prohibit helical pile use. Rather, uncertainty will be introduced into preliminary design.
Is the soil cohesive (clay)?					Helical pile use is conducive to cohesive soils.
Is the soil non-cohesive (sands and gravels)?					Helical pile use is conducive to non-cohesive soils.
Is there a presence of cobbles, hard rock, or debris?					The presence of cobbles, hard rock, or debris does not necessarily prohibit the use of helical piles, but special attention should be paid to these soil conditions given a more suitable foundation option may exist. Typical penetration limits for helical piles are 70 psf ultimate bearing pressure.
If weathered rock is present, is the strength known?					Weathered rock can provide additional end bearing capacity to helical piles.
Is corrosion protection of the piles required?					It is typical for helical piles to be corrosion-protected prior to onsite delivery. This affords the piles more protection against corrosive environments.
Will the piles be installed into disturbed soils?					The oxygen content in disturbed soils is greater, which can lead to increased corrosion rates of unprotected steel.
Will the piles be installed into soils that contain cinders or high concentrations of organic materials?					Organic material can increase the rate of corrosion on bare and protected steel. Adding sacrificial thickness in severe conditions is common.



Question	Yes	No	Maybe	N/A	Commentary
Is the pile being installed into soils where the water table fluctuates and has appreciable salt content?					Corrosion of steel is accelerated in partial submersion zones. Sacrificial thickness and hot-dipped zinc galvanization can be used to protect the piles.
<b>Design Considerations</b>					
Is there a governing code for helical pile use/installation at the location of the bridge?					
Are the vertical loads for the foundation structure known or reasonably estimated?					Helical piles come in numerous sizes. The capacity is a function of size and soil conditions.
Are the lateral loads for the foundation structure known or reasonably estimated?					Battered helical piles can be used in cases where the lateral loads are significant.
Are overturning loads for the foundation structure known or reasonably estimated?					Helical piles offer significant tensile load capacity.
Is there a preferred pile layout?					Helical piles are generally adaptable to any preferred layout. However, the layout and pile size can be optimized if a specific layout is not required.
Is there a tolerable maximum displacement?					Helical piles offer similar maximum displacements as other deep foundation options.
Will multiple piles in single locations be allowed in the event of large loads?					Where large loads exist, helical pile sizes can be increased or multiple smaller piles can be used.
Will the pile layout be prescribed by the bridge designer?					A prescribed pile layout can be restrictive to a helical pile designer. Collaboration between the bridge designer and pile designer is recommended.
Can the pile spacing be optimized by the pile designer?					It is recommended that the helical pile designer be involved early on in order to optimize the pile size and layout.
Will battered piles be allowed to resist lateral loads?					Battered piles reach beyond the plan dimensions of the pile layout and should be coordinated with other underground objects.
Can the foundation reinforcement be readily kept free from touching the helical piles?					Steel reinforcement in contact with steel piles, including helical piles, has the potential to increase corrosive action. Ensuring non-contact where the pile terminates into the footing reduces the potential.
<b>Totals:</b>					



## 4. HELICAL PILE INSTALLATION EQUIPMENT

The list of equipment necessary to install helical piles is relatively short. A hydraulic machine such as a backhoe, forklift, or skid-steer, among others, can be used with a torque motor capable of producing high torques at low speeds to install piles.

The torque motor should also be capable of clockwise and counterclockwise rotations and produce torques from 4,500 ft-lb for smaller piles up to 80,000 ft-lb for larger piles. The size of the hydraulic machine should be matched with the size of the torque motor, and the torque motor size should be matched with the piles being installed to ensure enough torque is provided without overstressing the piles.

A torque indicator should be used either in line with the torque motor and helical pile or as part of the hydraulic system of the machine. Applied torque is correlated to the capacity of the pile and provides surety with respect to the ultimate capacity.

## 5. HELICAL PILE INSTALLATION PROCEDURE

- Once the torque motor and torque indicator have been properly attached to the hydraulic machine, the helical pile lead section is coupled to the assembly with a drive pin. The lead section is positioned at its location of installation and the plumbness or inclination is checked from multiple vantage points.
- A downward force, or crowd, is applied to the pile by the hydraulic machine forcing the tip into the ground. Once this is complete, the hydraulic machine can advance the pile into the ground until the point at which an extension is required.
- An extension is coupled to the top of the installed section with connection bolts and to the hydraulic assembly with the drive pin. The process repeats until sufficient depth has been achieved to provide the capacity specified.
- It is recommended that piles be installed without start and stops and at a rate of rotation less than 30 rpm. Faster rates can create an auguring effect if advancing into hard soils from soft ones.

## 6. HELICAL PILE INSTALLATION SAFETY

Marking utilities and being aware of overhead power lines must be done prior to installation commencing. Installing piles through underground utilities, especially electric or gas, or contacting overhead power lines could result in death.

Proper maintenance of hydraulic components reduce the risk of breakage. Bursting hydraulic lines can cause injury or death if someone is struck.

Installation can best be safely completed using a minimum of two workers with one worker operating the hydraulic machine while the other serves as a spotter, moves the pile sections, and completes the coupling and decoupling as necessary. The spotter also checks for plumbness and correct positioning. The hydraulic machine operator and spotter should have a clear site line to one another to communicate quickly with hand signals.

Taking precautions against heavy equipment rollover is another essential to ensuring safe installation. An advantage to using helical piles is the ability to install them in locations that many other machines may not be able to access. However, this creates a risk for machine operators if the proper attention is not paid to safety on the site.

Personal protective equipment, such as hard hats, boots, eye protection, and ear protection should also be worn at all times to reduce the risk of injury.



## 7. HELICAL PILE INSTALLATION INSPECTION

The frequency of inspection for helical pile installation can vary depending on the needs of the project and the willingness of the owner to invest in an inspection program. Some projects require inspection on all installed piles, while others may only require a small percentage be inspected.

The subsurface conditions may also dictate the level of inspection required, since highly variable conditions will likely result in variable torque readings at differing elevations. The variability may require modifications to the as-planned installation.

At a minimum, the torque and depth during installation during installation and the final depth should be logged for each pile. Deviations from the plan should be recorded for as-built files.

## 8. BEARING CAPACITY

Subsurface conditions are used to determine the shaft size and total number of helices on the shaft to achieve the required bearing capacity. Two methods are used to determine the helix spacing: individual bearing and cylindrical shear.

A relatively wide helical spacing dictates that the helices act independently, and the total bearing capacity is simply the sum of that from each. Alternatively, if the spacing is relatively narrow, the helices act as a group. The total bearing capacity is the sum of the bottom helix and the side friction comprised of the projected cylinder between each of the helices.

The closeness of the helical bearing plates is relative based on the diameter of the helices and the surrounding soil conditions. The ideal spacing of helical bearing plates occurs where the calculated individual method and the cylindrical method capacities are equal. This creates efficiency by minimizing the shaft length and number of helices required.

For smaller shaft sizes (1.5 in. square to 3.5 in.<sup>2</sup> in diameter), the optimal spacing is often taken as two to three times the average diameter of the helical bearing plates. The helical bearing plates should be spaced with respect to the pitch to ensure the same path during installation.

The final report for this project covers the following, in detail, and includes equations:

- Individual bearing method
- Cylindrical shear method
- Limit state analysis
- Pile deflection/settlement

## 9. PULLOUT AND TORQUE RATIO CAPACITIES, SIZING, LATERAL LOAD RESISTANCE, LIFE EXPECTANCY, ENVIRONMENTAL SUSTAINABILITY, ETC.

The final report for this project also covers, in detail, pullout capacity, the capacity to torque ratio, sizing, lateral load resistance, life expectancy, and environmental sustainability. It also covers economics, codes and acceptance criteria, and design guides.

The final report also includes questions posed to and answers from a contractor/installer, a cost comparison based on three accelerated bridge construction (ABC) projects completed in Iowa, and images from a helical pile installation demonstration.



## 10. COST COMPARISON SUMMARY

The comparison of deep foundation costs for the three completed ABC projects in Iowa to the expected helical pile costs showed the costs of helical piles (\$35/LF to \$75/LF) to be within the range of that for the H-piles (\$48/LF to \$80/LF) previously installed.

While costs ultimately depend on the soils present and the number of piles required to resist the load, past projects are, generally speaking, a good indicator of future expectations. It is likely the remaining portions of the substructure would maintain the same or with slightly modified connection detailing, so any deviation in costs is substantially in the deep foundation elements.

## 11. CONCLUSIONS FROM THE FINAL PROJECT REPORT

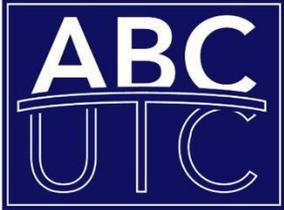
ABC can benefit from the accelerated construction of foundations of bridge structures. There are opportunities to further decrease project duration and reduce disruption to road users with the adoption of newer or lesser-used foundation technologies.

From a design perspective, the technology is fairly well-defined. There has been extensive research and development of helical piles completed, which includes such things as pile configuration, soil interaction, durability, etc. Design guides have been published and several design software packages exist to assist the designer.

The load carrying capacity is well-known and is also verifiable by correlating the capacity to the torque of the installation equipment. The capacity of helical piles is on par with several other deep foundation technologies. Helical piles have been proven effective in the building industry and their use has been codified in the US since 2009.

In recent history, a concerted effort was put forth to introduce this deep foundation option to the building industry by many individuals and organizations. Conversely, minimal effort has been allocated to doing the same for the bridge industry. This is not for lack of potential application, but rather a need to focus the effort in one area to effectively move it forward. One nationally recognized leading expert of helical pile use has suggested this was the case and recognized the opportunity for use in bridge foundation structures.

Dahlberg, J. 2021. *Investigation of the Efficacy of Helical Pile Foundation Implementation in Accelerated Bridge Construction Projects – Phase I*. Accelerated Bridge Construction University Transportation Center (ABC-UTC), Florida International University, Miami, FL.



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