



ADVANCES IN THE USE OF HELICAL PILES FOR FOUNDATION PERFORMANCE AND SEISMIC MITIGATION

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ABSTRACT

Helical piles have emerged as an effective alternative for deep foundations, offering advantages such as fast installation, low environmental impact, and high load-bearing capacity. Compared to conventional piles, they provide more efficient and economical execution with reduced labor requirements and lower project costs. Moreover, the technology behind helical piles has proven effective in mitigating the effects of soil liquefaction during earthquakes, as evidenced by several studies that show a significant reduction in permanent settlements and tilting of foundations. Another important benefit is the superior performance of these piles in offshore environments, where their installation without acoustic emissions is a valuable characteristic in sensitive locations. Numerous studies and experiments conducted in various geotechnical contexts, including shaking table tests and numerical simulations, demonstrate that helical piles can be optimized to perform in a wide range of soil conditions, including both liquefiable and non-liquefiable soils. The combination of technical innovation and economic efficiency positions helical piles as a strategic solution for foundation projects in diverse geotechnical and seismic scenarios.

Keywords: Helical piles. Seismic mitigation. Liquefaction. Deep foundations. Geotechnical engineering.

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INTRODUCTION

The use of continuous flight auger (CFA) piles has gained popularity as an efficient solution for deep foundation projects, especially in urban environments or areas with environmental restrictions. Their cost-effectiveness stems from the combination of quick execution, technical precision, and minimized impact during installation.

Economically, CFA piles may have a slightly higher unit cost compared to conventional driven or bored piles. However, several factors offset this difference: reduced project duration, the elimination of waste and soil removal, and the absence of the need for backfilling or temporary support structures, which are common in other foundation techniques.

From an operational perspective, CFA piles offer a virtually vibration- and noise-free installation, making them an ideal choice for construction in proximity to sensitive buildings or in densely populated urban areas. Additionally, the continuous drilling and concreting process ensures that the risk of borehole collapse is minimized, contributing to both safety and the overall quality of the foundation.

Material efficiency is another key advantage of CFA piles. Through precise control over concrete injection and reinforcement placement, it is possible to achieve piles that are structurally optimized with minimal material waste. However, to realize the full cost-benefit potential of CFA piles, it is essential to conduct thorough geotechnical investigations, use modern equipment, and rely on skilled technical teams. With these elements in place, CFA piles provide an excellent balance between cost, performance, and sustainability.

In a study by Esmailpour, Jafarian, and Cerato (2022), the performance of helical piles was examined as a method for mitigating liquefaction effects on shallow foundations subjected to seismic loading. The research utilized twelve shaking table tests with saturated and loose Babolsar sand to simulate various scenarios, including free-field conditions, unreinforced shallow foundations, and shallow foundations reinforced with helical piles. The results indicated that the inclusion of helical piles reduced permanent settlements, tilting, and horizontal displacements. Specifically, settlements decreased by 45% with four piles and by 75% with eight helical piles. This research underscores the effectiveness of helical piles in enhancing the stability of foundations built on liquefiable soils, offering both technical and economic benefits.



Figure 1: Specific advantages of using helical piles.

SPECIFIC ADVANTAGES OF USING HELICAL PILES

Helical piles are not necessarily a new innovation, but their incredible usefulness has gone a bit under the radar since their development in the 19th century. Keep reading below to understand why helical piles are so advantageous for any worksite foundation.

EASY INSTALL



Helical piles require a small crew and no specialized machinery for installation. And a helical pile can be drilled at a rate of about 10 feet every five minutes, meaning an expedited process that can be efficiently completed.

COST EFFECTIVE



Other than being very easy to install, helical piles are also cheap to produce, transport, and fit. They also don't require any costly upkeep like a concrete pile might, and a helical pile can even be reused for foundations at other worksites.

MINIMAL IMPACT



Because their install doesn't require much space, machinery or manpower, helical pile installations produce less unwanted impact to a worksite and the environment than any other foundation method. They don't even require the removal of soil, as the installation process simply displaces the soil instead.

LOAD BEARING



As any good foundation should be, helical piles have a wide range of load-bearing capacity. The helical piles produced by Ideal Manufacturing can handle up to 500 tons, and they can handle even more by adding more helical plates to the pile.

FUNCTIONAL IN POOR SOIL



Soil quality usually has an important role for construction foundation methods, as poor quality soil can cause the foundation to shift. The design of helical piles allows them to compress the existing soil and apply tension to it, which makes the pile fix itself into place.

Helical piles are very advantageous to any construction job or foundation role. Ideal Manufacturing is a proud producer and distributor of helical pile systems, because they are so effective and efficient. Contact us today to learn more.



Source: Ideal Foundation Systems.



The study by Bilal et al. (2023) examined the behavior of helical piles under axial loading, comparing their performance with conventional piles in natural soil conditions. Eighteen experiments were conducted, varying the number and configuration of helical piles (single and multiple helices) in a foundation raft. The piles were driven vertically into the soil, subjected to an axial load of 512 kg, and settlement was monitored using sensors. The results showed that increasing the number of piles, their spacing, and the number of helices significantly reduced settlement. Specifically, nine double-helical piles reduced settlement by 80.5% compared to nine conventional piles. The study also highlighted that the reduced number of piles required to support the same load led to substantial cost savings, demonstrating the technical and economic viability of helical piles in geotechnical engineering projects.

In another study, Bak et al. (2020) focused on the performance of tapered helical piles as an alternative to improve material efficiency in hollow-section tubular piles. The research combined experimental tests, using the Taguchi method, with finite element analyses to evaluate various factors such as bearing capacity, stiffness, frictional behavior, and material efficiency. The study revealed that frictional resistance increased with settlement, and the effect of tapering was more significant at lower stress levels. Additionally, the optimized tapered piles showed a material efficiency factor 2.5 times higher than non-optimized piles using the same amount of material. This study highlights the potential of tapered helical piles as an innovative solution for improving the structural and economic performance of deep foundations.

Ullah et al. (2023) explored the application of helical piles in offshore environments, focusing on their ability to reduce acoustic emissions during installation while offering superior load-bearing capacity compared to conventional driven piles. The study combined centrifuge experiments with large deformation numerical analyses using the Coupled Eulerian-Lagrangian method to assess the tensile capacity and installation torque of helical piles. The experiments validated the numerical simulations and quantified the variation in undrained tensile capacity over time. The simulations expanded the scope of the experiments by analyzing parameters such as the number of helices, spacing, pitch, shaft-to-helix diameter ratio, and soil shear strength profile. These findings contributed to the development of a new analytical model for calculating tensile capacity, which aligned well with both experimental and numerical results, supporting the use of helical piles in marine applications.



In their 2020 study, Jun, Lee, and Park investigated the performance of helical piles, focusing on their ability to improve bearing capacity and pullout resistance through the addition of spiral plates affixed to the central shaft. The research incorporated both model testing and numerical modeling to analyze how different configurations of helical piles affect their performance. The results demonstrated that both bearing capacity and pullout resistance improved as the number and diameter of helices increased. When the helix was positioned near the base of the pile, performance was particularly enhanced. The study also emphasized that the optimal positioning of the helix plays a crucial role in maximizing bearing capacity, suggesting that helical piles can be optimized to improve their performance, especially in terms of material efficiency and cost-effectiveness.

Finally, El Naggar (2022) examined recent advancements in evaluating the axial and lateral capacities and performance of helical piles, with a particular focus on their response to seismic loading. Helical piles have gained traction in large-scale projects due to their faster installation, lower labor costs, and superior performance compared to conventional straight shaft pipe piles. Despite well-established knowledge about their response to axial and lateral loading, few studies have explored the seismic behavior of individual helical piles and their group behavior. El Naggar's study highlighted cases in which helical piles performed exceptionally well during earthquakes in countries like New Zealand, Japan, and the United States. The research incorporated full-scale shaking table tests and numerical analyses to assess the seismic behavior of helical piles in both liquefiable and non-liquefiable soils, showcasing their potential for enhancing foundation stability in seismic-prone regions.

The use of helical piles has become established as an effective solution for deep foundations, particularly in urban areas and locations with environmental constraints. The combination of low vibration, reduced environmental impact, and superior load-bearing capacity compared to conventional piles makes helical piles an advantageous choice for large-scale projects. Additionally, their fast execution and reduced labor requirements contribute to cost reduction, reinforcing the economic viability of this solution. When combined with in-depth technical studies and strict execution control, helical piles provide an excellent balance between performance, sustainability, and efficiency.



Recent research has demonstrated the potential of helical piles in various applications, including their effectiveness in mitigating the effects of soil liquefaction during seismic events. Experimental studies and numerical simulations have shown that incorporating these piles into shallow foundations significantly reduces permanent settlements and tilting, improving the stability of foundations on liquefiable soils. Moreover, seismic testing and analysis of the seismic behavior of helical piles in liquefiable soils enhance the understanding of their performance during earthquakes, highlighting their critical role in seismic-prone regions.

Finally, the use of helical piles is also being explored in offshore environments, due to their ability to be installed without acoustic emissions and their high pullout resistance, which is crucial for the stability of foundations in extreme conditions. Continuous innovations in modeling techniques and performance analysis of these piles, including shaking table tests and numerical investigations, suggest that they are a promising solution for improving the strength and durability of foundations in various geotechnical scenarios, both onshore and offshore.



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