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

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Eliomar Gotardi Pessoa[1]

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.

[1] Federal University of Rio de Janeiro

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 Esmaeilpour, 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.

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.

REFERENCES

1. Bak, H., Halabian, A., Hashemolhosseini, H., & Rowshanzamir, M. (2020). Axial response and material efficiency of tapered helical piles. *Journal of rock mechanics and geotechnical engineering*. https://doi.org/10.1016/j.jrmge.2020.04.007.

2. Bilal, H., Alam, M., Sarir, M., Khan, A., Safdar, M., & Qureshi, H. (2023). Experimental Modelling of Helical Piles Subjected to Axial Loading. *International Journal of Emerging Engineering and Technology*. https://doi.org/10.57041/me7rjy70.

3. El Naggar, H. (2022). Seismic Performance of Helical Piles. *World Congress on Civil, Structural, and Environmental Engineering*. https://doi.org/10.11159/icgre22.003.

4. Esmaeilpour, P., Jafarian, Y., & Cerato, A. (2022). Mitigating Liquefaction-Induced Displacements of Shallow Foundation using Helical Piles. *International Journal of Physical Modelling in Geotechnics*. https://doi.org/10.1680/jphmg.21.00039.

5. Jun, S., Lee, H., & Park, B. (2020). Experimental and Numerical Study for Analyzing Applicability of Helical Piles, 20, 215-223. https://doi.org/10.9798/kosham.2020.20.3.215.

6. Ullah, S., O'Loughlin, C., Hu, Y., & Hou, L. (2023). Torsional installation and vertical tensile capacity of helical piles in clay. *Géotechnique*. https://doi.org/10.1680/jgeot.22.00014.

7. Venturini, R. E. (2025). Technological innovations in agriculture: the application of Blockchain and Artificial Intelligence for grain traceability and protection. *Brazilian Journal of Development*, *11*(3), e78100. https://doi.org/10.34117/bjdv11n3-007

8. Turatti, R. C. (2025). Application of artificial intelligence in forecasting consumer behavior and trends in E-commerce. *Brazilian Journal of Development*, *11*(3), e78442. https://doi.org/10.34117/bjdv11n3-039

9. Garcia, A. G. (2025). The impact of sustainable practices on employee well-being and organizational success. *Brazilian Journal of Development*, *11*(3), e78599. https://doi.org/10.34117/bjdv11n3-054

10. Filho, W. L. R. (2025). The Role of Zero Trust Architecture in Modern Cybersecurity: Integration with IAM and Emerging Technologies. *Brazilian Journal of Development*, *11*(1), e76836. https://doi.org/10.34117/bjdv11n1-060

11. Antonio, S. L. (2025). Technological innovations and geomechanical challenges in Midland Basin Drilling. *Brazilian Journal of Development*, *11*(3), e78097. https://doi.org/10.34117/bjdv11n3-005

12. Moreira, C. A. (2025). Digital monitoring of heavy equipment: advancing cost optimization and operational efficiency. *Brazilian Journal of Development*, *11*(2), e77294. https://doi.org/10.34117/bjdv11n2-011

13. Delci, C. A. M. (2025). THE EFFECTIVENESS OF LAST PLANNER SYSTEM (LPS) IN INFRASTRUCTURE PROJECT MANAGEMENT. *Revista Sistemática*, *15*(2), 133–139. https://doi.org/10.56238/rcsv15n2-009

14. SANTOS,Hugo;PESSOA,EliomarGotardi.Impactsofdigitalizationontheefficiencyand qualityofpublicservices:Acomprehensiveanalysis.LUMENETVIRTUS,[S.l.],v.15,n.4 0,p.44094414,2024.DOI:10.56238/levv15n40024.Disponívelem:https://periodicos. newsciencepubl.com/LEV/article/view/452.Acessoem:25jan.2025.

15. Freitas,G.B.,Rabelo,E.M.,&Pessoa,E.G.(2023).Projetomodularcomreaproveitamen todecontainermaritimo.BrazilianJournalofDevelopment,9(10),28303-28339.https:// doi.org/10.34117/bjdv9n10057

16. Pessoa,E.G.,Feitosa,L.M.,ePadua,V.P.,&Pereira,A.G.(2023).Estudodosrecalquesp rimáriosemumaterroexecutadosobreaargilamoledo Sarapuí.BrazilianJournalofDeve lopment,9(10),28352–28375.https://doi.org/10.34117/bjdv9n10059

17. PESSOA,E.G.;FEITOSA,L.M.;PEREIRA,A.G.;EPADUA,V.P.Efeitosdeespéciesdea lnaeficiênciadecoagulação,Alresidualepropriedadedosflocosnotratamentodeáguas superficiais.BrazilianJournalofHealthReview,[S.l.],v.6,n.5,p.2481424826,2023.DOI: 10.34119/bjhrv6n5523.Disponívelem:https://ojs.brazilianjournals.com.br/ojs/index. php/BJHR/article/view/63890.Acessoem:25jan.2025.

18. SANTOS,Hugo;PESSOA,EliomarGotardi.Impactsofdigitalizationontheefficiencyand qualityofpublicservices:Acomprehensiveanalysis.LUMENETVIRTUS,[S.l.],v.15,n.4 0,p.44094414,2024.DOI:10.56238/levv15n40024.Disponívelem:https://periodicos. newsciencepubl.com/LEV/article/view/452.Acessoem:25jan.2025.

19. Filho, W. L. R. (2025). The Role of Zero Trust Architecture in Modern Cybersecurity: Integration with IAM and Emerging Technologies. *Brazilian Journal of Development*, *11*(1), e76836. https://doi.org/10.34117/bjdv11n1-060

20. Oliveira, C. E. C. de. (2025). Gentrification, urban revitalization, and social equity: challenges and solutions. *Brazilian Journal of Development*, *11*(2), e77293. https://doi.org/10.34117/bjdv11n2-010

21. Pessoa, E. G. (2024). Pavimentos permeáveis uma solução sustentável. *Revista Sistemática*, *14*(3), 594–599. https://doi.org/10.56238/rcsv14n3-012

22. Filho, W. L. R. (2025). THE ROLE OF AI IN ENHANCING IDENTITY AND ACCESS MANAGEMENT SYSTEMS. *International Seven Journal of Multidisciplinary*, *1*(2). https://doi.org/10.56238/isevmjv1n2-011

23. Antonio, S. L. (2025). Technological innovations and geomechanical challenges in Midland Basin Drilling. Brazilian Journal of Development, 11(3), e78097. https://doi.org/10.34117/bjdv11n3-005

24. Pessoa, E. G. (2024). Pavimentos permeáveis uma solução sustentável. *Revista Sistemática*, *14*(3), 594–599. https://doi.org/10.56238/rcsv14n3-012

25. Eliomar Gotardi Pessoa, & Coautora: Glaucia Brandão Freitas. (2022). ANÁLISE DE CUSTO DE PAVIMENTOS PERMEÁVEIS EM BLOCO DE CONCRETO UTILIZANDO BIM (BUILDING INFORMATION MODELING). Revistaft, 26(111), 86. https://doi.org/10.5281/zenodo.10022486

26. Eliomar Gotardi Pessoa, Gabriel Seixas Pinto Azevedo Benittez, Nathalia Pizzol de Oliveira, & Vitor Borges Ferreira Leite. (2022). ANÁLISE COMPARATIVA ENTRE RESULTADOS EXPERIMENTAIS E TEÓRICOS DE UMA ESTACA COM CARGA HORIZONTAL APLICADA NO TOPO. Revistaft, 27(119), 67. https://doi.org/10.5281/zenodo.7626667

27. Eliomar Gotardi Pessoa, & Coautora: Glaucia Brandão Freitas. (2022). ANÁLISE COMPARATIVA ENTRE RESULTADOS TEÓRICOS DA DEFLEXÃO DE UMA LAJE PLANA COM CARGA DISTRIBUÍDA PELO MÉTODO DE EQUAÇÃO DE DIFERENCIAL DE LAGRANGE POR SÉRIE DE FOURIER DUPLA E MODELAGEM NUMÉRICA PELO SOFTWARE SAP2000. Revistaft, 26(111), 43. https://doi.org/10.5281/zenodo.10019943