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**Report on the Doctoral Dissertation :**

"Centrifuge Modelling of Tapered Pile Installation Effects in Sand" by Mr. Worku Firomsa Kabeta

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## Overall academic merit of the thesis

This thesis enhances the understanding of the load-displacement behavior of tapered piles in sand and examines how pile tapering influences installation effects. The main findings are derived from centrifuge modelling conducted under plane-strain conditions—using model walls to simulate piles—and supported by Particle Image Velocimetry (PIV) analyses and numerical simulations.

This work is original, and the findings highlight the critical role of pile installation effects in foundation design—an aspect that has received limited attention in existing research. In this context, the thesis makes a significant contribution to the field of deep foundations by offering new insights into the behavior of tapered piles during both installation and loading. These insights advance current understanding and support the development of more accurate and reliable design methodologies.

## Structure, composition and layout

The thesis comprises 163 pages, excluding the appendices. Its structure is coherent, with a logical progression from chapter to chapter. The main content is organized into eight chapters. They are: (1) Introduction; (2) Principal tools for physical modelling in geotechnical engineering; (3) Pile classification, bearing capacity, and installation-induced effects; (4) Research methodology (5) Stress distributions and pile load-settlement behavior; (6) Soil displacement and strain fields; (7) Numerical analysis of load-settlement and failure mechanism; and (8) Conclusions and recommendations. Each chapter concludes with a summary that highlights the key points discussed. The formatting of the thesis is satisfactory, and the writing demonstrates a high academic and professional standard.

**General content**

Chapter 1 (7 pages) provides a general introduction to the thesis, outlining the background of the study, the research motivation, clearly defined objectives, and the scope of the investigation. Together, these elements establish a coherent framework for achieving the overarching aims of the research.

Chapter 2 (13 pages) reviews key physical modelling techniques used in geotechnical engineering to study soil-structure interaction under controlled conditions, with particular emphasis on those relevant to the subject of this study. The text is divided into three main parts. The first section is dedicated to the principal tools employed in physical modelling within geotechnical engineering. The second section addresses grain size and boundary effects, which are critical considerations in physical modelling. The third and final section focuses on image-based analysis techniques used in physical modelling. Overall, the text is clearly structured, well-written, and easy to follow. The bibliographic sources provide a concise and insightful overview, essential for contextualizing the present study.

The third chapter (33 pages) focuses on pile foundations, covering pile types, load transfer, and bearing capacity. It also introduces tapered piles and discusses the effects of pile installation. This section is well-written and effectively summarized, providing a strong foundation for interpreting the research results. Finally, this chapter highlights that the present study addresses a critical gap in the existing literature by experimentally investigating the behavior of tapered piles during in-flight installation in geotechnical centrifuge testing, that has not been previously examined.

Chapter 4 (15 pages) provides a detailed account of the research methodology, encompassing the experimental setup, model piles, soil characterization, instrumentation, and testing procedures employed to investigate the installation effects of tapered piles in sand. Centrifuge model tests were conducted at Gustave Eiffel University in France and were complemented by numerical simulations using the Finite Element Method (FEM) to analyse pile behavior and failure mechanisms. The physical models were instrumented with pressure cells embedded in the soil and mounted along the container walls to monitor stress variations during installation. Additionally, the Particle Image Velocimetry (PIV) technique was utilized to quantify soil deformations based on high-resolution images captured throughout the testing process. Details of the numerical modelling procedure are also presented in this chapter.

Chapter 5 (37 pages) presents the results of the physical modelling, focusing on the stress distributions along the wall surface—comparing three model walls: one straight and two with different taper angles—as well as within the surrounding soil mass during both monotonic installation and loading phases. The load–settlement performance of the model walls is also analyzed. Comparisons between wall geometries reveal that the tapered walls mobilized higher lateral stresses than the straight wall during both installation and loading, underscoring the influence of wall geometry (i.e., taper angle) on lateral contact stress mobilization. Toward the end of the chapter, the calculated values of lateral stress coefficients (K) and shaft friction coefficients (β) for the tapered piles are presented. Furthermore, the results indicate that, for the low slenderness walls investigated in this study, the tapered configurations exhibited lower bearing capacity compared to the straight wall. However, for longer piles, a greater contribution from shaft resistance is expected, potentially enhancing the performance of tapered geometries.

Chapter 6 (13 pages) presents the results of soil deformation and strain fields obtained through Particle Image Velocimetry (PIV), based on the analysis of digital images captured during three stages of wall installation, corresponding to the depths at which stress sensors were embedded in the soil mass. The displacement and strain contour results indicate that the zone of soil affected by installation is significantly larger for tapered walls compared to the straight wall. Additionally, for the straight wall, horizontal displacement at a given soil point tends to stabilize once the wall base passes, whereas tapered walls continue to induce increasing horizontal displacement at the same point during further penetration.

Chapter 7 (15 pages) presents the results of numerical simulations conducted to evaluate the bearing capacity of different tapered wall configurations installed in sand. This chapter is divided into two parts: finite element analysis (FEM) of the load–displacement behavior, and limit analysis to investigate the effect of taper angles on the failure load and mechanisms. The comparison between bearing capacities obtained from centrifuge tests and numerical models indicates that the experimental values are higher, primarily due to installation effects. These effects—which tend to become more significant with increasing taper angle—are attributed to soil densification and the mobilization of lateral stresses during installation, factors that are not accounted for in the numerical simulations.

Finally, text ends with general conclusions and recommendations (Chapter 8 with 3 pages). The conclusions present a synthesis and are very clear in highlighting the key points of the thesis and the details of the main contributions of the work. Overall, the study highlights the importance of accounting for installation effects in numerical simulations of tapered piles. Both experimental and numerical results demonstrate that tapered piles exhibit distinct behavior compared to straight piles during both the installation and loading phases.

In terms of recommendations, the candidate proposes several directions for future research, including the investigation of longer piles and the development of numerical simulations that incorporate installation effects.

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**Recommendation**

Mr. Worku Firomsa Kabeta presents a thesis focused on an interesting and complex theme which uses physical and numerical modelling to evaluate the behavior of tapered piles during installation and loading in dense sand. The results demonstrate that the taper angle significantly influences pile performance, with installation effects increasing as the taper angle increases. Additionally, the study shows that horizontal (normal) stresses along the pile shaft are higher in tapered piles compared to cylindrical ones. The results of the numerical analysis indicate that the installation effects of tapered piles should be included in predictive models. Tapered piles enhance overall performance due to their specific geometry, and the findings of this study provide valuable insights into the mechanisms driving this improvement—an important consideration for foundation designers.

In summary, this thesis represents an original contribution to both the body of knowledge in the field and the design of tapered piles. I recommend that the candidate be awarded the degree of Doctor of Philosophy without the need for further revisions or corrections.

São Carlos, 02 October 2025
Cristina de Hollanda Cavalcanti Tsuha