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for the degree of Doctor of Philosophy (Ph.D.)

"Analysis of Pile Foundation Systems in Multi-layered Soil Strata"

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Civil, Environmental and Geomatics Engineering

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ABSTRACT OF DISSERTATION
Analysis of Pile Foundation Systems in Multi-layered Soil Strata

Pile foundations are subjected to vertical loads and significantly higher lateral loads due to wind, seismic effects, ocean waves and currents, and floating ice sheets. Applied vertical load on a pile is resisted by the skin friction and base resistance. The base resistance is provided by the soil layer and skin friction develops at the soil-pile interface. The lateral load on the pile is resisted by the soil-pile interaction effect, which is dependent on the pile and soil parameters. Published literature shows that a properly designed Pile-to-Pile Cap (PTPC) connection will offer significant lateral resistance to the applied loads. The soil-pile system behavior is highly non-linear which requires a detailed study on the soil-structure interaction considering multi-layered soil strata and their properties. This Dissertation is divided into two parts: Evaluation of (A) the behavior and performance of PTPC connections, and (B) the load-displacement responses of a pile embedded in a multi-layered non-linear elastic soil strata subjected to static loads. A comprehensive literature review has been performed to study the factors affecting the PTPC connection performances and the load-displacement behavior of piles subjected to static lateral and axial loads considering soil-pile interactions. The objective of the study in Part A is to develop a PTPC connection design capable of producing adequate moment capacity of the pile by relying only on plain pile embedments without any special connection reinforcement details. The present study evaluates the local and global behavior of the PTPC connections with plain pile embedment through Finite Element Analyses (FEA). The plain pile embedment depth preferably with a value identical to the width of the pile (or) a value in the range of 1.2 – 1.5 times the pile diameter is sufficient to develop the full moment capacity for the piles. However, further experimental investigations are necessary to establish the minimum pile embedment depth to develop adequate pile moment capacity for steel PTPC connections. Most of the published literature only considered uniform soil strata properties and hence further studies are necessary in developing analytical models of the PTPC connections in multi-layered soil-strata with varying properties. In Part B, a discretized continuum-based analytical model is utilized to consider the three-dimensional (3D) soil-pile interactions for piles embedded in multi-layered non-linear elastic soil strata. A power law is used to characterize the non-linear soil properties which are idealized by degradation of shear moduli with strain (with depth). Part B presents development of the software GEOS© Version 1.0: GEOS-ALPILE©, GEOS-LLPILE© and GEOS-GLPILE© for a pile subjected to static axial loads, lateral loads and the combined action of axial and lateral loads, respectively. The idea to develop such a software was based on the unavailability of a user-friendly geotechnical software in understanding such complex soil-pile models. Based on the present study, GEOS© Version 1.0 is under provisional patent status with "U.S. Provisional Patent Application No.63/347,890" filed on June 1, 2022 and will require the author's permission in order to receive access and permission for copyright infringement. The results from the studies from parts A and B are analyzed by the licensed software MATLAB (Version R2019a –R2021a) and ANSYS Workbench (Version 2019R3 – 2021R1). These results are further validated by the development of an Artificial Neural Network (ANN) model using the back-propagation (BP) algorithm with a mean squared error of $R^2 = 0.99$. ANN models prove to be a promising alternative over the traditionally adopted experimental and analytical/numerical methods. The main objective of developing an ANN model

is to build a database using the data from GEOS© software. This ANN model will (i) preserve the huge amount of data for the soil-pile system which can be readily used to predict the pile-displacement responses, and (ii) will be constantly updated based on the dataset of current and future research potentials relating to the pile foundations with plain pile embedments in multi-layered soil strata. Recommendations for further study are presented to include the effect of pile embedment depths on the behavior of piles under combined loads in a multi-layered soil strata. Further studies can be extended to analyze and understand the behavior of pile groups.

BIOGRAPHICAL SKETCH
Born in Hyderabad, India.
B.S., Guru Nanak Institutions, Jawaharlal Nehru Technological University (JNTU), Hyderabad, Telangana, India, 2014
M.S., University of Bologna, Bologna, Italy, 2018
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CONCERNING PERIOD OF PREPARATION
& QUALIFYING EXAMINATION

Time in Preparation: Year – 2018-2023

Qualifying Examination Passed: Fall 2019

Journal Publications:

Madasamy Arockiasamy and Arvan Prakash Ankitha. 2021.
"Behavior, Performance and Evaluation of Prestressed Concrete/steel Pipe/Steel H-Pile to Pile Cap Connections: State-of-the-Art Review".
Practice Periodical on Structural Design and Construction, American Society of Civil Engineers (ASCE).
Status: Published
Note: Paper has been added to the Editor's Choice Collection.
Paper nominated for the ASCE State-of-the-Art of Civil Engineering Award.

Arvan Prakash Ankitha and Madasamy Arockiasamy. 2021.
"Energy-based Approach: Analysis of a Vertically Loaded Pile in Multi-layered Non-linear Soil Strata".
Geotechnics, Multidisciplinary Digital Publishing Institute (MDPI).
Status: Published

Arvan Prakash Ankitha and Madasamy Arockiasamy. 2022.
"Analysis Methods for Understanding the Effect of Embedment Depth concerning Pile-to-Pile Cap Connections".
Practice Periodical on Structural Design and Construction, ASCE.
Status: Published

Arvan Prakash Ankitha; Rahul Dev Raju; Madasamy Arockiasamy; and Khaled Sobhan. 2022.
"State-of-the-Art Review on Offshore Wind Turbine (OWT)-Monopile Foundation Systems in Multi-layered Soil Strata under Aerodynamic and Hydrodynamic loads".
Practice Periodical on Structural Design and Construction, American Society of Civil Engineers (ASCE).
Status: Published
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Arvan Prakash Ankitha and Madasamy Arockiasamy. 2022.
"Energy-based Approach – Part I: User-friendly Standalone Application for The Analysis of a Vertically Loaded Pile in Multi-layered Non-linear Soil Strata".
Geotechnics, Multidisciplinary Digital Publishing Institute (MDPI).
Status: Accepted for publication

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Status: Accepted for publication

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"Application of Artificial Intelligence Techniques in the analysis of Pile-to-Pile Cap Connections".
Practice Periodical on Structural Design and Construction, ASCE.
Status: Accepted for publication

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Geotechnics, Multidisciplinary Digital Publishing Institute (MDPI).
Status: Submission in Progress

Arvan Prakash Ankitha, Madasamy Arockiasamy, Nakin Suksawang and Harry Alan Craik. 2022.
“Finite Element Analysis of a Double Composite Box Girder Bridge”.
Journal of Bridge Engineering, ASCE.
Status: Submission in Progress

Isaac Elishakoff, Arvan Prakash Ankitha and Alessandro Marzani. 2019.
“Rigorous versus naïve implementation of the Galerkin method for stepped beams”.
Acta Mechanica, Springer.
Status: Published
DOI: https://link.springer.com/article/10.1007/s00707-019-02393-z

Isaac Elishakoff, Marco Amato, Arvan Prakash Ankitha and Alessandro Marzani. 2021.
“Rigorous implementation of the Galerkin method for stepped structures needs generalized functions”.
Journal of Sound and Vibration, Elsevier.
Status: Published
Note: The research work has been recognized by Wikipedia under the title “Galerkin method for stepped structures” and can be viewed at https://en.wikipedia.org/wiki/Galerkin_method.
DOI: https://www.sciencedirect.com/science/article/pii/S0022460X20305381