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Discussion of "Systematic literature review and mapping of the prediction of pile capacities"*

Katia Vanessa Bicalho[1#], Reno Reine Castello[1], Nelson Aoki[2]

Discussion

The readers appreciate the valuable contribution that the authors have made to the systematic literature review and mapping (SLRM) concerning prediction of pile capacities. The article has reviewed and mapped the main papers in English published in journals on the Web of Science and Scopus databases over the last decades. The objective of the work was to indicate the main methods used for predicting pile capacities and lacks that can be fulfilled in future research. The search string used in the SLRM was: "Regression OR neural network" AND "bearing OR load" AND capacity AND piles. The SLRM included: (a) description (i.e., protocol of research); (b) selection of publications based on the reading of titles and abstracts; (c) extraction of information (i.e., types of piles, tests, statistic methods, and characteristics inherent to the data) to understand the subject under investigation. The study also analyses the keywords on the theme, the number of citations, number of publications per country, year and journal. The results indicated a lack of works in helical piles and instrumented pile load tests results, dividing point and shaft resistance. The purpose of this discussion is to make a few comments that seem important in appreciating the contribution of the article.

The bibliographic analysis is required to provide quantitatively a picture of pile foundation bearing capacity research. And the use of previous SLRM can bring better performances for extending the investigated research topic. The authors have identified different publications dealing with artificial neural networks (ANNs) for pile capacity prediction. A limitation of the ANN methodology is its "black box" nature and proneness to overfitting effect. The knowledge of study sites is essential for foundation designs. When selecting suitable databases, it is important to ensure that the pre-processing of the available database is adequate to represent the site being investigated. The expected diversity of the data (laboratory and field measurements) employed to develop the predictive pile capacities models using ANN implementation is a challenging issue and (or) problem to consider in future studies extending the investigated research topic. And the readers would like to include some additional comments on the uncertainties associated with potential heterogeneities of the geotechnical databases in the selected publications.

The authors have identified many variable keywords (up to 244 different expressions) used by the researchers in the published papers and presented the fifteen (15) most recurrent keywords as they appear in the papers. A systematic review involves using a stepwise approach to select relevant keywords and search strings. The readers aim to highlight the limited (qualitative) information concerning the soil behavior, testing, and site characterization (i.e., field subsurface exploration and laboratory geomaterials testing data). Although the diversity of the types of sandy soils is vast regarding their geological and geotechnical conditions, yet only a basic granulometric soil classification, i.e., sandy soil, is listed as keywords in 04 papers of a total of 80 publications. Further, the authors search show that 01 of 06 main keywords grouped in recurrence (12 of 202) mentioned the in-situ soil testing considered in the analysis, i.e., Cone Penetration Test (CPT).

Concerning the evaluation of the bearing capacity of the driven piles (i.e., most cited type of pile according to the authors search), many factors regarding geotechnical data collection and field site geological and geotechnical information have consistently been found to affect pile capacities (single piles and pile groups), such as subsurface conditions, ground water level information, in-situ soil testing, soil classification, and pile characteristics (Castello, 1979; Coyle & Castello, 1981). Moreover, for a given pile driven, the mode of disturbance depends on the soil type, and affect the pile bearing capacity calculations. This requires in-depth study of the field investigation to reduce uncertainty over differences in the performance of driven piles.

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#Corresponding author: E-mail address: katia.bicalho@ufes.br
[1]Universidade Federal do Espírito Santo, Departamento de Engenharia Civil, Vitória, ES, Brasil.
[2]Universidade de São Paulo, Escola de Engenharia de São Carlos, Departamento de Geotecnia, São Carlos, SP, Brasil.

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List of symbols

SLRM systematic literature review and mapping
CPT Cone Penetration Test
ANNs artificial neural networks

References

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Authors' reply

Sofia Leão Carvalho, Mauricio Martines Sales, André Luís Brasil Cavalcante

The authors appreciate the discussion that has emerged following the publication of the paper titled "Systematic literature review and mapping of the prediction of pile capacities."

The aim of this systematic literature review and mapping (SLRM) was to identify the main current studies that propose methods to predict load capacity in piles. As shown in the provided search string, no distinction was made between methods using regressions and neural networks. The search, though, revealed a clear predominance of the second option.

Machine Learning (ML) based methods are often considered "black-boxes" due to their difficult-to-interpret learning processes and the significant issue of lacking physical meaning in their analyses. However, ML techniques prove valuable in nonlinear analyses with numerous variables, such as the studies in Geotechnical Engineering. According to Juwaied (2018) geotechnical engineering deals with a range of materials and properties whose variety and uncertainty in behavior is a challenge for soil and rock analyses. Many mathematical models handle different geotechnical materials by employing simplifications and creating highly specific models. In that respect, ML learning models have the capability to handle multiple parameters simultaneously, eliminating the need for simplification assumptions like linear responses, for example.

Overfitting occurs when a statistical learning method model becomes too closely aligned with training data and fails to generalize to new data. This can lead to models that perform exceptionally well on training datasets but poorly on other set of data, which can be problematic in practical applications. While ML methods may be more susceptible to overfitting compared to other statistical approaches, this tendency can be managed during the training process through established mechanisms like cross-validation, regularization, and the use of learning curves. These methods of controlling overfitting can be continuously monitored and adjusted throughout the algorithm's training and validation phases, and their effectiveness can be assessed through the partitioning of test samples.

The lack of studies combining helical piles with instrumented load testing suggests either a limited use of this combination in practical applications or a lapse in academic research. It could also indicate a need for more comprehensive studies in this area to better understand the performance characteristics of helical piles and to validate or improve upon existing design methods. This gap presents an opportunity for future research, potentially leading to improvements in the design and application of helical pile systems in foundation engineering.

Regarding the low number of instrumented piles, two perspectives can be considered. The first is that the practice of instrumentation in cast-in-place piles is still well below the desirable level. On the other hand, in driven piles, many authors have relied on information from dynamic tests (PDA) as a tool for monitoring the construction process.

In addressing the concern raised about the lack of critical information on in situ soil tests, the authors would like to remark that they did not make any value judgments in the SLMR regarding the topics or specific methods presented in the papers. The authors agree on the importance of the geological origin and texture of soils considering the load-bearing behavior of piles.

However, in tests where classification is done indirectly – via graphs, such as CPT – the particle size distribution is already considered in the other variables that feed into the model. For prototype tests in the laboratory, sand tests predominate due to the greater difficulty in preparing representative cohesive soil samples.

In any case, the conducted search reflects what prevailed in the found articles. While many papers do demonstrate various aspects, some proposed methods are specific to certain soil types. And even though the SLMR did not focus on obtaining the input data of each paper, to detail the parameters used for calculating driven pile capacities, a review of each article individually is necessary.

The authors are thankful for the valuable insights shared in the discussion and hope that the systematic literature review and mapping conducted not only reinforces current understanding but also help in the development of new innovative methods in predicting pile load capacity.

List of symbols

CPT	Cone Penetration Test
ML	Machine Learning
PDA	Pile Dynamic Analyzer
SLMR	Systematic Literature Review and Mapping

References

Juwaied, N.S. (2018). Applications of artificial intelligence in geotechnical engineering. *Journal of Engineering and Applied Sciences*, *13*(8), 2764-2785.