ESTIMATION OF PILE CAPACITIES USING CASE-BASED REASONING METHOD

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1. Introduction

In current practice of offshore foundation design, the axial capacity of an offshore pile may be assessed using CPT-based methods, e.g. NGI-05, Fugro-05, ICP-05, and UWA-05. As expected, these methods perform well in the domain they have been calibrated, but their predictions exhibit more scatter when they are applied to other pile load tests. In fact, recent reliability analyses performed for pile foundation of actual platforms show that the model uncertainty associated with different prediction methods is the most important contributor to the uncertainty in foundation performance.

The idea of this work is to propose a 'method-free' CPT-based approach for estimating pile capacities directly from a database of pile load tests using Case-Based Reasoning (CBR). The method is applied on high quality database of pile tests in sand and clay sites. Case-Based Reasoning is an Artificial Intelligence method that captures previous experiences and provides them to solve new problems. A CBR system carries out a similarity-based retrieval in order to best match a new problem to the collection of past cases. Once a CBR system is implemented as learning system, new and adapted cases can be added to the case base, therewith increasing the competence of the system [1]. The method is superior to ANN (Artificial Neural Networks) since it allows the user (i.e. expert engineer) to follow the reasoning step on every level. The method gives possibility of expanding the case base without updating the established control parameters. CBR has been used in other disciplines, but its potential application to geotechnical problems has not been explored. The paper presents the application of the method to estimating pile capacities in layered soils, and compares its predictions with those of the established CPT-based methods in use today.

2. Case-Based (Method-free) Estimation of Pile Capacities

In this work, we implemented a CBR system that estimates pile capacities based on previous observed (measured) capacities from high-quality pile load tests. For the implementation and testing, we used the myCBR tool [2] that has been successfully applied in various domains [3]. Figure 1 summarizes the process schematically.

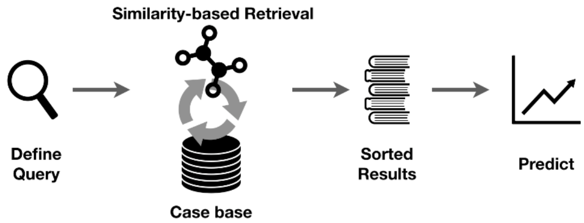

Figure 1. Process of defining a query for a given problem, comparing it to the case base, sorting the results according to their similarity and using the most similar case for making a prediction.

The case-based approach allows one to define customized similarity measures and weights for selecting and prioritizing cases from the case base and therewith provide predictions more suitable than in a pure database retrieval.

We created two different case bases, one for the pile tests in sand and one for the pile tests in clay, with cases following a homogeneous case structure. A case contains of 11 attributes with individual similarity measures as well as a weighted function for the similarity-based retrieval.

Defined attributes are pile ID, site name, testing info (compression or tension), pile material (concrete or steel), pile diameter (D), (segment) length to diameter ratio L/D, outer surface area of the pile shaft, average in-situ vertical stress (for sand cases only) and average cone resistance along pile length, average unit skin friction, average plasticity index (for clay cases), as input, and average unit base and skin resistances, as output. For the cases, in which only total pile capacity was measured, percentage of shaft and tip resistances were separated based on the average of the predictions of the CPT-based design methods, i.e. Fugro-96, Fugro-10, ICP-05, NGI-05, and UWA-05. The method is verified by testing the cases from the database, i.e. obtaining similarity of 1.0 (i.e. exact match). The retrieval query is initiated with 11 attributes, while the validation testing is performed excluding irrelevant (e.g. pile ID) or unavailable data (e.g. plasticity index).

3. Results

The Tokyo Bay pile test [4] was used for validation case. The results show quite successful prediction of the total capacity as well as the top 12 m skin friction capacity of the pile using the CBR method. However, the skin friction distribution and base resistances deviate from the measurements significantly. The tip resistance is quite significantly overestimated even compared to few CPT-based design methods, which overestimate the base resistance about ~50%. However, this is not surprising as identifying the relative contributions of tip capacity and skin friction of the lowest part of the pile (5 to 10 times the diameter) in pile load tests is very difficult. Nevertheless, the authors believe that the presented CBR tool can be improved by calibrating the number of attributes, their local similarity measures and global weights to obtain successful estimates of pile capacities (both skin and base capacities) in layered soils.

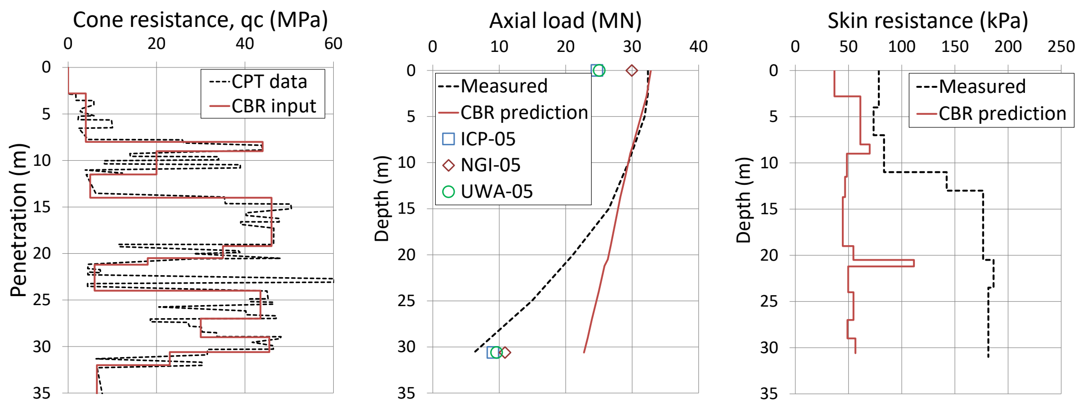

Figure 2. Tokyo Bay pile testing site a) actual and simplified CPT data, b) comparison of field measurements, CBR and CPT-based design method predictions, and c) comparison of measured and predicted skin friction distributions.

5. References

[1] Aamodt, A. & Plaza, E. (1994). Case-based reasoning: Foundational issues, methodological variations, and system approaches. *Artificial Intelligence Communications*, 7(1), 39–59

[2] http://www.mycbr-project.net/index.html

[3] Bach, K. & Althoff, K.-D. (2012). Developing Case-Based Reasoning Applications Using myCBR 3. In: Watson, I., Agudo, B.D. (eds.) *Case-based Reasoning in Research and Development, Proceedings of the 20th International Conference on Case-Based Reasoning (ICCBR-12)*. pp. 17–31. LNAI 6880, Springer.

[4] Shioi, Y., Yoshida, O., Meta, T. & Momma, M. (2012). Estimation of bearing capacity of steel pipe pile by static loading test and stress-wave theory. *In Proc. 4th Int. Conf. on the Application of Stress-Wave Theory to Piles*: 325–330. AA Balkema, Rotterdam.