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CHARACTERIZATION OF METHOD UNCERTAINTY FOR AXIAL PILE DESIGN

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The paper describes two approaches for deriving the mean, standard deviation and probability density function of the method uncertainty for an axial pile capacity calculation method. The focus of this paper is on estimating the statistical description of the method uncertainty parameters for a pile design method on the basis of performance of the method in predicting the capacities of high-quality pile load tests. The method uncertainty can have a strong influence on the safety level associated with the foundation design. Establishing the statistics of the "error" in a calculated capacity prediction (Q_c) from the measured values of capacity (Q_m) in pile load tests requires careful consideration of several factors. In particular, case studies demonstrated that only the pile load tests where the pile capacity method overpredicts the actual (measured) capacity are of interest. Therefore, with method uncertainty defined as Q_m/Q_c, the part of the cumulative distribution function where $Q_m/Q_c < 1$ should be fitted as well as possible. The possible dependence of the standard deviation of method uncertainty on pile penetration depth was also investigated in the derivation of method uncertainty statistics.

Keywords: Pile capacity, Method uncertainty, Probabilistic analysis, Pile penetration depth.

1 Introduction

There is an increasing demand for reliability-based design of offshore piles, where the design criterion is defined in terms of a target annual failure probability. Lacasse *et al.* (2013) demonstrated the importance of method uncertainty for the probabilistic calculation of axial pile capacity and resulting annual probability of failure. This paper describes two approaches for deriving the mean, standard deviation and probability density function of method uncertainty for an axial pile capacity prediction method using a database of high-quality pile load tests. The NGI-05 method for prediction of axial pile capacity in clay (Karlsrud *et al.* 2005) and the NGI "super piles" database of pile load tests are used in the demonstration example.

2 Quantification of Method Uncertainty

In Approach 1, the mean and standard deviation of the method uncertainty for axial pile capacity calculation method are taken as constants, independent of the pile length. In a study of the calibration of the partial safety factor against a target annual failure probability, the coordinate of the design point (the most likely combination of random variables in the reliability analysis that would cause failure) in terms of foundation capacity is always less than the mean capacity.

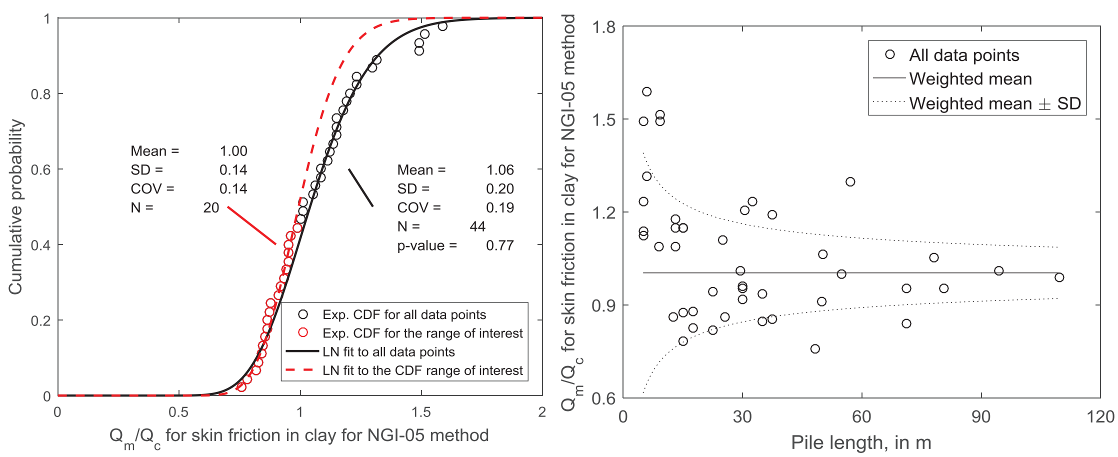
To establish the method uncertainty, only the cases where the design method overpredicts the measured capacity (i.e. $Q_m/Q_c < 1$) are therefore of interest.

In Approach 2, the design methods for which standard deviation appeared to vary with pile length were tested using the NGI "super piles" database. The weighted least squares method was used to compute the regression equations. The weights assigned to each data point were assumed to be equal to the pile penetration depth to follow a suggestion by Ronold (2016).

3 Results

In Approach 1, the probability density function (PDF) should be derived by fitting the relevant part of the cumulative distribution function ($Q_m/Q_c < 1$) as closely as possible (red dotted curve in example in Fig. 1a). The 'outlier' data on the low side (i.e. $Q_m/Q_c < 0.5$) are also ignored. The maximum likelihood method estimated the parameters using a lognormal (LN) distribution.

Figure 1b shows the standard deviation as a function of pile penetration depth for the pile capacity calculated with the NGI-05 method (Approach 2). The mean did not vary with pile length. The reduced standard deviation for longer pile may however also be due to the fewer number of pile load tests available for pile penetration depths greater than 60 m.



(a) (b)

Figure 1. Q_m/Q_c for skin friction in clay interpreted by: (a) Approach 1; (b) Approach 2.

4 Conclusions

The paper presented two different approaches for the evaluation of method uncertainty of an axial pile capacity method. The lognormal distribution was found to be representative for the method uncertainty for the pile design method in Approach 1. In Approach 2, it is assumed that there is a variation of standard deviation with pile penetration depth.

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