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Influence of Model Choice on the Calculated Reliability of a Single Pile

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ABSTRACT

This paper first describes the various models considered and the rationale behind the short-listing of four. It then compares the results of reliability analyses performed using the chosen models and discusses the significance of the differences observed. The reliability analysis is performed with full Monte Carlo simulation. This is followed by recommendations and conclusions.

INTRODUCTION

One of the most challenging problems in geotechnical engineering is the prediction of the load-carrying capacity of piles. This is mainly due to the lack of understanding of the phenomenon of soil-pile interaction and limited quantity as well as inexact quality of soil information that is, or can be, available for analysis. This leads to uncertainties.

These uncertainties, arising partly from the mathematical models themselves, can become a nightmare for the designers. They often expect errors of plus or minus 50% in relation to the load test results (Tomlinson, 1986). Accuracy of the estimates of pile capacity based on any theory that does not include the effects of the driving process or installation technique involved is bound to be suspect.

Most engineers are aware of this problem. However, many find themselves ill-prepared and ill-equipped to manage it. Most of the time, they use engineering judgement or experience to establish appropriate factors of safety to cope with the uncertainties involved. The authors accept that there are exceptional and experienced geotechnical engineers who may have confidence in their choice of the factors of safety, but the consequence is that the chosen factors of safety will differ from one engineer to another. Such differences are rarely analysed systematically. Furthermore, very few; if any, would have confidence in their estimation of the equivalent probability of failure.

Previously, the authors presented a philosophical and practical basis for a methodology for carrying out the design of piles based on a desired probability of failure, using the Monte Carlo Simulation Technique (Singh et al., 1994). Details of this methodology can be found in this conference proceedings. The selection and development of this methodology were based on an objective statement of the desirable features of a rational approach to reliability analysis followed by, in turn, the review of the existing reliability methods as well as the review of the past work on risk assessment in pile design. Limitations of the existing work were pointed out. Comprehensive Monte Carlo technique, without resorting to variance reduction techniques (VRT), was thought to be more rational compared to the conventional factor of safety as well as the reliability index (β) methods, and is expected to produce not only more reliable results but also better clarifications of the influences of soil parameters and models used in the analysis and design. In the authors' considered view, variance reduction methods are a retrograde step that should be avoided in reliability studies and used, if at all, only in studies where the decision makers wish to seek only the means and the standard deviations of the alternative configurations.

The aim of this paper is to review some of the existing models available for designing a single axially loaded pile in sand. The selected models are compared with respect to the computed probabilities of failure, and the influence of the soil parameters on the reliability analysis results is discussed briefly. Example design charts which allow designers to select appropriate probability of failure, to achieve a relatively consistent level of safety in the design, are presented. As declared in the title, this paper highlights the large differences (or 'errors') in the various models in current use and thus emphasises the importance of very careful selection of model/s. This selection/response must depend on the considered attitudes of the engineers and their employers to the calculated risks with minimum cognitive and emotive biases. Therefore, only a limited range of variations in soil properties is considered so as to make the comparisons convenient.

A very detailed study of the effects of a wide range of load and soil uncertainties is being carried out by the authors and the results will be presented at the ISOPE-96 Conference (Singh et al., 1996).

VARIOUS MODELS AVAILABLE

The weight of and load on a single pile embedded in sand are supported by frictional resistance of the sand on the surface of the shaft and bearing resistance at the base. These two resistances generally act together and it is customary to assume that the ultimate bearing capacity of a pile is reached when both resistances are fully mobilised. The ultimate axial load capacity of a pile in sand, based on soil strength parameters, is summarised by the model:

$$Q_{max} = Q_s + Q_b$$
$$= A_s k_s \sigma'_{VL} \tan\delta + A_b \sigma'_0 N_q$$

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