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VALUABLE INFORMATION FROM RELIABILITY ANALYSIS OF PILE FOUNDATIONS

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EXTENDED ABSTRACT

The work presented in this paper was developed under the PhD thesis entitled "Reliability and Cost Models of Pile Foundations". Our main goal is to present guidelines for geotechnical engineers to carry out reliability based designs (RBD). This analyses help evaluate the probability of a particular behavior in a time period, with the knowledge of the input parameters randomness (uncertainties). The biggest benefit is that it quantifies and gives information about the parameters that mostly influence the behavior under study. This capacity is important, not only because of the new regulation codes and social concerns, but also because these probabilistic formats support decision making under uncertainties, providing qualitative judgments and investments, very important in geotechnical area. Based on that, this work shows valuable information that a geotechnical engineers can obtain from a simple reliability analysis of a pile foundation, such as the most influential uncertainties in pile design or the minimum dimensions of the pile (Figure 3a) and maximum load (Figure 3b) that lead to a previously established probability of failure. Furthermore, a comparison between two widely known RBD methodologies was done, First Order Reliability Method (FORM) and Monte Carlo Simulations (MCS). FORM is the most traditional one, an approximate method (level II of reliability), while ordinary MCS has a higher level of accuracy (level III, pure probabilistic) and is a very straight forward method. Nevertheless, FORM has some limitations when complex performance functions are necessary and it is not possible to approximate normal distributions. The uncertainties considered in this work and the methodology scheme is presented in Figure 1 (Honjo *et al.*, 2010 and Honjo *et al.*, 2011).

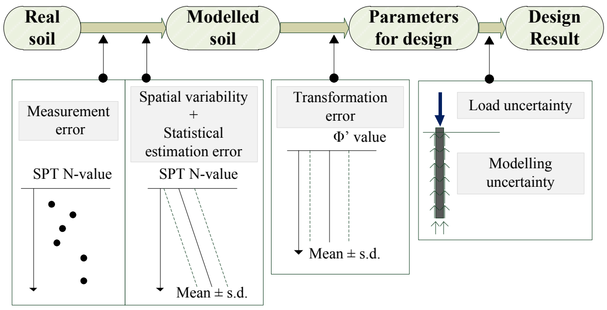


Figure 1: Methodology and uncertainties considered for reliability based design (RBD) of pile foundations

MAIN RESULTS AND CONCLUSIONS

The results here presented are from a concrete bored pile foundation in residual soil with 60 centimeters of diameter (static load test result to failure of 1350 kN).
In sensitivity analyses, the uncertainties were studied one by one to determine their influence, both FORM and MCS methods were applied. The impact on the performance of the pile and consequently the reliability can be assessed and different lengths or loads can be analysed (Teixeira *et al.*, 2011). This analysis, with one of the main results depicted in Figure 2, showed that when performance function is simple FORM method is applicable and show consistent results with MCS. Both methods revealed that modelling uncertainties (resistance calculation) has high influence in probability of failure calculations. The contribution of side and tip uncertainties depends greatly on the type of pile.

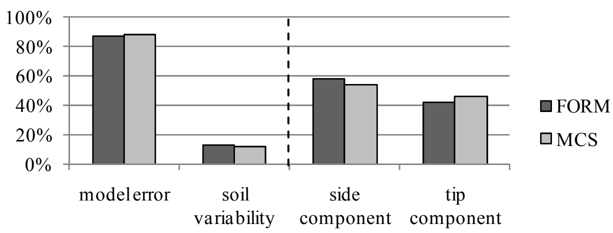


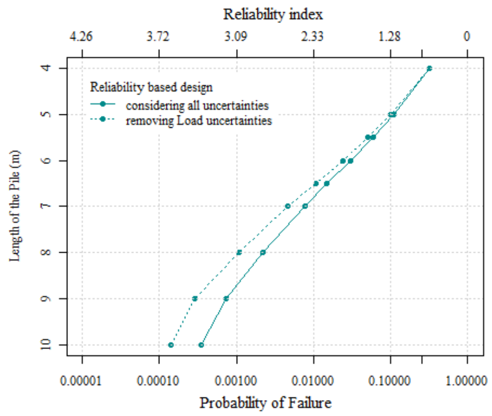
Figure 2: Influence of each uncertainty(%) in pile RBD

As referred, for a pile foundation the RBD can be done in order to determine the necessary length or the maximum axial load for a required reliability, β, normally around 3.0 (this value depends on many factors, eg.: type of structure – see Table 1).

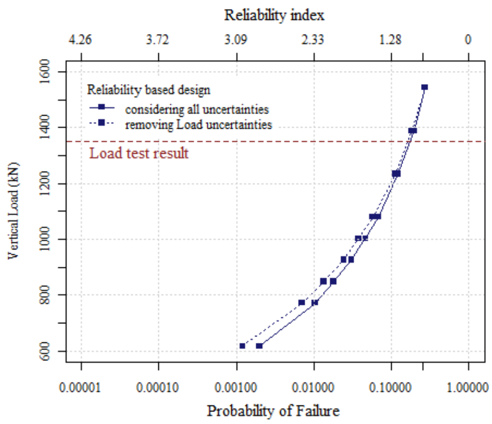
Table 1: Recommended values for reliability index by Eurocode 0 (CEN,2002) (design of working life of 50 years)

Reliability class	Limit state	Minimum β	Probab. failure
RC3	ULS	4.30	8.5/1,000,000
RC2	ULS	3.80	7.2/100,000
RC2	Fatigue	1.50-3.80	-
RC2	SLS	1.50 (irreversible)	6.7/100
RC1	ULS	3.30	4.8/10,000

Figure 3 shows the results of the two ways of RBD, the minimum diameter and maximum load that a pile can withstand to verify the probability of failure.



a) minimum length (~8 meters)



b) maximum load (~600 kN)

Figure 3: Results of RBD for a pile foundation example

The results show a semi-log relationship between probability of failure and the length of the pile while for axial load this relationship is more exponential. This is believed to be a very friendly methodology to support the design of pile foundations, that allows a more rational way to deal with uncertainties of a problem, instead of just introducing a "blind" factor of safety. Also, it is in agreement with the regulation codes as well as helping save time and optimize resources on investigations of variables in pile reliabilty, since uncertainties characterization is not an easy task in geotechnical engineering.

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