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REPORT ON MANUSCRIPT DOCTORAL THESIS

By Daniel Kefelegn Teshager

on

"Probabilistic Analysis of Shallow Foundations Settlement Using the Hardening Soil Model"

The manuscript is written in English. It consists of 167 pages organized into an abstract, the list of abbreviations, the list of notations, 7 chapters, the bibliography, 4 Appendices, the list of figures and tables divided into chapters. All the paragraphs are well organized and this arrangement facilitates the reading of this dissertation.

The thesis focuses on the assessment of the settlements of shallow foundations carried out on granular soils which are spatially variable. The analyses follow two different constitutive laws: the Mohr-Coulomb and the Hardening models. The numerical analyses were performed through the commercial software (ZSoil) and the PhD student's procedures implemented in MATLAB in the framework of the Monte Carlo method. The study investigates both one- and two-layer soil profile settlements of a strip footing. The probabilistic analyses performed through the hardening soil model and the Mohr-Coulomb model point out that (1) the hardening soil model predicts higher settlements than Mohr-Coulomb model; (2) the joint analysis of spatially variable stiffness and strength parameters show a higher impact on foundation settlement magnitude than the variability of those parameters were separately considered. Finally, two sensitivity analyses on the settlement assessment have been undertaken. The first one was aimed at estimating the impact of the vertical and horizontal scale of fluctuation calculated through the maximum likelihood estimation method. The second one was performed to assess the goodness-of-fit of the lognormal distribution for predicted settlements through the Kolmogorov-Smirnov statistical test. Both these two sensitivity analyses are relevant for reliability-based designing.

The thesis is rationally arranged and well-written. The abstract is exhaustive although the numerous results about the coefficient of variation trends in many different cases were briefly summarised.
The topic developed is not new but the use of the hardening soil model is a novelty in probabilistic calculations of shallow foundation settlements. Furthermore, the two sensitivity analyses described in

Chapters 5 and 6 are of methodological interest for practical applications of the spatial variability characterization of subsoil layering and shallow foundation settlements assessment.
Chapter 1, that is the introduction, is well structured: the objectives of the PhD study are clearly stated (through a bulleted list) and reasoned. The manuscript structure is clearly described through a summary of each chapter.

The state-of-the-art, in Chapter 2, is related to the uncertainty propagation in Geotechnical Engineering. The literature review is articulated and is focused on the procedures for the estimation of shallow foundation settlement, numerical methods in foundation settlement analysis, soil behavior models and their application, methods to deal with soil spatial variability, and the uncertainty propagation approaches in probabilistic methods. It is complete and effectively summarised. *Paragraph 2.9 "Conclusions" of the Literature Review chapter is not necessary* because the Chapter is a summary of the literature on this topic so no conclusions are needed.

Chapter 3 illustrates the methods adopted in this dissertation. In this section, *two weak points arise*: 1) Eq. 73, only one type of correlation function is employed. Why this choice? Does it fit better than others in the case study? 2) The type of soils considered in the numerical analyses is neither described nor the choice was discussed. A detailed description of the granular soil case study used in this thesis *is expected to be given during the Defence of this PhD thesis.* Another point that must be clarified is: "Why sandy soils are chosen?" Further on, the candidate discusses the use of Monte Carlo Simulations through RFEM and the effects of spatial soil variability on the settlement calculation of a strip foundation. Mean values, coefficients of variation, and the resulting probability distributions of settlements are carried out for two different soil constitutive laws: Hardening and Mohr-Coulomb Models. Monte Carlo simulations cannot take into account the correlations between mechanical parameters that characterize the soil strengths, such as friction angle and cohesion: *a brief discussion on this point should be provided during the thesis defense*.

The results are illustrated and discussed in Chapter 4. It introduces and compares differences in results (settlements) from the two mechanical models used in this study: the hardening soil and the Mohr-Coulomb. The investigation of the hardening soil model in probabilistic settlement calculations is a novelty and results show larger settlement uncertainties than the ones from Mohr-Coulomb mechanical model. The results are interesting and their possible applications must be investigated. To accomplish this point, the numerical analyses, although aiming at a parametric study, investigate some possible

real case studies of layered subsoil and spatial variability characters. *Thus, during the thesis defense, the candidate should even suggest to which real subsoil types these results can be applied*.

Chapter 5 proposes a comparison between the settlement results from (1) adopting the maximum likelihood method to calculate the vertical and horizontal scales of fluctuation (SoF) values and (2) using values from Chapter 4. This comparison is useful to understand the importance of a correct estimation of the SoF. This point was evidenced and stated by Mr. Teshager even in the chapter conclusion section.

Chapter 6 shows an interesting focus on the resultant probability distributions of the settlements starting from lognormal distributions of the resistance variables in both constitutive laws (Mohr-Coulomb and Hardening models). *The choice of the log-normal distributions for the starting variables could be better justified although it is reasonable*.

Finally, in Chapter 7, the conclusions are drawn from the results. The conclusions are stated clearly through a bulleted list. The implications of this study's results are even pointed out. In this paragraph the sub-section "Introduction" is useless.

My evaluation of Mr. Teshager's thesis is positive and I think his research work is a novel insight into the probabilistic approach to assessing the shallow foundation settlements.
According to what I have previously written, as an examiner, I give a favorable opinion for the defense of this doctoral thesis by Mr. Daniel Kefelegn Teshager to obtain the degree of Doctor of the Wroclaw University of Science and Technology.

Chieti, 30 May 2024

Faithfully

Prof. Ing. Giovanna Vessia – Associate Professor in Engineering Geology
at University "G. d'Annunzio" of Chieti-Pescara