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Modeling Uncertainties in Soil Properties by Random Finite Element Method

A.Johari[1], Z.Abedini[2], M.Jahanandish[3], S.Beshkoofeh[4]
1- Assistant Professor, Department of Civil and Environmental Engineering, Shiraz University of Technology, Shiraz, Iran
2- M.Sc. Candidate of Geotechnical Engineering, Department of Civil and Environmental Engineering, Shiraz University, Shiraz, Iran
3- Associated Professor, Department of Civil and Environmental Engineering, Shiraz University, Shiraz, Iran
4- M.Sc. Candidate of Geotechnical Engineering, Department of Civil and Environmental Engineering, Shiraz University of Technology, Shiraz, Iran

johari@sutech.ac.ir
z.abdni@gmail.com

Abstract
The Finite Element Method offers great potential for implementing uncertainties in properties of materials such as soil. In many cases, soil parameters should be considered as random variables or random fields. This paper discusses the Random Finite Element Method in predicting the variation of the elastic settlement due to the uncertainties of the elastic modulus. The geometry and the Poisson's ratio are considered as invariable parameters. The correlation length for the 30×60 m field is considered 30 m in order to have a conservative estimation of the elastic modulus variation. The number of 400000 realizations of the random field are generated. By generating and analyzing multiple realizations, the statistics and the density function of the maximum settlement is estimated. The reliability of the foundation according to limit state failure, in the form of excessive settlements is estimated.
Keywords: Finite Element Method, Random Finite Element Method, Random Field, Monte Carlo Simulation, Elastic Settlement.

1. INTRODUCTION

Once a footing has been designed and constructed, the actual settlement it experiences on a real soil mass can be quite different than expected, due to the soil's spatial variability. The deterministic Finite Element Method (FEM) has been increasingly used in practise, especially for geotechnical problems with complex geometries and parameters. Unfortunately, the validity of the results obtained using this technique can be drastically limited by the variability of the parameters introduced in the model. Variability often leads to uncertainty. We do not know what a typical parameter of a soil is at a particular location unless we have measured it at that location. As we know a parameter varies from point to point in a soil layer and it has a spatial correlation.

The basic representation of uncertain parameters in the FEM model is obtained by introducing random variables or fields. Coupling probability theory with the FEM cannot eliminate uncertainties but can indeed provide a quantitative evaluation of their influence on the reliability of the results of the analysis. Random Finite Element Method (RFEM) has been applied to various kinds of geotechnical problems including two-dimensional slope stability [1-3], differential settlement due to tunnelling [4], infiltration analysis with a spatially varying permeability function [5] and so many other problems. The RFEM attempts to understand the effect of property variations and the spatial correlation between the parameters. RFEM uses many individual realizations of uncertain properties within an FEM, combined with the Monte Carlo method, to determine the probability of an undesired event. The method has found widespread use in the field of geotechnics, as it is relatively simple to be implemented and provides a comprehensive analysis of the effects of variability.

In this paper we take a problem of elastic foundation settlement and critically examine the applicability of RFEM in the context of reliability analysis. The paper considers the case of a single footing and estimates the Probability Density Function (PDF) of the maximum elastic settlement by the Monte Carlo simulation (MCs). This elastic soil layer is underlain by bedrock. A superstructure founded on this soil mass is idealized as a uniform pressure applied over the free surface. Only the soil elasticity is considered to be