

ABSTRACT

From the geotechnical aspects, the deterministic analysis usually treats the soil medium as a single layer with uniform soil properties or a multi-layered system with layer-wise uniform soil properties. This approach also represents only a specific realization within the broader context of stochastic analysis and often fails to provide the actual failure mechanism, particularly where the failure surface passes through the weakest zone of the soil. Consequently, the deterministic analysis is unable to represent the practical scenarios consisting of several uncertainties. The uncertainties exist in the geotechnical system for several reasons, including soil spatial heterogeneity, restrictions and ambiguities regarding sampling and testing procedures, and errors in model transformation. To minimize these sources of variability, the deterministic study employs the factor of safety concept in the system to ensure the safety of the structure. Within the controlled environment, the errors associated with the sampling, testing techniques, and model transformation can be eliminated to a large extent. However, inherent soil spatial heterogeneity cannot be eliminated from the system as it occurs in the soil profile due to several natural geological processes. Subsequently, the deterministic analysis integrated with the factor of safety concept is unable to capture soil spatial variability and the actual failure mechanism of the geotechnical system, leading to unreliable and overestimated design of the geotechnical structures. These setbacks of deterministic analysis provide the motive for performing the stochastic analysis, laced with the failure probability concept, under the soil spatial variability framework.

The analysis of shallow foundations is an intricate domain of study where research is ongoing to attain more accurate and reliable foundation responses. The incorporation of spatial variability in the study of shallow foundations leads to a step forward in the reliable estimation of the responses. The current thesis selects the shallow foundation problems in terms of the bearing capacity analysis of two-dimensional strip footing and three-dimensional circular, square, and rectangular footings in various types of spatially variable soil under vertical loading. Since the selected problems are classical and require rigorous attention, this thesis comprehensively addresses them individually. The study uses the transverse anisotropic and rotated anisotropic autocorrelation structures to generate the random fields of soil properties, as the given autocorrelation structures are of practical importance. The transverse anisotropic autocorrelation structure in the soil profile exists because of the soil deposition process, and the rotated anisotropic autocorrelation structure in the soil profile can be observed due to the movement of the tectonic plates and other complex geological processes.

The present thesis employs the finite difference method integrated with random field theory using FLAC software (FLAC^{2D} and FLAC^{3D}) to analyze the given problems within the Monte Carlo simulation (MCS) framework. The problems include the bearing capacity analysis of a three-dimensional circular surface footing on spatially variable sandy soil, spatially variable undrained clay with a non-stationary random field of undrained shear strength, and spatially variable two-layered cohesive-frictional soil. These three problems are addressed considering the transverse anisotropic autocorrelation structure. In contrast, problems regarding the stability analyses of two-dimensional surface strip footing

Abstract

over an unsupported tunnel in spatially variable undrained clay and three-dimensional square and rectangular footings on spatially variable sandy soil are addressed considering the rotated anisotropy framework. Notably, the selected problems are not analyzed in the existing literature, defining the novelty of the current thesis. The soil parameters are assumed to be lognormally distributed random fields, and the random fields are discretized utilizing the Cholesky decomposition method. The statistics of the footing bearing capacity responses (i.e., mean and coefficient of variation) and the system failure probability considering a factor of safety value of 1 are evaluated using the MCS approach for various soil, geometric, and spatially variable parameters. The failure mechanisms of the foundation are also included in the study in terms of maximum shear strain rate and velocity vector plots to describe the impact of spatial variability effectively. The cumulative distribution and probability density function plots of the responses are also generated for the given parameters. Finally, for the reliable design of the foundation, the study determines the required factor of safety to achieve a small target failure probability, considering the given parameters. This thesis aims to investigate the specific area of interest, with the expectation that the outcomes of the study will offer practical value to practicing engineers.

Keywords: Shallow foundation; Soil spatial variability; Finite difference method; Monte Carlo simulation; Required factor of safety; Target failure probability.