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Reliability analysis of embankments using stochastic finite element method

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Abstract

Embankments are impounding structures made from compacted soil. Several methods can be used for determining mechanical behavior of these structures. Among them, the deterministic Finite Element Method (FEM) is a powerful method for this purpose. The main drawback in the application of this technique generally arises from the large uncertainties affecting the mechanical properties of materials in the model. Hence, finite element method in conjunction with stochastic analysis methods should then be used to assess the results of the analyses in probabilistic terms. In this paper, the usefulness of this approach for engineering purposes is investigated by analyses of embankments constructed by compacted soil. Finite element analyses are performed together with Monte Carlo simulations (MCs) and Point Estimate Method (PEM) and the results are compared. The results show that this technique can be useful to evaluate the relative influence of each designing parameters. Uncertainties affecting vertical displacements which may influence a large earth dam are also presented.

Keyword: Finite Element Method, Embankment, Reliability, Monte Carlo Simulation, Point Estimate Method

1. INTRODUCTION

Embankments are among the most widely used structures both in hydraulic and geotechnical engineering projects. Embankment dams and levees are two common examples. Settlement of embankments due to applied loads can cause severe problems. For example, in design of earth dams, maximum expectable settlement should be carefully calculated since large settlement of dam results in reducing the freeboard and overtopping.

Analysis of embankments is composed of many uncertainties. These uncertainties usually arise because of spatial variability of material properties, lack of accurate geotechnical parameters and approximations made in the modeling. Therefore, many problems in engineering require consideration of stochastic properties of materials, geometry or loads. Since traditional approaches do not consider many uncertainties in their calculations, reliability analysis is inevitable to take these uncertainties into account. Reliability analysis employs other analysis tools to determine the probability of exceeding a limit state which could be for instance a specified displacement. Due to importance of embankments in addition to their high costs, it is advantageous to develop reliability based analysis approaches to consider the uncertainties. For practical problems, finite element method is a powerful tool for analysis of structures. Unfortunately, the validity of results obtained using this technique can be drastically limited by the uncertainties introduced in the model. Hence, it is desirable to combine this method with some other powerful methods such as Monte Carlo simulation or point estimate method to take the stochastic nature of problem into account.

Shinozuka applied the Monte Carlo simulation and the standard FEM in the reliability analysis of structures with random excitation, random material properties or random geometric configurations [1, 2, 3]. Hasofer and Lind used the First Order Reliability Method (FORM) and Second Order Reliability Method (SORM) [4] techniques. Rackwitz noted that FORM and SORM are the most popular approximate techniques to date, which are used in calculating the probability integral encountered in reliability analysis of structures [5].