Chapter 15

Liquefaction Modelling of Granular Soils using Discrete Element Method

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ABSTRACT

The damage induced by seismic events is well known among the civil engineering, geological and seismological community. Seismologists and geologists who study this hazard at a deeper level are concerned more with the history and cause of earthquake events rather than their effects. When seismic energy is released during an earthquake it passes from the bedrock, then through the soil and to the substructure through which it is transmitted to the superstructure. Liquefaction phenomenon is a consequence of earthquake induced pore water pressure in the soil due to this released energy. Various deterministic and probabilistic based methods have been developed in the recent past after various case histories. It is crucial to understand the performance of critical structures such as pipelines, road networks, nuclear reactors etc during liquefaction. The current chapter majorly focuses on the liquefaction assessment using numerical modeling.

INTRODUCTION

Liquefaction is a high strain problem. The nonlinearity of soil is prevalent when exposed to high strain amplitudes (> 10^-3). High strains or dynamic forces acting on the soil result in stiffness degradation, decrease of effective stress and large deformations. Nonlinear behaviour of soils was investigated by many researchers and various methods have been postulated to demarcate and quantify such behaviour. Most of the researchers successfully employed laboratory testing and theoretical analysis to arrive at crucial conclusions. In spite of the analysis, the mechanism involved in the resulting behaviour of soil is yet to be understood. Numerical simulation studies can be employed for providing insight into the complex behaviour of soil.

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Soil is an aggregation of discrete particles and it requires to be modelled as discrete elements. Discrete element methods have the capacity to capture the mechanical interaction of discrete particles which cannot be solved by continuum based methods. From the discrete particle model of an idealized granular assembly, the motion of individual particles can be estimated. Using this method, quantification of required properties is from microscopic to macroscopic behaviour of the considered assembly. Particle interactions and overall behaviour of the system apart from internal and external physical conditions are predominantly influenced by material parameters such as the stiffness of the particles, nature of fluid filling the space between them, grain geometry (size, shape, and surface roughness). The state of the granular particles ascertains the forces acting on them. A constitutive model that considers such factors is to be postulated and used for the study. The aim of exploring the influence of different characteristics of soil under low, medium and high strains is assumed to be possible by numerically simulating the laboratory tests such as cyclic triaxial, resonant column and torsional shear test. These findings could be useful for the selection of sites for crucial structures and the vulnerability towards liquefaction.

BACKGROUND

Granular systems are omnipresent and the understanding of these systems at micro and macro level is crucial. Granular materials are characterized by hard inelastic contacts with friction and negligible thermodynamic effects. Usual state of granular systems is metastable state that is far from equilibrium. They can be activated with vibrations, shear, external volume forces (such as gravity, electric and magnetic fields), and motion of the interstitial fluid or gas (e.g. water or air). Such driving forces can induce transitions between solid and fluid.

Many researchers have been working on granular materials dating back to the work by Coulomb (1773), who introduced the idea of static friction, Faraday (1831), who discovered the convective instability in vibrated powders, and Reynolds (1885), who observed that a compacted granular material must expand in order to undergo any shear.

In the current study, the emphasis is on granular soils which include gravel, sand or silty soils that have negligible amounts or no clay present due to which the cohesive strength is considered to be zero are termed as granular soils. In certain cases, moist granular soils may exhibit apparent cohesion (Mitarai and Nori, 2006). Such cohesionless aggregates do not have a clear ‘linear elastic region’ defined by an initial yield surface (Petrakis et al., 1991). But the yield surface in a cohesionless soil is the locus of all points in stress space at which gross sliding between soil particles start. In geotechnical earthquake engineering, the behaviour of these soils susceptible to liquefaction has to be readily studied. Such complex phenomenon required large information at both micro and macro scale. Analytical and experimental studies provide only qualitative information but not quantitative. So, it is required to numerically simulate the phenomenon to understand the background. This can be achieved by simulating the laboratory tests used to understand the phenomena. Using laboratory tests limit the scale of granular particles to be modelled and the analysis can also be validated easily. To select the important inputs required in the study and the possible outputs, further sections describe the possibilities and previous studies in this area.
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