

A soil dynamics based liquefaction potential assessment framework for urban sites

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Abstract

Liquefaction hazard (soil losses its strength and starts to flow like fluid) is one of the most costly hazards caused by strong earthquakes. Reliable hazard assessment of urban areas is critical for making sound disaster mitigation plans.

Conventional empirical-correlation-based liquefaction hazard assessment methods, e.g. evaluating indices such as FL (Factor of safety against Liquefaction) and PL (Potential of Liquefaction), are wildy used for their simplicity: assessment usually only requires simple borehole data with basic physical properties of soil and SPT (Simply Penetration Test) N values. However, past experience, e.g. filed survey after the 2011 Tohoku Earthquake in Japan, showed that such assessment methods are prone to overestimate the liquefaction hazards. This can be attributed to the oversimplification of ground motions, i.e. only the maximal acceleration is considered to estimate earthquake-induced load and other characteristics of ground motion in the time and frequency domains are ignored.

The progress in the study of soil dynamics, especially the advances in constitutive models, enables successful numerical analysis of liquefaction potentials of soil layers for important civil engineering constructions, e.g. earth embankments and reservoir dams. For a given input ground motion, a time history of soil response can be obtained by using such soil dynamics based simulation. Though capable of taking into account the full characteristics of ground motions to achieve a more thorough assessment, such simulation asks for more sophisticated laboratory experiments to measure and calibrate soil constitutive models used in simulation.

This paper proposes an assessment framework, as a trade-off of the simplicity of conventional method and the rigorousness of the numerical seismic response analysis: 1. Start with borehole data for a target site, we construct soil model automatically. 2. Then required material parameters and control parameters for constitutive models are estimated based on borehole data. 3. For a given ground motion, the site response is computed by a soil dynamics library (a tested nonlinear Finite Element code with an elasto-plastic constitutive model). 4. Liquefaction potential is assessed according to the simulation result, i.e. the time history of the excessive pore water pressure. Though we admit that the estimation of certain parameters moderates the rigorousness of soil dynamics based simulations, we should point out that our interest is a general assessment framework for multiple sites in urban areas, making effective use of existing data for hazard mitigation purpose. Such assessment could be considered as a pre-screen procedure, to single out those sites that need further detailed analysis, i.e. rigor laboratory tests for soil parameter. Considering that the proposed framework can take into account the full characteristics of ground motions, it can serve as an effective alternative for (if not better than) the conventional liquefaction assessment methods.

In this paper, we first explain the details of the assessment framework proposed and the constitutive model applied. Then we show simulations of cyclic shear experiments of a single element for calibration and validation of the simulation code. Last, we carry out seismic response analysis for a target site using the proposed framework and compare the results with seismic records.

Keywords: Liquefaction potential assessment, Soil dynamics, Elasto-plastic finite element analysis