Chapter 6
Minimax Probability Machine:
A New Tool for Modeling Seismic Liquefaction Data

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ABSTRACT

Liquefaction in soil is one of the other major problems in geotechnical earthquake engineering. This chapter adopts Minimax Probability Machine (MPM) for prediction of seismic liquefaction potential of soil based on Shear Wave Velocity (Vs) data. MPM has been used as a classification technique. Two models (MODEL I and MODEL II) have been adopted. In MODEL I, input variables are Cyclic Stress Ratio (CSR), and Vs MODEL II uses Peck Ground Acceleration (PGA) and Vs as input variables. The developed MPM has been compared with the Artificial Neural Network (ANN) and Support Vector Machine (SVM) models. The developed MPM is a robust tool for determination of liquefaction susceptibility of soil.

INTRODUCTION

Liquefaction of soil during earthquake is a major concern for the stability of civil engineering structure. Liquefaction is a phenomenon whereby a granular material transforms from a solid state to a liquefied state as a consequence of increase in pore water pressure. The effective stress of the soil therefore reduces causing loss of bearing capacity. Liquefaction of saturated sandy soils during the past earthquakes has resulted in building settlement and/or severe tilting, sand blows, lateral spreading, ground cracks, landslides, dam and high embankment failures and many other hazards. So, the determination of liquefaction susceptibility of soil is an important task in civil engineering. Liquefaction of soil depends on the following parameters:

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- Intensity of earthquake and its duration,
- Location of ground water table,
- Soil type,
- Soil relative density,
- Particle size gradation,
- Particle shape,
- Depositional environment of soil,
- Soil drainage conditions,
- Confining pressures,
- Aging and cementation of the soil deposits,
- Historical environment of the soil deposit,
- Building/additional loads on the soil deposit.

Civil engineers use different methods for determination of liquefaction susceptibility of soil (Seed & Idriss, 1971; Dobry et al., 1981; Seed et al., 1983; Seed & Idriss, 1982; Seed et al., 1985; Robertson & Campanella, 1983; Skempton, 1986; Seed & de-Alba, 1986; Stokoe et al., 1988a; Ambraseys, 1988; Tokimatsu & Uchida, 1990; Stark & Olson, 1995; Arango, 1996; Andrus & Stokoe, 1997; Youd & Noble, 1997a; Olsen, 1997; Robertson & Wride, 1998; Andrus & Stokoe, 2000; Moss et al., 2006). Liquefaction potential is evaluated by comparing equivalent measure of earthquake loading and liquefaction resistance. Earthquake loading characterization is generally done by using cyclic shear stress. By normalizing the cyclic shear stress amplitude by initial effective overburden stress, a cyclic stress ratio (CSR) is defined. CSR represents the level of cyclic loading induced at different depths in a soil profile, which corresponds to a specific earthquake. The resistance is mostly characterized based on field observation and potential for liquefaction is classified by comparing CSR with the liquefaction resistance, cyclic resistance ratio (CRR) [Factor of safety (FS) $=\frac{\text{CRR}}{\text{CSR}}$]. There are different methods available for determination of liquefaction potential based on standard penetration test (SPT) (Seed & Idriss, 1967, 1971; Seed et al., 1983; Seed et al., 1984; Youd et al., 2001). These methods proposed boundary lines that separate field conditions causing liquefaction from conditions not causing liquefaction in sandy soils. Using this method, the CSR induced by the earthquake at any point in the ground is estimated as (Seed & Idriss, 1971).

$$CSR = \frac{\tau_{av}}{\sigma'_v} = 0.65\left(\frac{a_{\max}}{g}\right)\left(\frac{\sigma_v}{\sigma'_v}\right)r_d \tag{1}$$

where τ_{av} = average equivalent uniform cyclic shear stress caused by the earthquake and is assumed to be 0.65 of the maximum induced stress; a_{max} = peak horizontal ground surface acceleration; g = acceleration of gravity; σ'_v= initial vertical effective stress at the depth in question; σ_v= total overburden stress at the same depth and r_d= shear stress reduction coefficient to adjust for the flexibility of the soil profile and it has been estimated from the chart by Seed and Idriss (1971). The value of CSR is corrected to an earthquake magnitude of 7.5, using the magnitude correction (C_m) proposed by Seed et al. (1985). Seed et al. (1985) proposed a standard blow count N_{60}. N_{60} has determined from the following relation: