Comparison of equivalent linear and nonlinear ground response analysis methods in the time domain

A.Johari1[1,*] - A.Heidari[1]
[1] Department of Civil and Environmental Engineering, Shiraz University of Technology, Shiraz, Iran

ABSTRACT

Earthquake resistant design is an important consideration for designing structures in seismic prone areas. On the other hand to get the design earthquake motion at the ground surface or at the foundation of a structure, engineers need to make a seismic site response analysis. The motion equation is a second-order propagation type of equation. This equation can be solved in either frequency domain or time domain. QUAKE/W is a geotechnical finite element software product used for the dynamic analysis of earth structures subjected to earthquake shaking and other sudden impact loading. This software solves the equation of motion in the time domain by integrating in a small time increment. In this paper, the Coyote Lake problem is simulated by the software. This modeling is carried out without any boundary conditions and only by enough increasing the width of the soil layers. The analyses were done by equivalent linear and nonlinear methods. The peak ground acceleration and response spectrum at the ground surface are determined by the two approaches for the site. Comparison of the results shows that the nonlinear approach predicts closer response to real recorded data with respect equivalent linear.

Keywords: Time domain, Peak ground acceleration, Seismic ground response, Equivalent linear and nonlinear

1. INTRODUCTION

Seismic ground response analysis is an essential tool for the practical engineers. Several input data are required in the seismic ground response analysis which can be classified into four categories. Geological or topological configuration, such as soil profiles and cross-sectional shape, soil properties of site, input earthquake motion and the method of the analysis (linear, nonlinear or equivalent linear methods). Site response has been studied in large number of earthquakes since 1960 [1]. Available methods of the seismic ground response analysis can also be categorized in terms of their calculation domain. In this respect, these methods are categorized into time domain [2], [3] and frequency domain [4].

There are many researches have been developed to analyzed the seismic ground response. Among important contributions are the presented researches in [5] to [11]. Ragozzino [5] analyzed the ground motion records of events and compares the observed peak accelerations and the H/V and V/H spectral ratios with those revealed from numerical simulations. The finite element method was considered herein to perform 2D dynamic modeling on a geologic cross-section of the upper Aterno River Valley. Rizzitano, et. al. [7] analyzed the effects of slope inclination and of the characteristics of the input motion were also investigated. In order to calibrate the numerical model, the results obtained in linear visco-elastic analyses were compared with the results of parametric numerical analyses available in the literature. Bolisetti. et. al. [9] purposed of this study sheds light on the applicability of some industry-standard equivalent linear (SHAKE) and nonlinear (DEEPSOIL and LS-DYNA) programs across a broad range of frequencies, earthquake shaking intensities, and sites ranging from stiff sand to hard rock, all with a focus on application to safety-related nuclear structures. Johari and Momeni [10] used the non- recursive algorithm in linear and nonlinear Hybrid Frequency Time Domain (HFTD) approaches for stochastic analysis of site amplification. The non-recursive algorithm causes time reduction of analysis that is the essential base of stochastic analysis.

Since soil is a nonlinear material, there is no proportionality between stress and strain. The deformation characteristics, and of course the strength, vary drastically with : (a) the magnitude of effective stress that stands for the contact forces among soil grains, (b) history of stress application in the past, (c) rate of loading, (d) material strength of soil among others. Thus, the basic understanding of soil behavior requires us to do many efforts experimentally. Consequently, many stress–strain models of soils have been proposed by a number of researchers [12], [13] and [14].

The goal of this paper is comparison between the equivalent linear and nonlinear methods in time domain. For this purpose, a wide site for neglecting the effect of lateral boundary is supposed. The soil profile is simulated soil in QUAKE/W software. The predicted peak ground acceleration of bench mark site Coyote Lake is considered.