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ScienceDirect

Procedia Computer Science 125 (2018) 357–366

Procedia Computer Science

www.elsevier.com/locate/procedia

6th International Conference on Smart Computing and Communications, ICSCC 2017, 7-8 December 2017, Kurukshetra, India

Earthquake Response Analysis of Sites in State of Haryana using DEEPSOIL Software

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Abstract

Earthquake response analysis has been carried out for various locations in the State of Haryana (India) adopting the equivalent linear approach. For this purpose, geotechnical data have been collected from different government and private organizations. Based on the provisions of National Earthquake Hazards Reduction Program (NEHRP), all the sites have been classified using average N-value (N_{30}) for the soil profile. The shear modulus (G_{max}) values of the layers in a soil profile have been estimated using standard correlations. Cyclic Response has been accounted for using the standard shear modulus degradation and damping curves. Time histories from Himalayan Thrust System have been used as an input and soil amplification has been estimated at the surface using DEEPSOIL software. The results of the study have been formulated in terms of soil amplification map, response spectra, PGA along the depth, surface time histories and strain along the depth. These results can be used for dynamic analyses and design of structures, planning of advanced dynamic lab test etc. Moreover, it has been observed that sites in Haryana can significantly amplify ground motions and hence a site-specific design approach must be adopted for important structures.

Peer-review under responsibility of the scientific committee of the 6th International Conference on Smart Computing and Communications.

Keywords: Ground Response Analysis; Dynamic Analysis; Earthquake Hazard; PGA; Amplification; Haryana

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1877-0509
Peer-review under responsibility of the scientific committee of the 6th International Conference on Smart Computing and Communications
10.1016/j.procs.2017.12.047

1. Introduction

Seismic waves generally travel several kilometers in rock but a few meters in soil, yet the soil plays a very important role in determining the characteristics of ground motion and its analysis. The local soil conditions have a profound influence on the ground response during an earthquake. Also, the topography, nature of bed rock and the nature and the geometry of the deposits are the primary factors that influence the local modification of the wave motion between the bed rock and soil outcrop. Hence local site effects play a key role in earthquake-resistant design and must be accounted for on a case-by-case basis. Dynamic behavior of soils is quite complex and requires models which characterize the important aspects of cyclic behavior, but need to be simple, rational models. Ground response effects are generally evaluated using one dimensional models which assumes that seismic waves are propagating in vertical directions through the horizontal layers of the soil. Theoretical modeling of 1D site response can generally be accomplished using Equivalent-linear (EL) or nonlinear (NL) analysis. Equivalent Linear ground response modeling is widely used in practice to simulate true nonlinear soil behavior. The advantages of equivalent-linear modeling include small computational effort and few input parameters. The most commonly used equivalent-linear computer codes are SHAKE, DEEPSOIL, EERA, Pro-Shake etc. Equivalent-linear modeling is based on a total stress representation of soil behavior. In this method, the nonlinear stress strain loop is approximated by a single equivalent linear secant shear modulus that is a function of the amount of shear strain. Nonlinear analysis has more potential to simulate soil behavior accurately and is more realistic too. But the implementation of the same is seldom practiced by non-expert user due to its poorly documented and unclear parameter selection and as well as inadequate documentation of benefits of nonlinear analysis over equivalent linear analysis.

The analysis of site response with equivalent-linear modeling is an iterative procedure in which initial estimates of shear modulus and damping are provided for each soil layer. Using these linear, time-invariant properties, linear dynamic analyses are performed, and the response of the soil deposit is evaluated. Shear strain histories are obtained from the results, and peak shear strains are evaluated for each layer. The effective shear strains are taken as a fraction of the peak strains. The effective shear strain is then used to evaluate an appropriate equivalent shear modulus (G) and equivalent viscous damping ratio (β). The process is repeated until the strain-compatible properties are consistent with the properties used to perform the dynamic response analyses. In this study, effects of local soil conditions on earthquake ground motions have been estimated by carrying out detailed 1D equivalent linear wave propagation analysis using DEEPSOIL software [1]. The results will be useful for structural designers and town planners and can be used as a guiding tool for carrying out more advance dynamic analysis.

2. Study Area and Data Collection

Haryana is a non-coastal state in North India with its capital at Chandigarh. It is a moderate sized state having an area of 44,212 km^2, which is 40 times the area of Delhi. It ranks 19^{th} in terms of area in the country. It is surrounded by the states of Uttarakhand, Himachal Pradesh and Shiwalik hills on the North, Uttar Pradesh on the East, Punjab on the West and Delhi, Rajasthan and Aravali hills on the South. It lies between 27°39' to 30°35' N latitude and 74°28' and 77°36' E longitude. The state is covered by three Seismic Zones, II, III and IV, making it prone to low to moderate damage risk from earthquakes [2]. In a recent study on seismic hazard assessment (Puri and Jain, 2016), it has been concluded that the state of Haryana can experience high peak ground accelerations during an earthquake [3]. Based on the DSHA studies carried out for Haryana, the maximum magnitude potential values calculated for various seismogenic sources in the seismic study area range from 5.5 to 8.5 M_w. The value of PGA ranges from 0.071g to 0.60g. The previous hazard assessment studies for Haryana have been carried out for rock site conditions and therefore, a detailed estimation of local site effects is required for the State of Haryana. For this, geotechnical data collected from Public works department (PWD), Delhi Metro Rail Corporation (DMRC), Northern Railways (NR), Haryana Urban Development Authority (HUDA), Nuclear Power Corporation of India Limited (NPCIL), Rail Vikas Nigam Limited (RVNL) and several geotechnical consultants have been used in the study. The developed geotechnical database has information for 1053 distinct locations in the State of Haryana covering almost each district up to a depth of 50 m.