Seismic Site Classifications and Site Amplifications for the Urban Centres in the Shallow Overburden Deposits

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ABSTRACT

This paper presents seismic site classification practices for urban centres in Australia, China, and India with special emphasis on their suitability for shallow soil sites. The geotechnical aspects of seismic site classifications play a critical role in the development of site response spectra, which is the basis for the seismic design of new structures and seismic assessment of existing structures. Seismic site classifications have used weighted average shear wave velocity of top 30 m soil layers, following the recommendations of National Earthquake Hazards Reduction Program (NEHRP) or International Building Code (IBC) site classification system. The site classification system is based on the studies carried out in the United States where soil layer may extend up to several hundred meters before reaching any distinct soil-bedrock interface. Most of the urban centers in Australia, China, and India are located on distinct bedrocks within few meter depth of soil deposits. For such shallow depth soil sites, NEHRP or IBC site classification system is not suitable. A new site classification based on average soil thickness, shear wave velocity up to engineering bedrock is proposed. The study shows that spectral value and amplification ratio estimated from site response study considering top 30 m soil layers are different from those determined considering soil thickness up to engineering bedrock.

Keywords: Amplification, Shear Wave Velocity, Site Classification, Site Response, Soil Depth

INTRODUCTION

There has been a growing demand for the expansion of cities in the Asia Pacific regions due to rapid increase in populations leading to unplanned constructions. The urban centres in the Australia, China and India are prone to significant hazard even in low to moderate magnitudes earthquake events. Earthquakes in and around India are as inevitable as the autumnal fall of fruit from a tree (Bilham & Hough, 2006). As the earthquakes are not precisely predictable, only way to reduce damages is to design or retrofit the structures against earthquake induced forces in urban centers, where risk level is more due to large population and
existing unplanned structures. Seismic codes are becoming popular over the last few years due to frequent earthquakes around the world. Site effects represent seismic ground response characteristics and are inevitably reflected in seismic code provisions. The selection of appropriate elastic response/design spectra according to soil categories and seismic intensity is the simplest way to account for site effects both for engineering projects and for general purposes like microzonation study (Pitilakis, 2004). Modern seismic codes in America and Europe (International Building Code, 2009; UBC 97, NEHRP and EC8) have produced valuable data and have incorporated the site effects based on important experimental and theoretical results. The accurate soil categorization is introduced based on a better description of soil profiles using standard geotechnical parameters like plasticity index ($P_L$), undrained shear strength ($S_u$) and average shear wave velocity ($V_s$) values. Also, special attention has been given in the modern seismic design codes to incorporate site amplification factors to increase rock outcrop response spectral ordinates to properly account for the effect of soil sites reflecting field conditions. In general the important parameters describing site effects in seismic codes are expressed through: (a) site classification (b) spectral amplification factors and shapes of the response spectra. It is noted that seismic codes should always reflect the basic knowledge and technology of the present time. Code must be simple and realistic with an acceptable level of accuracy to adopt for the seismic design of the structures (Pitilakis, 2004).

Soil condition modifies ground motion and in many cases result in greater amplitude of motion together with change in frequency contents and duration of ground motion. Estimation of the earthquake response spectra with proper consideration of site effects is very important for the design of new structures and performance assessment of existing structures (Anbazhagan & Sitharam, 2008a, 2008b). The response at the surface of soil deposit is dependent on the frequency contents of bedrock motion, the geometry and material properties of the soil layers above the bedrock. These parameters are directly or indirectly quantified and represented by many researchers as part of the seismic microzonation study. Seismic site classification and empirical correlation between top 30 average shear wave velocities ($V_s^{30}$) are widely followed to quantify soil amplification or site effects. Although a number of methods are being recommended in design codes worldwide, most popular are those that consider borelogs with standard penetration test, (SPT)-N values, and shear wave velocity from Spectral Analysis of Surface Waves (SASW) and Multichannel Analysis of Surface Waves (MASW) (Anbazhagan, 2009). Most of the seismic site classification systems considers average of $V_s$ or SPT-N values of top 30 m soil layers, because of the direct correlation with the proposal of National Earthquake Hazards Reduction Program (NEHRP) (BSSC, 2001) and International Building Code (2006). Site classification considering weighted average $V_s$ of top 30 m soil layers has also been widely followed in seismic microzonation studies in many urban centers in Australia, China and India. These site classification schemes are then combined with probabilistic approach to estimate the surface level hazard accelerations (RaghuKanth & Iyengar, 2007; Anbazhagan et al., 2009). In spite of their wide use and well correlation with soil amplification factors, these site classification schemes (considering top 30 m soil layers) are still under research scrutiny (Marek et al., 2001; Anbazhagan et al., 2011b). In this study, for the assessment of site response, a suite of SPT-N and $V_s$ data are collated from Australia, China and India. These soil sites are first analyzed based on top 30 m soil depths, according to seismic site classification recommended in National Earthquake Hazards Reduction Program (NEHRP) (BSSC, 2001) and International Building Code (International Building Code, 2006). Second, site classification scheme has been proposed considering soil layers up to engineering bedrock. Shear wave velocity of 700 m/s is considered as engineering rock (Anbazhagan & Sitharam, 2009a). Site response of the soil sites has further been
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