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Seismic Ground Response Analysis of Input Earthquake Motion and Site Amplification Factor at KUET

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ABSTRACT Ground motion is the movement of the earth's surface due to explosions or the propagation of seismic waves. In the seismic design process, ground response analysis evaluates the impact of local soil conditions during earthquake shaking. However, it is difficult to determine the dynamic site response of soil deposits in earthquake hazard-prone areas. Structural damage has a great influence on the selection of input ground motion, and in this study, the importance of bedrock motion upon the response of soil is highlighted. The specific site response analysis is assessed through "DEEPSOIl" software with an equivalent linear analysis method. Furthermore, four input motions including Kobe, LomaGilroy, Northridge, and Chi-Chi were selected to obtain normalized response spectra. This study aims to obtain the site amplification of ground motion, peak spectral acceleration (PSA), and maximum peak ground acceleration (PGA) based on shear wave velocity from the detailed site-specific analysis of Bangabandhu Sheikh Mujibor Rahman hall at Khulna University of Engineering & Technology. The maximum shear wave velocity obtained was 205 m/s while the amplification factor varied from 4.01 (Kobe) to 1.8 (Northridge) for rigid bedrock properties. Furthermore, the Kobe earthquake produced the highest (4.3g) PSA and the Northridge earthquake produced the lowest (1.08g) PSA for bedrock, with Vs=205 m/s. The surface PGA values were acquired in the range of 0.254g (Northridge) to 0.722g (Kobe), and the maximum strain values for Kobe earthquakes were in the range of 0.016 to .303. Therefore, the surface acceleration values were very high (>0.12g) for the Kobe earthquake motion.

KEYWORDS Amplification Factor; PSA; PGA; DEEPSOIL; Shear Wave Velocity.

1 INTRODUCTION

Earthquakes are common phenomena that represent nature's most catastrophic and frightening event. However, an induced earthquake can be produced by an extended range of activities like mining, cave-ins, liquid injection, withdrawal, fracturing projects (Rubinstein & Mahani, 2015), and geothermal reservoir implementation (Majer *et al.*, 2007). They are directly generated due to the sudden release of stress and strain in the Earth's crust to produce a jerky movement. These events are characterized by small magnitudes concerning non-structural seismic damage (Filiatrault, Christopoulos, & Stearns, 2002) to buildings and infrastructure.

The geology of Bangladesh indicates a tectonically active country in the world for earthquakes. This is shaped by the movement of the Indian, Eurasian, and Burmese tectonic plates. There are many active faults along this boundary, which can also produce massive earthquakes. A significant earthquake can devastate the country at any time, for example, the epicentral distance in Dhaka was 230 km, and 1542 people died. This caused extensive damages to masonry buildings in many parts of Bangladesh (Ansary, Noor & Yasin, 2005; Govindaraju & Bhattacharya, 2012).

In the case of an earthquake event, the seismic design provides a dynamic response on a structure, which causes great losses in humans. With advanced technologies, a wide range of latest methodologies are demonstrated for earthquake-resistant structural design. In seismic design, the influence of local soil conditions, site topography, and rock properties on the expected seismic movements play a critical aspect. The effects of soil conditions are then estimated through seismic site response analysis (Govindaraju & Bhattacharya 2012).

This study focused on the seismic site response analysis in Bangabandhu Sheikh Mujibor Rahman hall at Khulna University of Engineering & Technology (KUET). Hashash, *et al.* (2011) conducted the analyses using DEEPSOIL software by an equivalent linear method. Furthermore, soil properties like the thickness of the layer, unit weight, shear wave velocity, and damping ratio were used as input to the study. The depth of the clay layer ranges from 3.0 to 30.0 meters, and the thickness of the sand layer ranges from 1.5 m to 3.0 m. The Shear Wave Velocity profile was first generated using some empirical formula of Ohta and Goto (1978) from SPT N value. Four input earthquake motions including Kobe, LomaGilroy, Northridge, and Chi-Chi were selected to estimate ground motion amplification, design response spectra. In addition, the motions determine the forces produced due to an earthquake which causes the instability of bedding planes' slopes (Boore & Atkinson, 2008).

2 METHODS

2.1 Site Information

The investigated area is "Bangabandhu Sheikh Mujibor Rahman hall" at Khulna University of Engineering & Technology of latitude 22°53'N and a longitude of 89°30'E (Figure 1). The area contained medium sand to clay type soil, and the depth of the clay layer ranges from 3.0 to 30.0 m. Furthermore, the cohesive nature of the soil with high organic, liquid, and plastic contents showed medium to high sensitivity to moisture, and cannot support heavily loaded infrastructure. Therefore, seismic ground response analysis is important to comprehend the impact of typical site conditions.

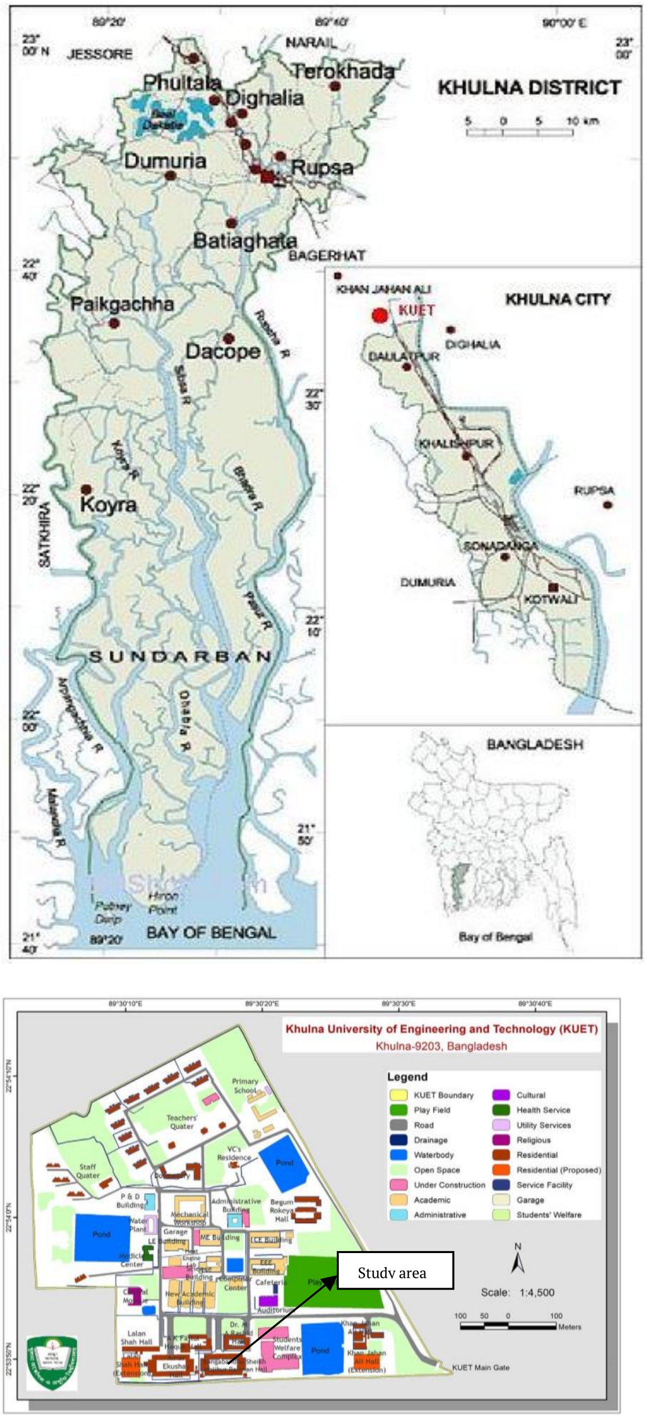


Figure 1. Site location

2.2 Sub Soil Investigation

The field investigation was conducted for "Bangabandhu Sheikh Mujibor Rahman hall" at the KUET campus through Standard Penetration Test. The execution of seven borings was up to the maximum depth of 30 m from the level of the ground surface. Meanwhile, the topsoil was clayey silt, bur grey at the depth of 1.5 m, and the medium sand was found from depth 1.5m to 3.0 m. The level of the groundwater table was 2'-3'' from the top of the subsurface, and the angle of internal friction for sandy soil was 30.9°. In addition, the maximum average of SPT value was 11 and using empirical relationship (Hossain, 2018) the collected borehole data was converted and the SPT- N value is commonly used to draw the soil profile in the subsurface.

The shear wave velocity is the most important property of soil due to its great effect in site response analysis (Boore & Joyner, 1997). The site amplification is assumed to change linearly with the change of V_{S30} (Boore & Atkinson, 2008; Chiou & Youngs, 2008; Choi & Stewart, 2005; Sandıkkaya, Akkar, & Bard, 2013; Walling, Silva, into shear wave velocity for the seismic site response study (Farrokhzad & Choobbasti, 2016).

2.3 The Velocity Profile

The main input parameter for the DEEPSOIL analysis is shear wave velocity and using an empirical equation of Ohta and Goto's (1978), the profile was generated (Figure 2) for "Bangabandhu Sheikh Mujibor Rahman hall". This empirical equation converts the standard penetration test-N value into shear wave velocity,

& Abrahamson, 2008; Seyhan & Stewart, 2014; and Kamai, Abrahamson, & Silva, 2014). The velocity profile was conducted by assuming the fixed reference of bedrock elevation at 30 meters below the existing ground surface, and can be time-dependent or independent (Salic et al., 2017). Furthermore, the linear site scaling does not control period independent and dependent values (Martin & Dobry, 1994).

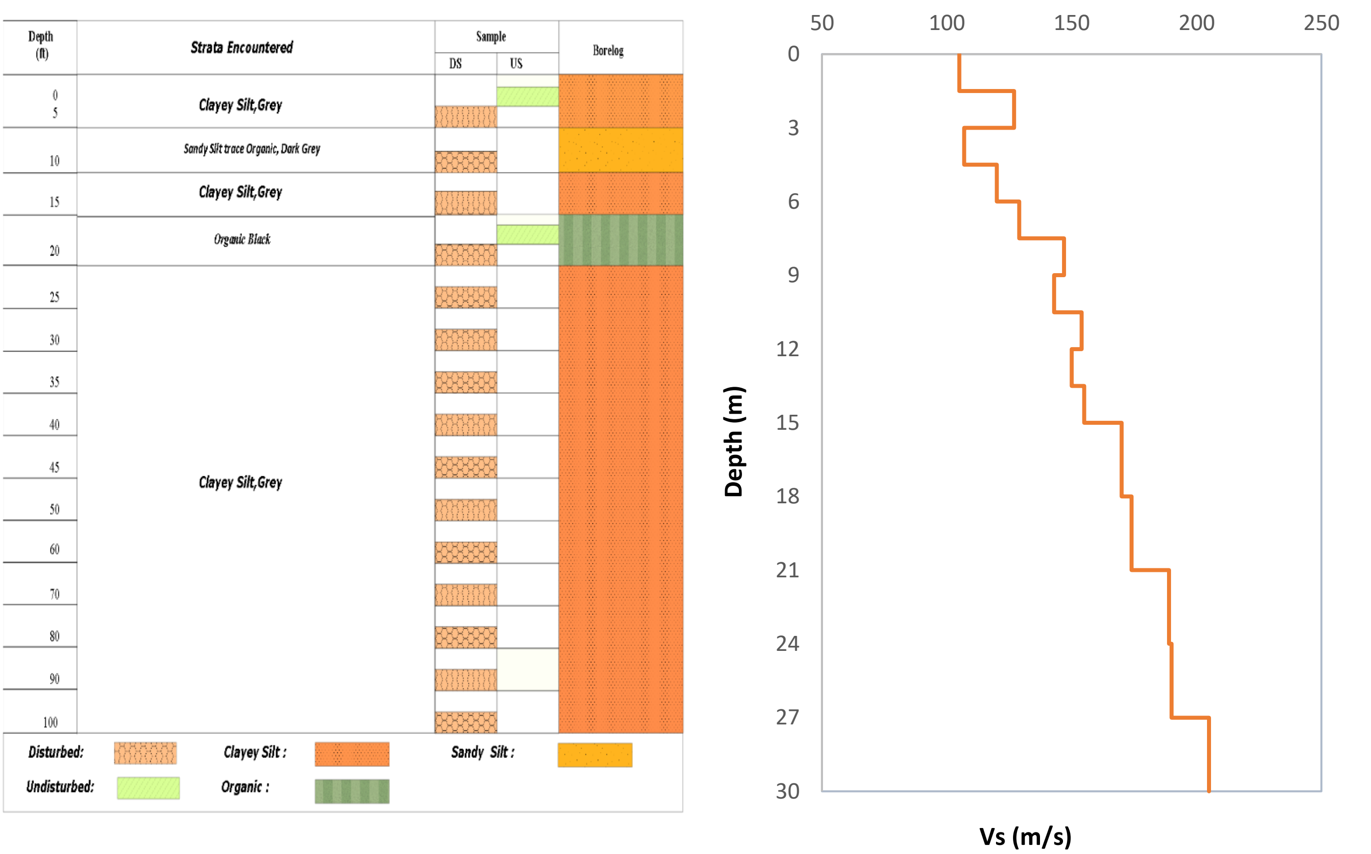


Figure 2. Site characterization.

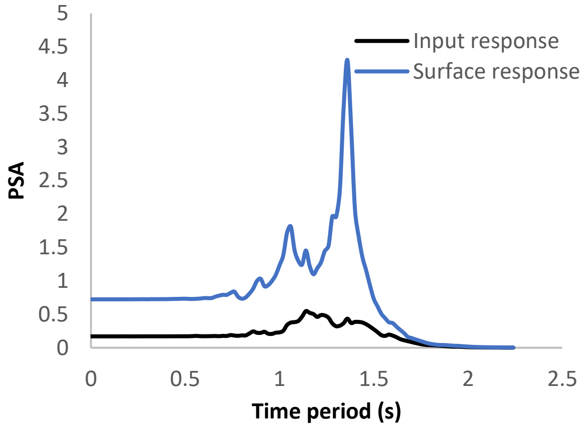
2.4 Ground Response Analysis

Ground response analysis contains the determination of soil amplification, potentiality of liquefaction, periods and soil stability analysis, etc. The relationship between stress and strain can be represented using three different methods. At low strain, the behavior of the soil is linear while at high strain it prevails nonlinearly. For seismic ground response analysis of the site consideration, the equivalent linear method was performed using the DEEPSOIL (Kwok, Stewart, & Hashash, 2008). It is accurate for computing PGA up to 3 seconds for general projects (Martin & Dobry, 1994; Dickenson & Seed, 1996; Dobry *et al.*, 2000). In this analysis, the bedrock properties are considered as rigid halfspace, and the solution type in equivalent linear analysis in the DEEPSOIL is frequency domain. Meanwhile, the input acceleration-time histories have an influential effect on the computed ground response analysis. The Kobe earthquake, LomaGilroy, Northridge earthquake, and Chi-Chi earthquake are chosen as the input ground motion, and the input rock motion is scaled to 0.12g value.

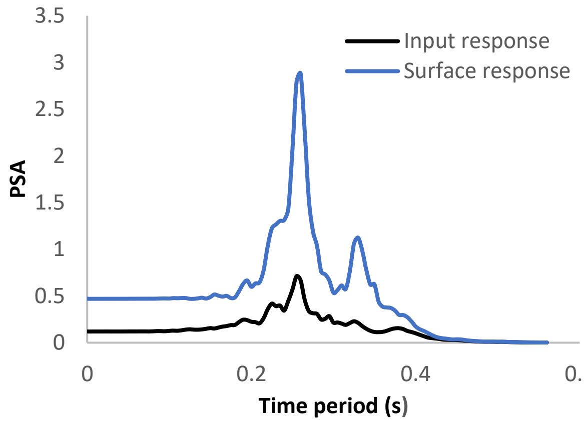
3 RESULTS AND DISCUSSION

3.1 Response Spectra

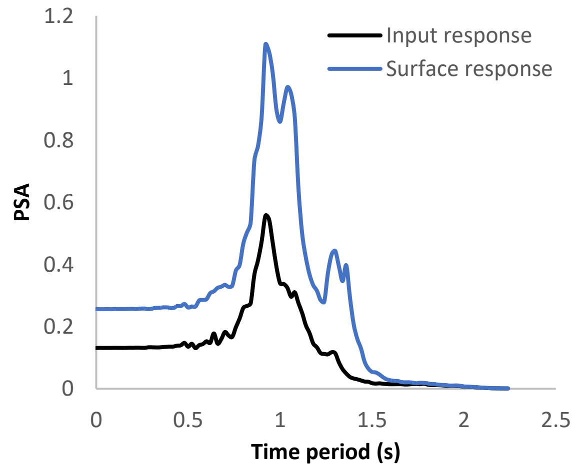
For rigid halfspace bedrock, the response spectra of four input earthquake motions are shown in Figure 3. Kobe earthquake generates the largest (4.30g) peak spectral acceleration (PSA) for this site while the Northridge earthquake generates the lowest (1.08g) peak spectral acceleration (PSA).



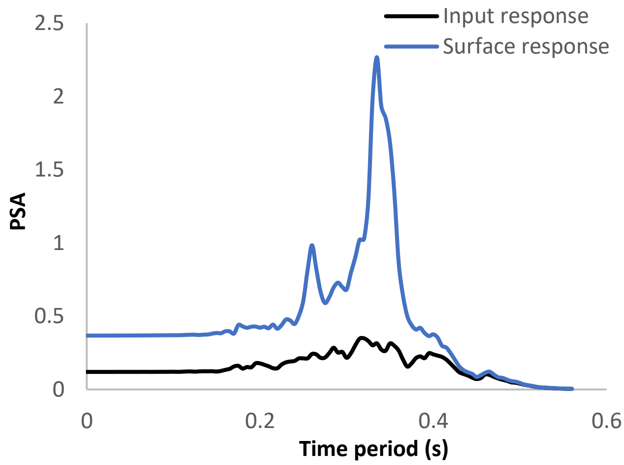
a) Kobe Earthquake



b) LomaGilroy Earthquake



c) Northridge Earthquake



d) Chi - Chi Earthquake

Figure 3. Response spectra

3.2 Time Histories

For rigid half-space bedrock, the design soil profile was excited with input motion of four earthquakes to measure the dynamic response of local soil, and an equivalent linear ground response analysis method was used for site response analysis. Figure 4 showed the acceleration of soil at the ground surface, and the ordinates of the value fluctuate with time.

3.3 Maximum Peak Ground Acceleration (PGA)

The maximum Peak Ground Acceleration (PGA) variation from the ground surface to 30 meters depth for this site is shown in Figure 5. Furthermore, the value of PGA at the surface and bedrock is attained from the analysis. The peak ground acceleration values at the surface are found to be in the range of 0.251g (Northridge) to 0.722g (Kobe) and that of the bedrock was found to vary from 0.118g (Chi-chi) to 0.180g (Kobe). Meanwhile, the level of damage to the building and infrastructure depends on the maximum PGA.

Site amplification factors are often used as one of the significant parameters to characterize the intensity of ground motion. The amplification factor is defined as the ratio of peak ground acceleration at surface and reference rock. Therefore, the amplification factors have also been computed and shown in Figure 6, and the variation is within 1.80 (Northridge) to 4.01 (Kobe).

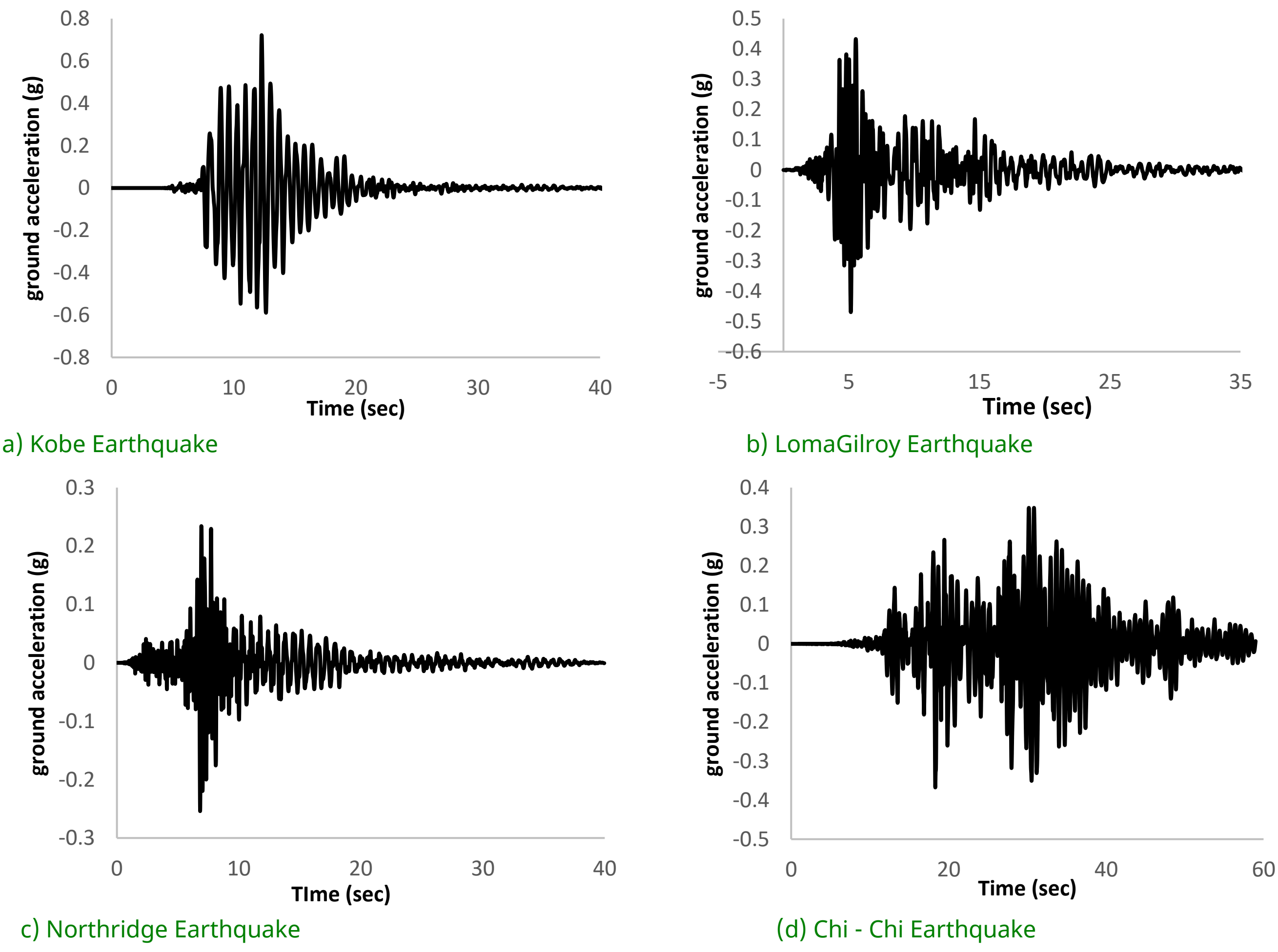


Figure 4. Time histories for local site effect

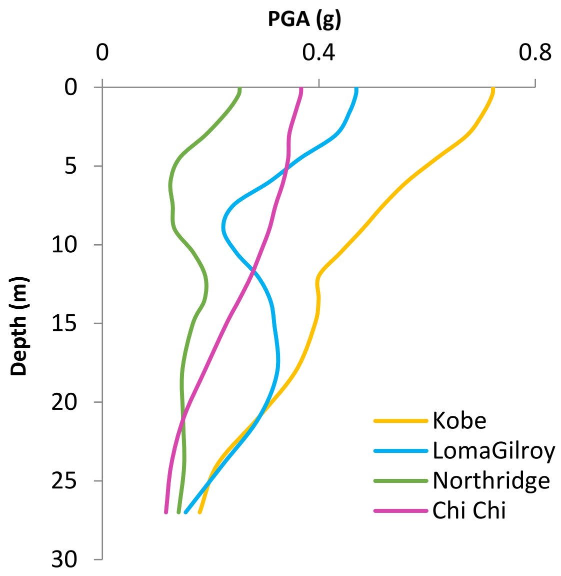


Figure 5. Maximum Peak Ground Acceleration

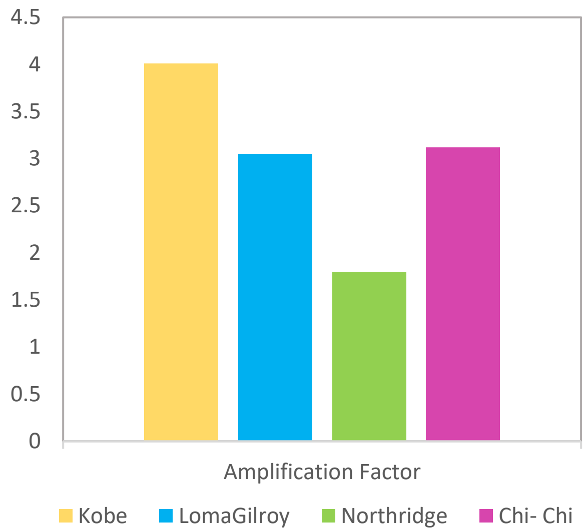


Figure 6. Site Amplification Factor

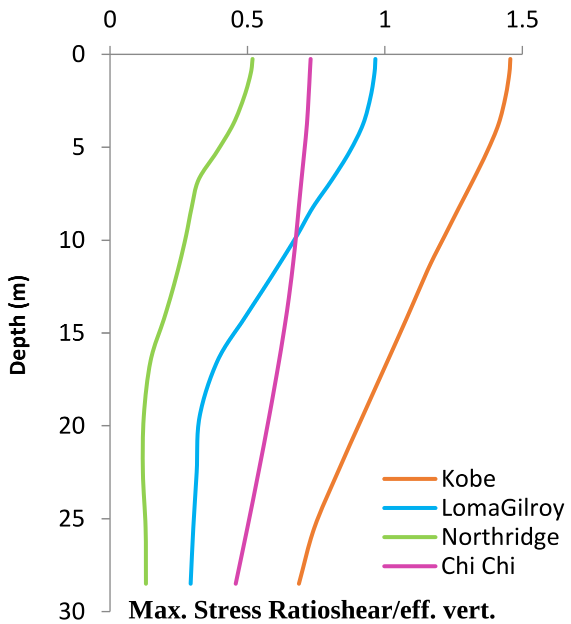


Figure 7. Maximum stress ratio for local site effect

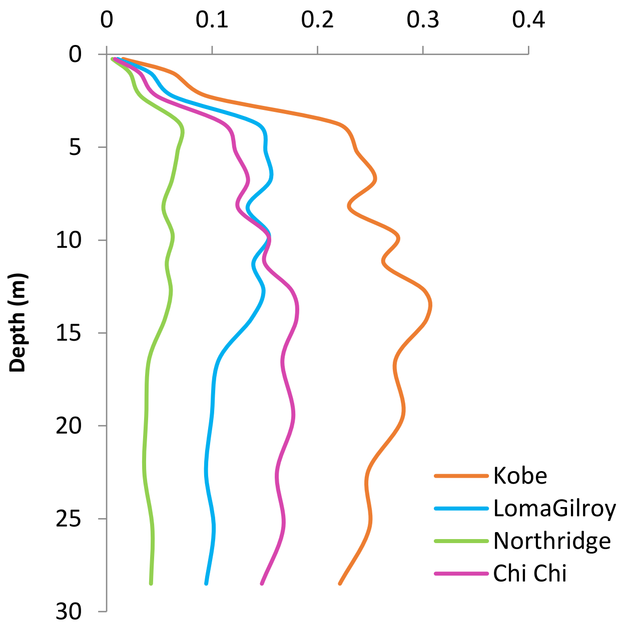


Figure 8. Maximum strain for local site effects

3.4 Maximum Stress Ratio

For rigid halfspace bedrock, the Maximum Stress Ratio of four input motions for this site is shown in Figure 7. Meanwhile, the Maximum stress ratio values for Kobe and Northridge earthquakes are in the range of 0.687 to 1.45, and 0.12 to 0.519 respectively.

3.5 Maximum Strain

A high range of strain values subjected to the input motions represents higher energy content. Meanwhile, the SPT-N value and the stiffer soils which released higher maximum strain are directly proportional. Due to cyclic loading, more energy is dissipated, and it represents a higher strain range. For rigid halfspace bedrock, the Maximum Strain for this typical site is shown in Figure 8, and the values for this site are obtained from the analysis. The Maximum strain values for Kobe and LomaGilroy earthquakes are in the range of 0.016 to .303, and 0.0104 to .155 respectively. In addition, the Maximum strain values for Northridge and Chi-Chi earthquakes are in the range of 0.006 to .0697, and 0.0079 to 0.18 respectively.

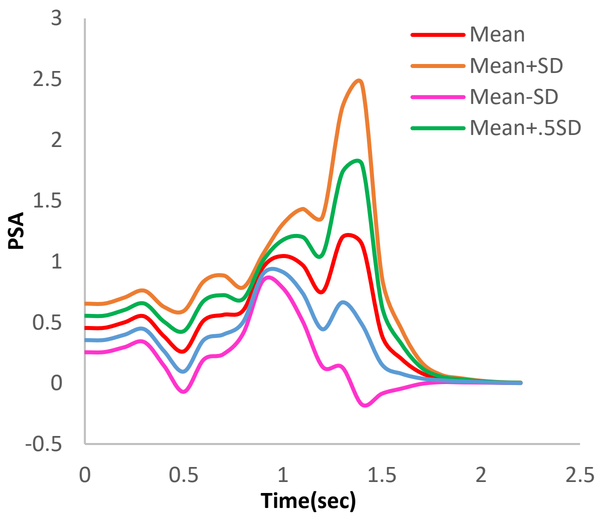


Figure 9 Comparison of Mean and Standard Deviation for Surface PSA

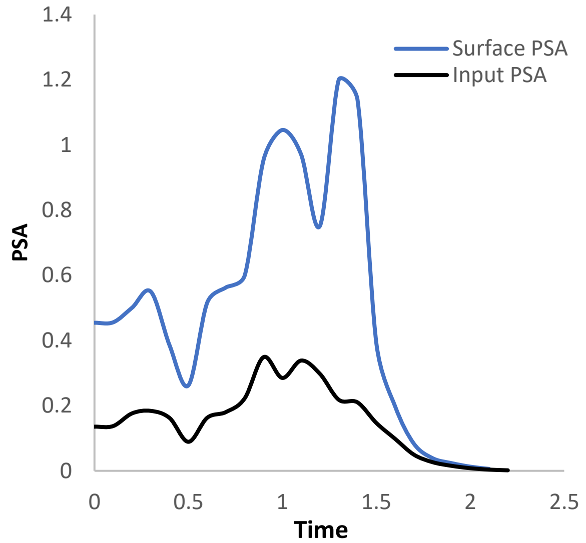


Figure 10 Comparison of Mean Input PSA and Mean Surface PSA

Figure 9 showed the comparison between Mean and Standard Deviation for surface PSA and Figure 10 showed the comparison between Mean Input PSA and Mean Surface PSA produced for different input motions.

4 CONCLUSION

As the behavior of the soil is dynamic during seismic loading, the site response analysis is very important in hazard analysis and checking the effect of the local site. The two important factors that affect the level of ground shaking are surface rock properties and local soil conditions. For a typical site, the ground response analysis method is considered equivalent linear. Furthermore, Kobe, LomaGilroy, Northridge, and Chi-Chi earthquake motions were chosen to comprehend the ground motion criteria representing the nearby and distant sources of earthquake hazard for the site under consideration. The depth of the clay layer varies from 3 m to 30 m. The analysis results showed that the soil subjected to input motions has a large amplification factor while considering the bedrock properties as rigid. The rate of amplification factor was maximum for Kobe earthquake motion (4.01) and minimum for Northridge Earthquake motion (1.8). More input motions can be attained to obtain the design response spectrum, and the peak ground acceleration value ranges from 0.722g (Kobe) to 0.118g (Chi-Chi). Furthermore, this study provides a guideline for generating the normalized response spectra under certain earthquake phenomena and it suggests suitable ground improvement techniques for such areas. It also found that the strong wave propagation of input motion affects the subsurface of the soil's response and its characteristics. Meanwhile, weaker soils that are prone to strong motions have high residual strain after seismic events.

DISCLAIMER

The authors declare no conflict of interest.

AVAILABILITY OF DATA AND MATERIALS

All data are available from the author.

AUTHOR CONTRIBUTION STATEMENTS

Sonia A. performed the analytical analysis and took a substantial contribution in discussing the result and drafting the manuscript.

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