ONE DIMENSIONAL GROUND RESPONSE ANALYSIS OF COASTAL SOIL NEAR NALIYA, KUTCH, GUJARAT

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ABSTRACT: More than 60% of the country’s landmass is exposed to earthquake hazard. The Kutch Coastal plains have several ports such as Kandla, Mundra and Mandvi and major industries such as Tata Power Ltd., Adani Industries, and Sanghi Cement. However region has experienced many earthquakes in the past, most recently 2001 Bhuj earthquake (Mw 7.8), caused considerable damage and human loss in the area and far off place like Ahmedabad and Surat. The intense activity of aftershocks of Bhuj earthquake is still continuing. Kutch region falls under zone V of seismic zoning map of India (IS 1893:2002). Hence earthquake studies are very essential in the coastal area of Kutch. In the present study an attempt has been made to carry out one dimensional ground response analysis by equivalent linear method using various professional and open source softwares like SHAKE 2000, DEEPSOIL, Seismo Signal etc for an Industrial site near Naliya, at Kutch coast. Shear wave velocity is an essential input for carrying ground response analysis, have been obtained from SPT ‘N’ values using empirical relations. The response of the soil profiles are calculated from the recorded acceleration time history at underlying rock half space considering vertically propagating waves. The acceleration time history and spectral ordinates at the surface were determined and the results of SHAKE 2000 and DEEPSOIL have been compared.

1. INTRODUCTION

North western part of Gujarat has been considered as a stable continental region since many years. It is primarily the damage caused during the 2001 Bhuj earthquake (Mw7.7) demanded the immediate study of the Kutch region. Kutch has been tectonic domain of high seismicity, included in zone V of the seismic zoning map of India (IS 1983:2002). Seismic energy release in order of $7.31 \times 10^{20}$ ergs/ year, which is comparable with certain active blocks of Himalaya. Kutch region has experienced many devastating earthquakes, recently 2001 Bhuj earthquake of Mw 7.7 struck 60 Km east of Bhuj and 4 Km NW of Bhachau village (USGS location 23.419° N, 70.233° E, 17 Km Depth) and caused widespread damage, affecting the various towns of Kutch region. The Bhuj earthquake was one of the most destructive earthquake in the Indian history causing over 20000 deaths and 1,66,000 injuries and damaging or destroying over a million structures including schools, village health clinics, water supply systems, communications, and power. The earthquake has caused an economic loss of $10 billion (Directorate of Information, Govt. of Gujarat, 2001). Though in March 2008, 14 aftershocks with M 5.0–5.8, about 200 aftershocks with M 4.0–4.9 and about 1600 aftershocks with M 3.0-3.9 have been recorded. Moreover in recent time, Kutch has emerged as a hub for chemicals, minerals, textiles, engineering, Oil and Gas and port based industries. The presence of Mundra, Kandla and Mandavi ports has made the district a trade and logistic hub and provides ideal gate way to Asian, African and American markets, Kutch accounts for 39.07 percent of the total projects currently under implementation in the State of Gujarat. According to Industrial Memoranda (IEM) filed from 1988 to 2007, Kutch has shown an investment of INR 1, 00,806 crores (USD 24,586.43 Million) in industries such as textiles, chemicals etc (Industries Commissionerate, Govt. of Gujarat). Considering all aspects, seismic studies have become very vital for the region.

In the present study an attempt has been made to carry out one dimensional ground response analysis by equivalent linear method for an Industrial site near Naliya, at Kutch coast using various professional and open source softwares like SHAKE 2000, DEEPSOIL, Seismo Signal etc. Shear wave velocity is an essential input for carrying ground response analysis, have been obtained from SPT ‘N’ values using empirical relations. The response of the soil profiles are calculated from the recorded acceleration time history at underlying rock half space considering vertically propagating waves. The acceleration time history and spectral ordinates at the surface were determined and the results of SHAKE 2000 and DEEPSOIL have been compared.
2. GEOTECHNICAL INVESTIGATION

Industrial site is located near the west coast of Kutch region, the location of site as shown in Figure 1. Geotechnical investigations were carried out to study the subsurface characteristics of the site. Total 8 nos. of borehole were drilled up to 25.0 m depth and out of five is selected for ground response analysis and site specific studies. Figure 2 shows the location of the boreholes in the area. Following stratification were observed during Geotechnical Investigation:

- The existing ground level is raised by filling brownish, fine to very fine grained, clayey sand with some gravels up to about 4.50 m depth. The underlying layer comprises of grayish and brownish, fine to very fine grained, loose to medium dense, silty sand with little plastic fines up to about 10.20 to 12.80 m depth. Followed by dark grayish, fine to very fine grained, very soft, silty clays of intermediate plasticity with much sand up to about 21.0 to 25.0 m depth. From 21.0 m onwards brownish, fine grained, weak rock mass with closely spaced discontinuities was encountered up to the depth of investigation. Bed rock is found to be deep towards sea. Ground water table were encountered at approximately 2.0 m to 2.75 m depth during investigation.

3. SELECTION OF INPUT TIME HISTORY

Deterministic Seismic Hazard Analysis (DSHA) has been used to assess Peak Ground Acceleration (PGA) at bedrock considering three line sources namely, Allah bund fault, Kutch Main land fault, Katrol Hill fault and 2001 Bhuj earthquake (Mw 7.7) considered as a point source as shown in Figure 1 considering the past Seismicity and PGA of about 0.088g have been estimated considered for the present analysis (Thaker et al. 2009). While selecting a suitable time history several important factors such as similar magnitude, Peak acceleration close to target value and similar site conditions (Kramer 1996). For the present analysis only available time history in Gujarat is 2001 Bhuj earthquake (Mw 7.7) recorded at Ahmedabad, Gujarat were scaled to PGA of 0.088g and considered for the analysis. Another time history of Feb 2001 aftershock (Mw 5.4) recorded at Bhuj were scaled to 0.088g and for the predominant period as suggested in literature (Seed 1969, Idriss 1971). Figure 3 shows the selected time histories considered for the analysis.
4. DETERMINATION OF SHEAR WAVE VELOCITY

The SPT ‘N’ value measured in the field by conducting standard penetration test have been corrected for various corrections using the following equation,

\[ N_{60} = N \times (C_N \times C_E \times C_B \times C_S \times C_R) \]  

(1)

Where, \( C_N \) = Correction for Overburden pressure, \( C_E \) = correction for hammer energy, \( C_S \) = Correction for Presence or absence of liner, \( C_B \) = correction for borehole diameter, \( C_R \) = Correction for rod length. The shear wave velocity (\( V_S \)) is estimated from corrected SPT ‘N’ value (\( N_{60} \)) by compiling and averaging the empirical equations given by Imai & Yoshimura (1970, 1990), Ohasaki & Iwasaki (1973), Imai (1977), Imai & Tonouhi (1982), Seed & Idris (1981) and Japan Road Association (1980) as shown in Figure 4. Following equation were considered for the present analysis.

\[ V_S = 114.14 \ln (N_{60}) - 85.53 \]  

(2)

5. GROUND RESPONSE ANALYSIS

Local site conditions profoundly influence most of the important characteristics mainly the acceleration amplitude and frequency characteristics of ground motion during an earthquake. In the present analysis one dimensional ground response has been carried out using Softwares like DEEPSOIL (Hashash et al. 2005), SHAKE 2000 and Seismo-Signal (Seismosoft, 2004).

DEEPSOIL is a one-dimensional site response analysis program that can perform both one dimensional nonlinear and equivalent linear analysis and can feature a spontaneous graphical user interface. The method is frequency independent unlike SHAKE2000, which is a frequency domain method and is a linear analysis. Seismo-Signal constitutes an easy and efficient way to process strong motion data, featuring a users-friendly visual interface and capability of deriving a number of strong motion parameters often required for the engineer, seismologists and earthquake engineers.

In the present analysis earthquake motion is assigned to a Engineering bed rock level (N>100) as a input to evaluate peak acceleration values and acceleration time history at the surface for all borehole locations. A soil property of each layer is modeled by using modulus reduction (G/Gmax) and damping (\( \beta \)) versus shear strain curves. The degradation curves for sand, Clay and rock used for the present work are those proposed by Seed & Idriss (1970), Sun & Idriss (1988) and Schnabel (1973) respectively depending upon the geotechnical property and plasticity of the soil and Peak ground acceleration at the surface, Response Spectra and Amplitude ratio have been obtained.

![Comparison of Vs-N Correlations for the Soils of Naliya, Kutch with other Correlations Reported in the Literature](image)

![Comparison of Response Spectra at 5% Damping Obtained by DEEPSOIL and SHAKE2000](image)

Figure 5 shows the Response spectra for BH-2 and BH-7 with input motion at roc surface for 5% damping ratios, obtained by both DEEPSOIL and SHAKE2000. It is observed that, both the programmes give almost the same results also Figure 6 shows the amplitude spectrum for the BH-2 and 7, it has been again confirmed that both the program is giving almost the same results.

A response spectrum is used extensively in earthquake engineering practice to indicate the frequency content of an earthquake motion. A response spectrum describes the maximum response of a Single degree of freedom (SDOF) system to a particular input motion as a function of the natural frequency/ period and damping ratio of the SDOF.
system. The ground response spectra for all five boreholes were plotted with 5% critical damping value, which is a pertinent value from the point of view of structural engineering. The peak spectral acceleration values ranges from 0.33g to 0.73g. Figure 7 shows the response spectra at 5% damping for all five boreholes.

Amplification spectrum gives the amplification ratio (frequency response function) has been used to identify the natural/predominant frequency of soil column/site. Figure 8 shows the amplification spectrum for all five boreholes. Figure 9 shows the Peak ground acceleration at the surface, as stated earlier, both the software give almost the same value hence only results of DEEPSOIL software is presented for the present analysis.

6. CONCLUSION

The Peak spectral acceleration at 5% damping ranging from 0.33g to 0.73g and amplification spectrum indicates that amplification ratio and predominant frequency for the site lies between 3.5 to 8.5 and 1.04Hz to 2.18 Hz respectively. Above frequencies indicate that building/structure above 3 storey to tall building are most vulnerable to earthquake damage.

Comparison of DEEPSOIL and SHAKE2000 indicates that both softwares yield almost same results.

Peak ground acceleration for the site has been obtained around 0.216g for a given rock motion having peak ground acceleration of 0.088g, indicating that site is amplifying in nature. Amplification factor for the site is ranging from 1.5 to 2.45. High amplification at some location is due to presence of higher thickness of soft layer, low SPT value which results in low shear wave velocities.
REFERENCES


