Earthquake Response Analysis of Sites Using DEEPSOIL

D. Nishanth Kiran, Mohammad Muzzaffar Khan, M. Madhu Sudhan Reddy, and Gonavaram Kalyan Kumar

Abstract Earthquakes are one of the natural disasters that cause a huge amount of loss in terms of economy and human life. The local site conditions such as the topographic condition and soil profile play an important role in amplifying earthquake waves thereby causing severe damage at particular site compared to other site. To achieve safety against natural disasters like earthquake, it is necessary to construct the building considering geotechnical problems like site effects. The site effects usually amplify the seismic waves which can be assessed by ground response analysis studies. In the present study, 1D earthquake response analysis has been carried out in different sites of Andhra Pradesh capital seed area of 16.5 km^2 in Amaravathi city in Guntur district. To evaluate site effects, borehole data up to a depth of 15 m has been collected. The earthquake time histories were used as input motion. The site amplification at surface has been assessed by using the equivalent linear approach in DEEPSOIL software. In addition to that, response spectra and variations of strain (%) time histories, PGA, and maximum strain (%) with depth were assessed. These results are used for dynamic analysis and design of earthquake-resistant structures. In this study, it is observed that waves are amplified at high level, and it results in high peak ground acceleration when compared to bedrock-level acceleration.

Keywords Ground response analysis · Amplification · Guntur

1 Introduction

Earthquakes are one of the devastating hazards in the world. The 1993 Latur earthquake (MW 6.3), 1997 Jabalpur earthquake (MW 6.0), 1997 Koyna earthquake (MW 6.5), and 2001 Bhuj earthquake (MW 7.9) are some of the recent earthquakes

D. Nishanth Kiran · M. Muzzaffar Khan · G. Kalyan Kumar (✉)
Department of Civil Engineering, NIT Warangal, Warangal 506004, India
e-mail: kalyan@nitw.ac.in

M. Madhu Sudhan Reddy
Department of Civil Engineering, KL University, Guntur 522502, India

A. K. Dey et al. (eds.), *Proceedings of the 7th Indian Young Geotechnical Engineers Conference*, Lecture Notes in Civil Engineering 195,
https://doi.org/10.1007/978-981-16-6456-4_33

occurred in peninsular India. This recent seismicity has revealed that the Indian peninsular shield which was considered to a stable is also prone to devastating earthquakes. Earthquake causes huge damage to the regions by ground shaking, landslides, tsunamis, etc. Therefore, there is a need for amplification studies to analyze the amount of destruction caused due to earthquake [1]. Seismic waves are the reasons for major destructions during earthquake. These waves travels several from a few meters in soil to a few kilometers in rock. Therefore, soil has a key role in the estimation of ground response analysis and its characteristics. It is evident from past earthquakes that response of soil is different at different locations to ground motions imposed by earthquake loading [2]. Therefore, there is a need to model the soil to characterize and analyze the cyclic behavior of soil by these studies. Ground response analysis are generally analyzed by 1D response assuming the waves generated by an earthquake travels vertically through soil layers [5]. 1D response modeling can be analyzed by (i) linear, (ii) equivalent linear, and (iii) nonlinear approach. Equivalent linear approach is mostly used and it is approximation of nonlinear behavior of soil [6]. This analysis is carried out in SHAKE, DEEPSOIL computer software which are popularly used. In equivalent linear approach, initial estimates of shear modulus and shear strain are estimated. These estimates are used to compute the peak strain, and from this peak strain, effective strain is computed which will be used to find the new shear modulus and damping ratio from standard curves given by Seed and Idriss [8] and Vucetic and Dobry [9]. This procedure is performed repeatedly until the values variation comes narrow and these parameters are taken as equivalent shear modulus and equivalent damping ratio to perform dynamic analyses. These parameters are used in evaluating the local site effects which plays an important role in our study. The results obtained can be used to construct earthquake-resistant buildings and liquefaction analysis and various dynamic analysis [7].

2 Study Area and Data Collection

The study area under scope is a location having an area of 16.5 km^2 in the villages of Lingayapalem, Udandarayapalem, and Thalayapalem in Thullurmandal of Guntur district, and map view of area is shown in Fig. 1 representing the locations of boreholes. It is located between 80°33′3.19″E, 16°31′15.03″N and 80°29′2.31″E, 16°32′37.37″N. It is the third most populous district in Andhra Pradesh. River Krishna is also partly flowing in the district, and there are other small rivers and channels flowing in the district. There are hills in surrounding areas and can be found forest reserves in the North East region. Guntur will come in zone 3 according to IS 1893 part-I [4] which makes moderate earthquake having magnitude from 4.9 to 6 Mw. For detailed estimation of local site effects, geotechnical data is collected from SPT test conducted at study area up to a depth of 15 m and detailed soil strata is shown in Fig. 2. In this study, first three boreholes were considered in each grid (A, B, C as shown in Fig. 1) for analysis of local site effects.

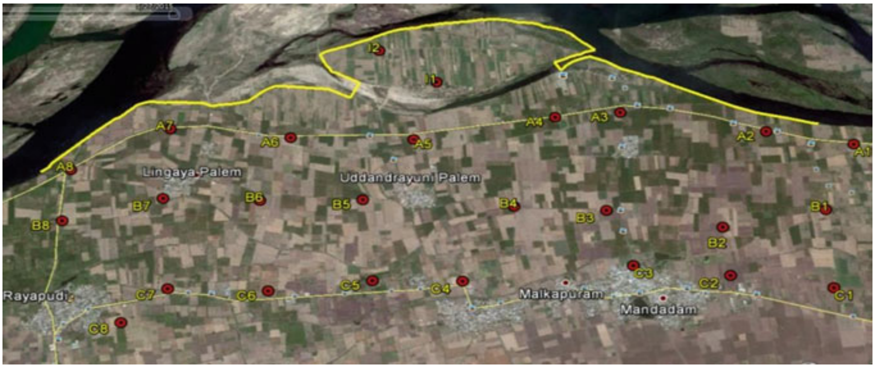

Fig. 1 Map view of study area with borehole locations

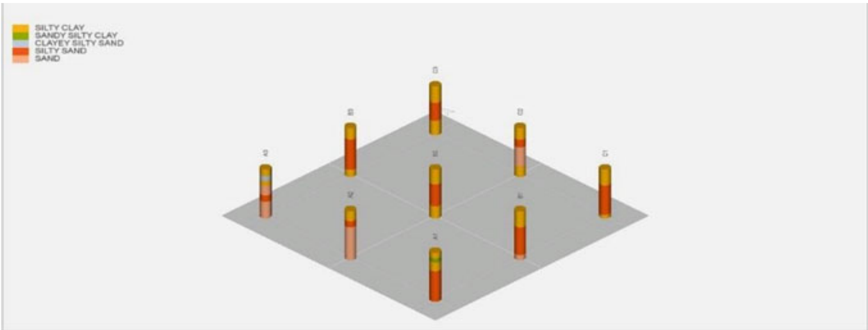

Fig. 2 Detailed soil strata at boreholes

3 Geotechnical Details

In the study area, SPT test was performed at different locations as shown in Fig. 1. Bedrock was observed at 15 m depth in few locations and extended to 30 m others. Site was characterized with different soils like silty clay (residual soils), silty sand, sand (alluvial soils), and stiff clay which were mostly found in eastern side, and with addition to this, soil, pebbles, and yellowish soft disintegrated rock can be found in the western side of the area. Undisturbed and disturbed samples were collected from test site and analyzed in laboratory. SPT–N values for every strata of entire soil depth were given in Fig. 3. Ground water table influences the site effects which should be considered. Water table levels are shallow, having depth up to 3–4 m at all the boreholes. It infers that their location is at the upstream side of the river.

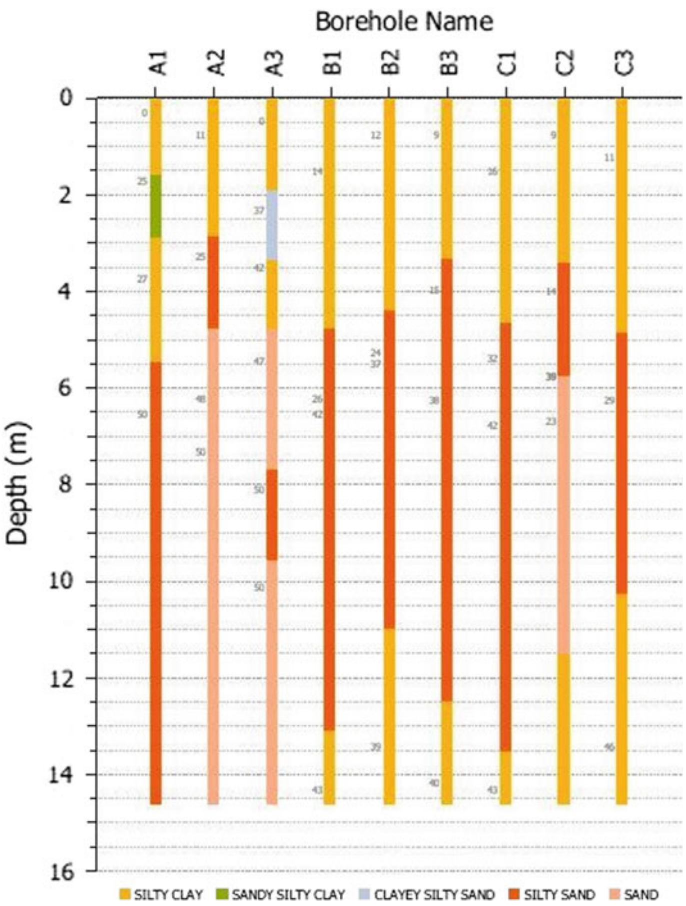

Fig. 3 SPT–N values along depth

4 Input Motions

Input motions are selected based upon regional seismicity and PGA values. The study area comes under zone 3 having a maximum PGA value of 0.16 g [4]. Chamoli earthquake ($Mb = 5.4$ and PGA $= 0.11$ g) of March 29, 1999, is selected as the input ground motion to analyze soil effects and is applied at hard stratum shown in Fig. 4.

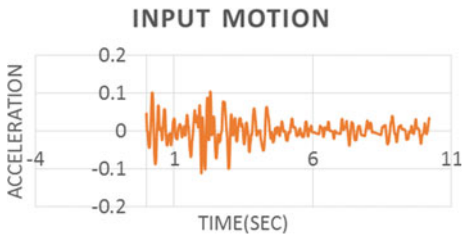

Fig. 4 "Chamoli" earthquake input motion

5 Results

5.1 *Surface Acceleration Time Histories*

The surface acceleration time history attained at these boreholes in response to Chamoli earthquake motion shown in Fig. 5a–c. The peak ground acceleration (PGA) observed as 0.2 g, 0.18 g, and 0.17 g at A1, A2, A3 boreholes. PGA at B1, B2, B3 boreholes are 0.23 g, 0.22 g, and 0.21 g. Similarly, at C1, C2, C3 boreholes was 0.18 g, 0.2 g, 0.21 g. PGA values are quite high at B and C to values at A, and it is due to the presence of clayey layers at these boreholes. The amplification is higher at all boreholes, due to availability of hard stratum at shallower depth (nearly 15 m) at all borehole locations.

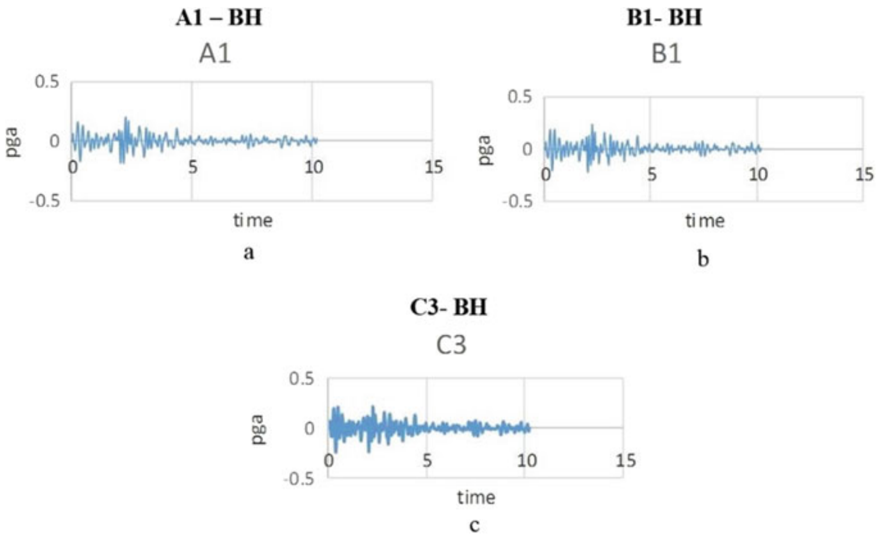

Fig. 5 **a**–**c** Surface acceleration time histories at boreholes A1, B1, and C3

5.2 Response Spectrum

Response spectrum is defined as the locus of maximum response for a particular damping ration to a single degree of freedom system. The response spectrum at 5% damping at ground surface for these boreholes was shown in Fig. 6. The IS 1893-part I (2016) spectrum for medium soils and zone III is shown for comparison. It is found that the IS spectrum is unconservative in low period range for all grids (A, B, C). It is analyzed that seismic design is mostly used for soil having lower period. This usually affects the structures of low to medium rise buildings, where the fundamental periods are generally less in comparison with high rise buildings. Further, considering only PGA in seismic design requirements is not reliable, since the soil present at a particular site of interest plays important role in amplifying the seismic waves thereby increasing the overall acceleration effect on the structures.

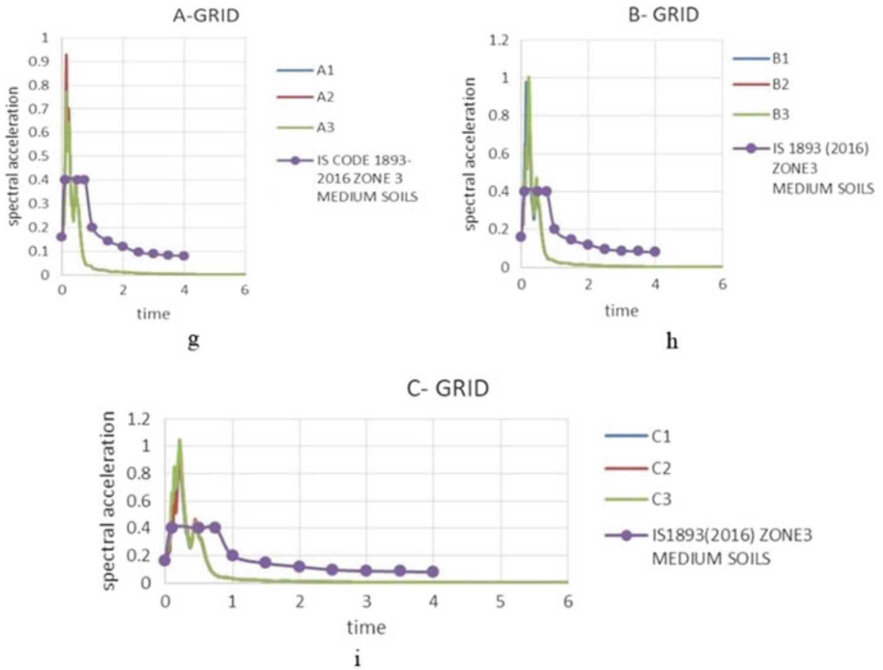

Fig. 6 Response spectra at different grids (A, B, and C)

6 Conclusions

This analysis is used to find the effect of local site effects at Guntur by using 1D equivalent linear approach using DEEPSOIL software [3]. The acceleration time histories of Chamoli earthquake has been used as input motion.

(i) The peak ground acceleration for same earthquake motion is different at different boreholes. The higher amplification were found (greater than 0.2) which shows the effect of local site effects on the seismic waves. These amplification is due to deposition of residual soils like silty clay at larger amount. These PGA values will be used for designing under drain pipes, sunderground structures.

(ii) Response spectrum for 5% damping have been obtained for different borehole locations. The variation of response spectrum in terms of spectral acceleration and time period are noted. It can be used as design guideline for different type of structures at these locations.

(iii) From the analysis, it is found that IS 1893 part (2016) codal spectrum for zone III is found to be unconservative at all boreholes.

(iv) It is found essential to consider local site effects in seismic design at all these locations.

References

1. Anbazhagan P, Sitharam TG (2008) Site characterization and site response studies using shear wave velocity. J Seismolog Earthq Eng 10(2):53–67
2. Desai SS, Choudhury D (2015) Site-specific seismic ground response study for nuclear power plants and ports in Mumbai. Nat Hazard Rev 16(4):04015002
3. Hashash YM, Musgrove MI, Harmon JA, Groholski DR, Phillips CA, Park D (2016) DEEPSOIL 6.1, user manual. Urbana, IL, Board of Trustees of University of Illinois at Urbana-Champaign
4. IS 1893 (2016) Part 1: criteria for earthquake resistant design of structures—part 1: general provisions and building. Bureau of Indian Standards
5. Mahajan AK (2009) NEHRP soil classification and estimation of 1-D site effect of Dehradun fan deposits using shear wave velocity. Eng Geol 104(3–4):232–240
6. Puri N, Jain A, Mohanty P, Bhattacharya S (2018) Earthquake response analysis of sites in state of Haryana using DEEPSOIL software. Procedia Comput Sci 125:357–366
7. Putti SP, Satyam N (2018) Ground response analysis and liquefaction hazard assessment for Vishakhapatnam city. Innovative Infrastruct Solutions 3(1):12
8. Seed HB, Idriss IM (1970, December) Soil moduli and damping factors for dynamic response analysis. Report No. EERC 70–10, University of California, Berkeley
9. Vucetic M, Dobry R (1991) Effect of soil plasticity on cyclic response. J Geotech Eng 117(1):89–107