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1-D Ground Response Analysis for Few Sites in Nellore using Deepsoil

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Abstract. The extent of an earthquake destruction varies from location to location because it is influenced by the local site impacts and the nature of the bedrock motion. The behavior of the soil beneath a structure during the propagation of earthquake waves determines the safety of the building at any location. When it comes to the ground surface, the amplitude, frequency, and duration of seismic motion at the bedrock changes owing to the topography of the site and the soil geomorphology. To determine the impact of local site conditions, borehole data from Sri Damodaram Sanjeevaiah Thermal Power Plant at Nellore is collected and one-dimensional ground response analysis is performed using both equivalent-linear and non-linear analysis using DEEPSOIL. SPT "N" value is used to correlate shear wave velocity. In this study, the amplitude content and frequency content of the Chi-Chi motion, Loma-Gilroy motion, and Kobe motion are taken into consideration. Peak surface acceleration and design response spectra are used to compare and illustrate the results of the two analyses.

Keywords: Non-linear analysis, Frequency, Bedrock motion & Peak surface acceleration.

1 Introduction

The damage caused by earthquakes varies from place to place as it depends on the local-site effects and characteristics of the bedrock motion. At any site, the structure safety depends on the response of soils lying beneath it during the propagation of earthquake waves. For earthquake-resistant designs of structures, the site behavior can be of two types. The first one is Liquefaction and the later one is Amplification. The amplitude, frequency, and duration of seismic motion at the bedrock can be altered when it comes to the surface of the ground as site topography and soil geo-morphology plays an important role in altering the earthquake motion. The hazard caused by seismic motions is more in soft soils compared to hard soils as during the propagation of earthquake motion soft soils are amplified. So that structures constructed on hard soils are less damageable than those constructed in soft soils when subjected to the same input motion. In the Equivalent-Linear approach, equivalent soil stiffness and damping ratio are used which are to be constant for a soil layer during the excitation of earthquake motion. But in the Non-Linear approach degradation of soil stiffness is considered during the excitation of earthquake motion. Thus, Non-Linear analysis represents the actual non-linear soil behavior subjected to cyclic loading. Generation and dissipation of excess pore-water pressure can be simulated only in Non-Linear analysis as both total stress analysis and effective stress analysis can be performed in this analysis. But in the case of Equivalent-Linear analysis, total stress analysis is only performed. So, in the present study, both Equivalent-Linear and Non-Linear analyses are carried out and results are presented in terms of peak surface acceleration, amplification factors, response spectra with a corresponding fundamental period, and shear stress ratio. The results obtained from this analysis are used in the earthquake-resistant design of structures. The effect of surficial layers of the earth on ground motion parameters from bedrock to surface using equivalent linear analysis was done in shake91 software for Ahmedabad City. Due to the soil deposited above the bedrock, there is an amplification of the bedrock motion to the surface from 0.064g to 0.106g with an amplification factor of 1.66 Govindaraju *et.al* (2004). Jaykumar Shukla and Deepankar Choudhury (2012) studied the response of soil sites at ports in Gujarat which consists of soft soil layers below the ground surface. The peak ground acceleration at the surface is amplified when the fundamental frequency of the soil site exceeds 2-3 Hz. The modulus reduction curve and damping curve used in this analysis for different types of soil were furnished in Table1.

Table 1. Modulus reduction curve and damping curve used

S.No	Soil type	Reference
1	Loose and Medium Dense sand	Seed and Idriss(1970); average
2	Dense sand	Idriss (1990), upper range
3	Clay	Vucetic and Dobry(1991)

2 Characterization of site

The borehole data of two typical sites in Nellore are collected and shear wave velocity for each layer at that site is correlated using empirical equations given by Hanumantha Rao et al. (2006). The thickness of each soil layer, soil type, unit weight, and shear wave velocity (V_S) of the sites are tabulated below.

Table 2. Input parameters for site 1

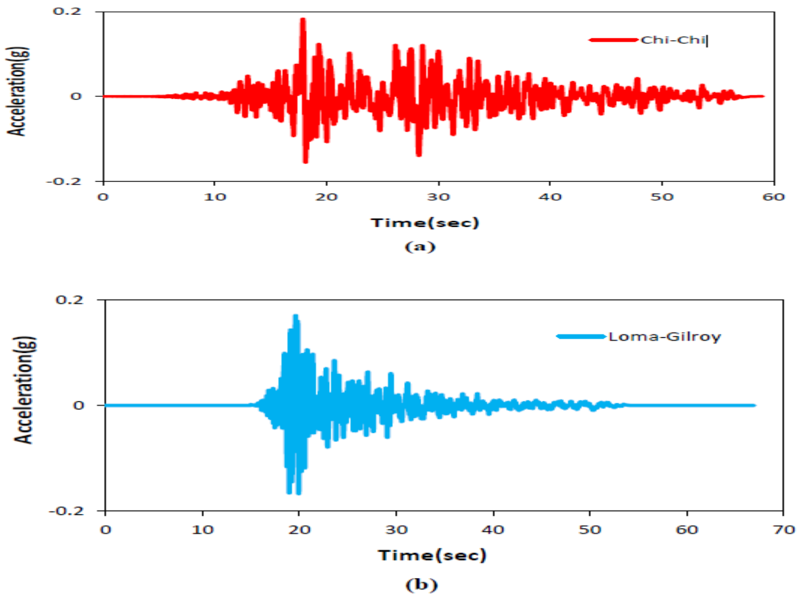
Layer No.	Thickness (m)	Soil type	Unit weight (kN/m^3)	SPT (N)	Vs(m/s)
1	2.5	Silty clay	17	7	191
2	2.5	Sandy silt	17	11	235
3	6	Sand	19	16	263
4	9	Sand	20	19	284

Table 3. Input parameters for site 2

Layer No.	Thickness (m)	Soil type	Unit weight (kN/m^3)	SPT (N)	Vs(m/s)
1	2	Brown clay	18	15	265
2	3	Sandy silt	17	6	183
3	15	Very fine Sand	17	2	115

2.1 Input motion

Three input motions Loma-Gilroy, Chi-Chi, and Kobe having peak horizontal acceleration of 0.17g, 0.18g, and 0.82g were considered. Chi-Chi motion and Loma-Gilroy motion have nearly similar amplitude but the frequency of the latter one is more than the former one. Kobe motion has been selected to know the effect of frequency content on the response of a given site.



(a)

(b)

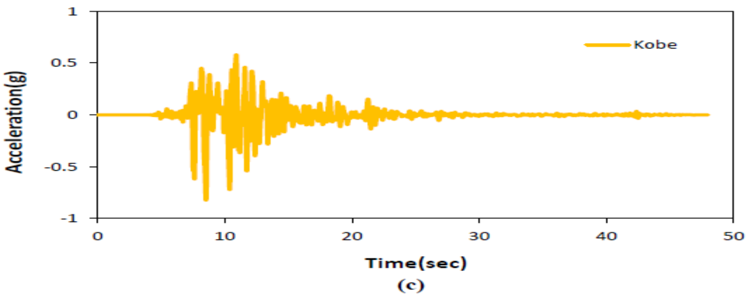


Fig. 1. Acceleration-time history for (a) Chi-Chi motion. (b) Loma-Gilroy motion. (c) Kobe motion.

3 Equivalent Linear and Non-Linear Analysis

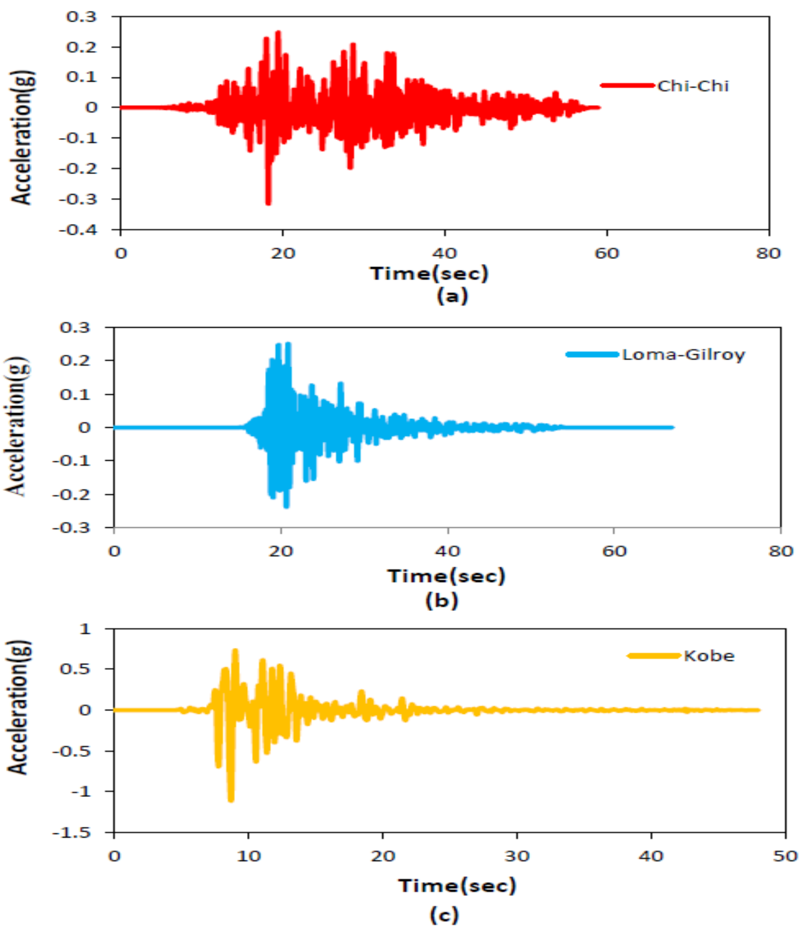


Fig.2. Acceleration-time history at the ground surface by Equivalent-Linear analysis for site 1 when subjected to (a) Chi-Chi motion. (b) Loma-Gilroy motion. (c) Kobe motion.

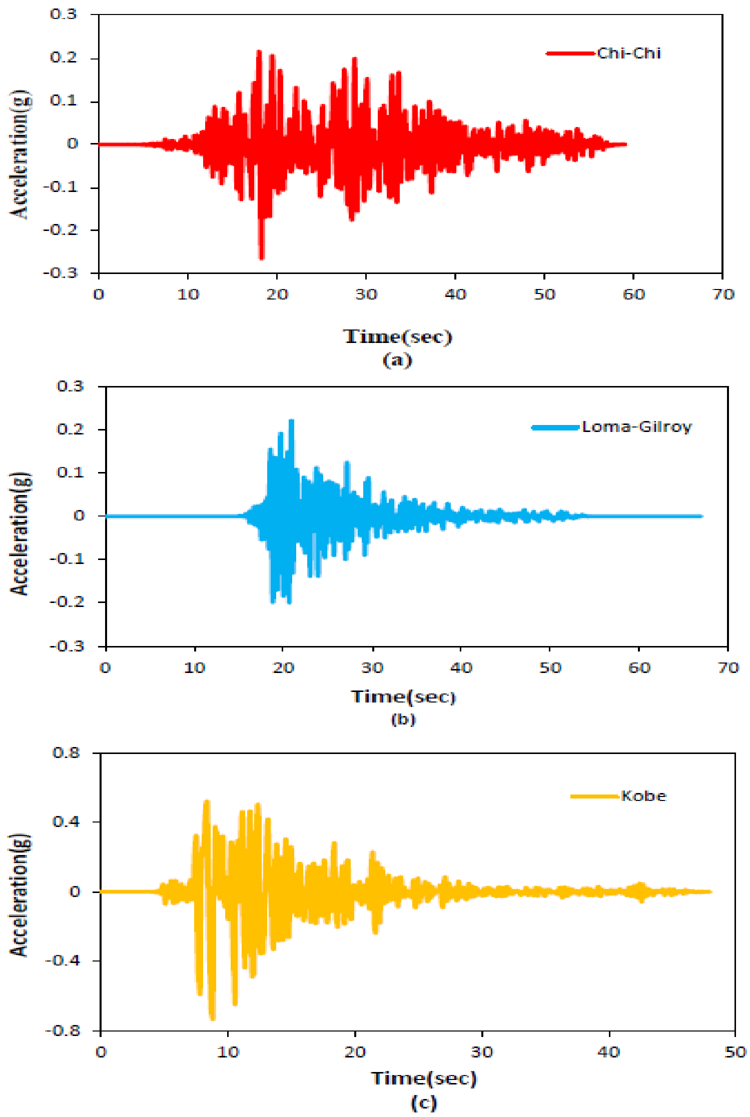


Fig.3. Acceleration-time history at the ground surface by Non-Linear analysis for site 1 when subjected to (a) Chi-Chi motion. (b) Loma-Gilroy motion. (c) Kobe motion.

Figure 2 shows the variation of acceleration with time for site 1 by Equivalent-Linear analysis. Peak surface accelerations are determined to be 0.25g, 0.25g, and 0.73g and corresponding amplification factors are 1.39, 1.47, and 0.89 when the given soil profile is subjected to earthquake excitations of Chi-Chi, Loma-Gilroy, and Kobe motions respectively at the bedrock as an input motion. Figure.3 shows the variation of acceleration with time for site 1 by Non-Linear analysis. Peak surface accelerations are determined to be 0.215g, 0.221g, and 0.52g and corresponding amplification factors are 1.2, 1.3, and 0.63 when the given soil profile is subjected to earthquake excitations of Chi-Chi, Loma-Gilroy and Kobe motions respectively at the bedrock as an input motion. When the soil site is subjected to low-input motion which is having lesser amplitude than Chi-Chi motion and Loma-Gilroy motion causes amplification at the surface of the ground. The following are the mechanisms responsible for the amplification of the strong ground motion. From bedrock to the ground surface, the magnitude of the shear wave velocity decreases which causes a larger energy density near the surface of the ground than at the preceding soil layers. The accumulated energy is released in the form of strain energy which results in amplification of the shear wave. When the soil site is subjected to high input motion (which is having higher amplitude) like Kobe's motion causes de-amplification at the surface of the ground. This is due to the fact that the increase in hysteretic damping during high level shaking. High-level shaking induces higher strains. But with an increase in strain, hysteretic damping increase which results in de-amplification. Therefore, an increase in amplitude content leads to a reduction in amplification factor due to an increase in hysteretic damping during high-level shaking. Compared to Equivalent-Linear analysis, Non-Linear analysis gives lesser acceleration values. In Equivalent-linear analysis, equivalent shear modulus and damping ratio were used in the analysis which is constant for a given soil through the excitation of earthquake motion which induces larger magnitudes of shear stresses. Whereas in the case of Non-linear analysis, degradation of soil stiffness is considered with the excitation of earthquake waves resulting in lower magnitudes of shear stresses. Since the peak ground acceleration is computed from the maximum shear stress developed. The Non-linear analysis gives lesser peak ground acceleration values compared to equivalent linear analysis owing to the representation of actual non-linear behavior of soil subjected to cyclic loading. The response spectra at the ground surface for site 1 when subjected to different input motions are evaluated by both Equivalent-Linear and Non-Linear approaches and the results are plotted in Figure 4. The response spectrum is evaluated considering 5% damping in all soil layers. It is observed that the peak spectral acceleration at the surface of the ground for Chi-Chi motion is 1.02g with a corresponding predominant period of 0.5sec by Equivalent-Linear analysis. But by Non-Linear analysis, peak spectral acceleration is found to be 0.92g with a corresponding predominant period of 0.53sec. For Loma-Gilroy motion, peak spectral acceleration is determined to be 1.2g with a corresponding predominant period of 0.24sec by Equivalent-Linear analysis and 0.99g with a predominant period of 0.24sec by Non-Linear analysis respectively. The peak spectral accelerations for Kobe motion are found to be 3.41g with a corresponding predominant period of 0.825sec by Equivalent-Linear analysis and the value of the same is about 2.95g with a predominant period of 0.684sec by using the Non-Linear analysis respectively. The non-linear analysis results in lesser spectral acceleration values owing to the representation of non-linear behavior than the equivalent linear analysis which considers the linear behavior of soil under cyclic loading.

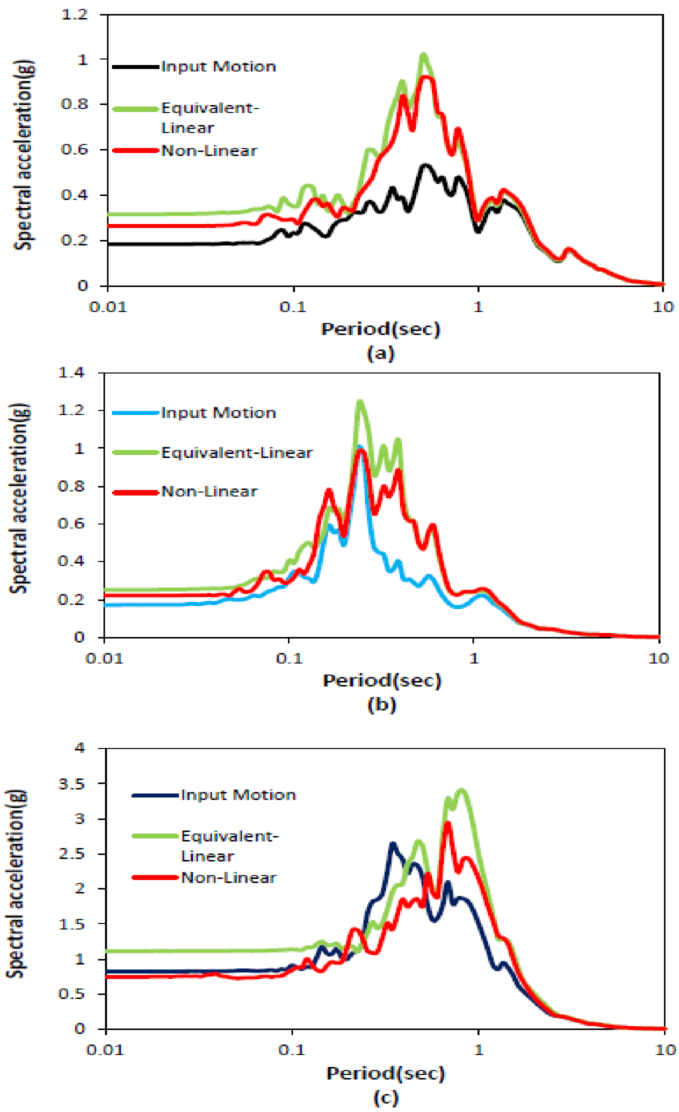


Fig.4. Response spectra for soil site 1 when subjected to (a) Chi-Chi motion. (b) Loma-Gilroy motion. (c) Kobe motion.

The time period of a given soil profile was found to be 0.313sec, which is close to the predominant period for Loma-Gilroy motion (0.24sec). Therefore, Loma-Gilroy motion causes the most damage to this soil profile. Loma-Gilroy motion is most vulnerable for small structures having a small predominant period, while Kobe motion is dangerous for high-rise buildings which are having a higher predominant period.

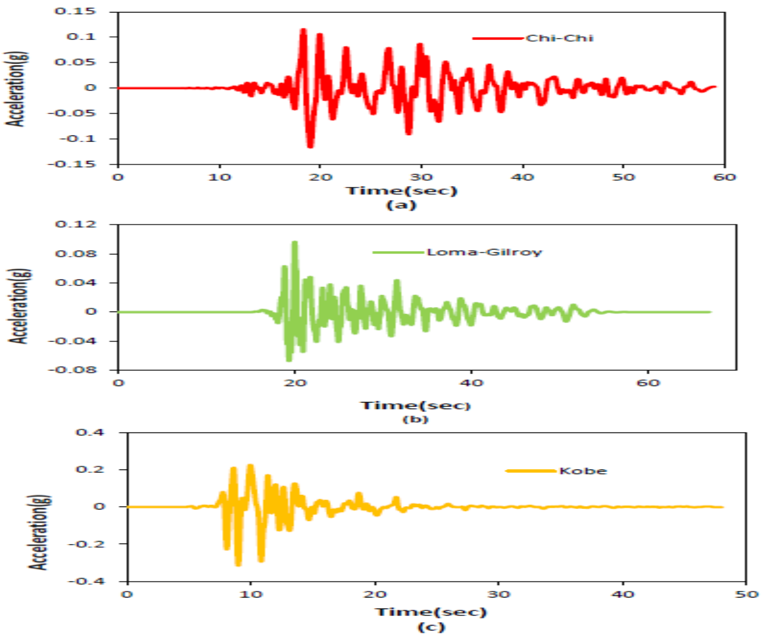


Fig.5. Acceleration-time history at the ground surface by Equivalent-Linear analysis for site 2 when subjected to (a) Chi-Chi motion. (b) Loma-Gilroy motion. (c) Kobe motion.

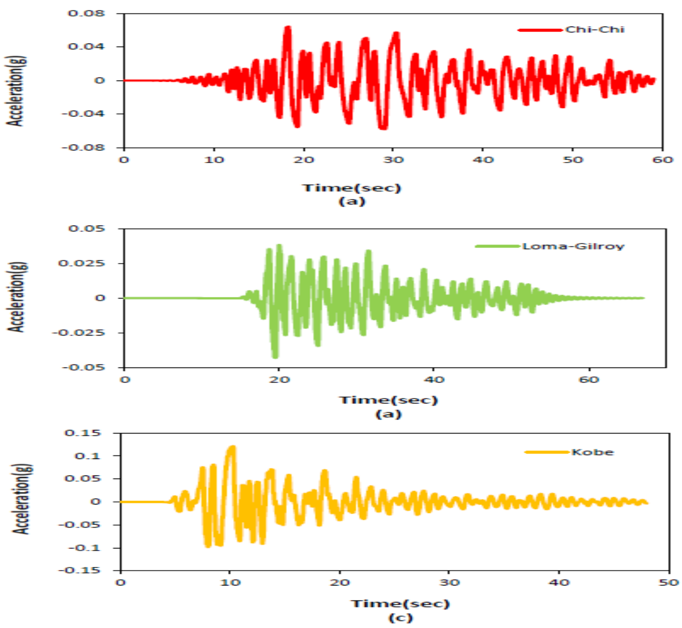
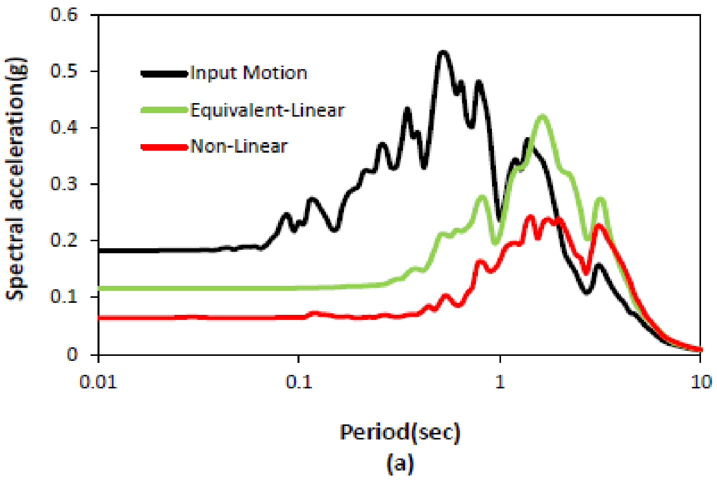


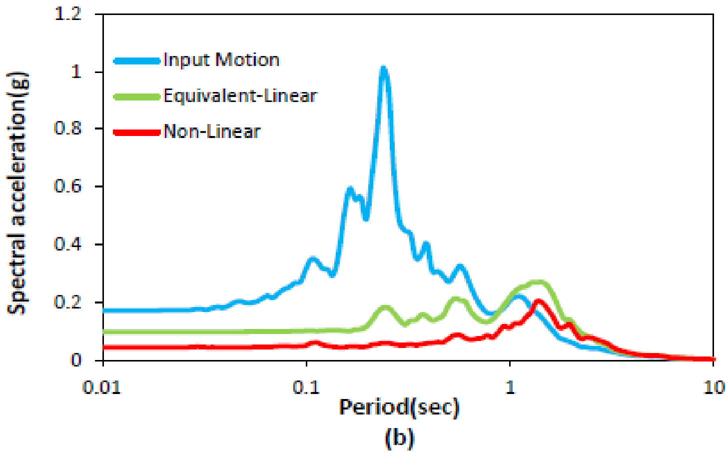
Fig.6. Acceleration-time history at the ground surface by Non-Linear analysis for site 2 when subjected to (a) Chi-Chi motion. (b) Loma-Gilroy motion. (c) Kobe motion.

Figure 5 shows the variation of acceleration with time for site 2 by Equivalent-Linear analysis. Peak surface accelerations are determined to be 0.116g, 0.097g, and 0.315g and corresponding amplification factors are 0.64, 0.57, and 0.384 when the given soil profile is subjected to earthquake excitations of Chi-Chi, Loma-Gilroy and Kobe motions respectively at the bedrock as an input motion. Figure 6 shows the variation of acceleration with time for site 2 by Non-Linear analysis when subjected to different earthquake motions. Peak surface accelerations are determined to be 0.064g, 0.043g, and 0.12g and corresponding amplification factors are 0.36, 0.25, and 0.14 when the given soil profile is subjected to earthquake excitations of Chi-Chi, Loma-Gilroy and Kobe motions respectively at the bedrock as an input motion.

Being a very loose soil present just above the bedrock, the soil is subjected to higher strains even though the bedrock is subjected to lower input motion. Because increase in hysteretic damping with an increase in strain causes dissipation of earthquake energy within the soil mass. Due to this, peak surface accelerations are found to be deamplified at ground level when subjected to all input motions. This may be also due to the liquefaction of the soil layer just above the bedrock.

The Chi-Chi motion and Loma-Gilroy motion have nearly the same amplitude but the latter one having high-frequency content than the former one. High-frequency motion resulting more strains than low-frequency motion which results in lesser amplification factors for Loma-Gilroy motion. But in the case of Kobe motion, which consists of more amplitude and high-frequency content among all input motions. Due to more amplitude and frequency of input motion causes lesser amplification factors among the other two input motions. This states that the response of a soil site is not only governed by amplitude content but also depends on frequency content and duration of the given earthquake motion. The response spectra at the ground surface for site 2 when subjected to different input motions are evaluated by both Equivalent-Linear and Non-Linear approaches and the results are plotted in Figure 6. The response spectrum is evaluated considering 5% damping in all soil layers. It is observed that the peak spectral acceleration at the surface of the ground for Chi-Chi motion is 0.42g with a corresponding predominant period of 1.63sec by Equivalent-Linear analysis. But by Non-Linear analysis, peak spectral acceleration is found to be 0.24g with a corresponding predominant period of 1.44sec. For Loma-Gilroy motion, peak spectral acceleration is determined to be 0.27g with a corresponding predominant period of 1.44sec by Equivalent-Linear analysis and 0.20g with a predominant period of 1.35sec by Non-Linear analysis respectively. The peak spectral accelerations for Kobe motion are found to be 0.97g with a corresponding predominant period of 0.87sec by Equivalent-Linear analysis and the value of the same is about 0.47g with a predominant period of 1.27sec by using the Non-Linear analysis respectively. The predominant period of soil site was found to be 0.62sec which is lower than that of the predominant period of response spectra of all motions. The predominant period of all motions is observed to be high which is more damageable for structures having more time periods i.e. high rise buildings.





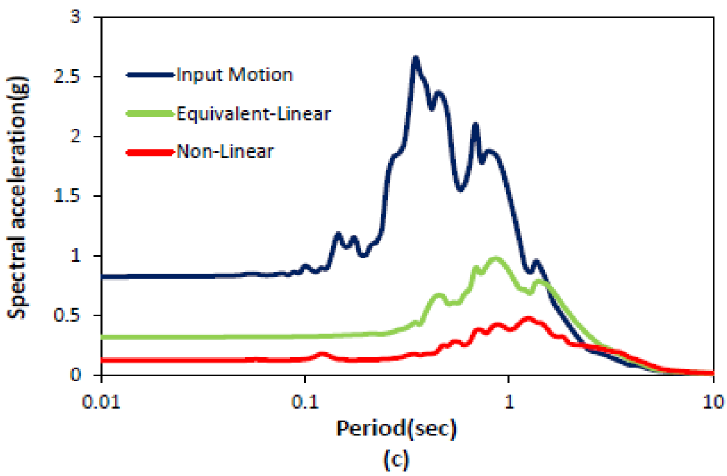


Fig.6. Response spectra for soil site 2 when subjected to (a) Chi-Chi motion. (b) Loma-Gilroy motion. (c) Kobe motion.

4 Conclusions

Ground response of Sri Damodaram Sanjeevaiah Thermal Power Plant at Nellore is carried out using both Equivalent-Linear and Non-Linear analysis subjected to Earthquake excitation of Chi-Chi, Loma-Gilroy, and Kobe motion, and the conclusions are summarized below.

- For the Site 1 peak surface accelerations are 0.215g, 0.221g, and 0.52g and corresponding amplification factors are 1.2, 1.3, and 0.63 when the given soil profile is subjected to earthquake excitations of Chi-Chi, Loma-Gilroy and Kobe motions respectively at the bedrock as an input motion.
- The presence of soft soils above the bedrock leads to the development of higher strains with excitation of low input motion causing de-amplification.
- The equivalent-Linear approach provides higher Peak surface acceleration, Peak spectral acceleration, and Shear stress ratio than the Non-Linear approach.

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