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Plotting of Site-Specific Spectra

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Abstract

This paper presents the procedure of determination and plotting of site-specific spectra. After conducting the probabilistic seismic hazard analysis for the region where the site is located, seismic hazard curve is plotted. Hazard de-aggregation is used to identify closer and distant seismic events, which are simulated by the scaled ground motion histories. Based on the soil properties at the site spectra is obtained.

Keywords: *Seismic Hazard Analysis, De-aggregation, Site spectra*

INTRODUCTION

The two general approaches for developing site-specific response spectra are the deterministic and probabilistic approaches.

a. Deterministic approach:

1. In this approach, often termed a deterministic seismic hazard analysis, or DSHA, site ground motions are deterministically estimated for a specific, selected earthquake, that is, an earthquake of a certain size on a specific seismic source occurring at a certain distance from the site. The earthquake size may be characterized by magnitude or by epicentral intensity.

2. Size and location of design earthquakes- In the deterministic approach, earthquake magnitude is typically selected to be the magnitude of the largest earthquake judged to be capable of occurring on the seismic source, i.e., MCE. The selected earthquake is usually assumed to occur on the portion of the seismic source that is closest to the site. After the

earthquake magnitude and distance are selected, the site ground motions are then estimated using ground motion attenuation relationships or other techniques.

b. Probabilistic approach:

In the probabilistic approach, often termed a probabilistic seismic hazard analysis, or PSHA, site ground motions are estimated for selected values of the probability of ground motion exceedance in a design time period or for selected values of annual frequency or return period for ground motion exceedance. As an example, ground motions could be estimated for a 10 percent probability of exceedance in 100 years or for a return period of 950 years. The probabilistic approach thus provides an expression of potential earthquake loading in terms analogous to those used for other environmental loads in civil engineering design such as wind and flood loading. Probabilistic ground motion assessment incorporates the frequency of occurrence of earthquakes of different magnitudes on the seismic sources, the uncertainty of the earthquake locations on the sources, and the ground motion attenuation including its uncertainty. A site-specific seismic hazard analysis is required in the design of important civil structure such as power plant, long-spanned bridges, hirise buildings, etc. A thorough examination of the geological and seismological history is required along with the collection of the seismic secondary data.

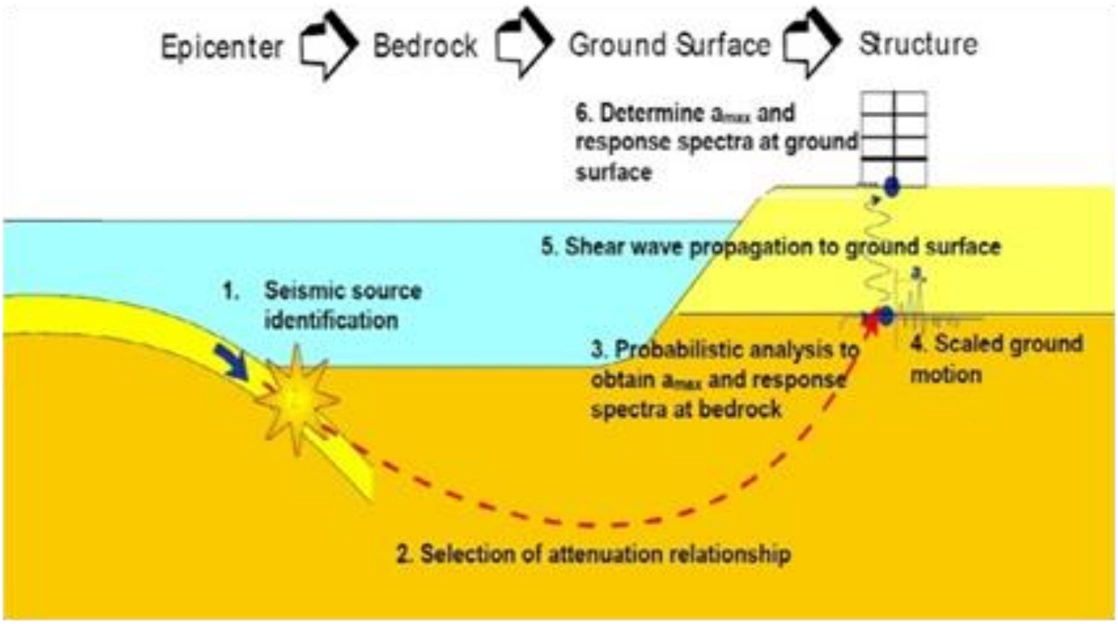


Figure 1: The steps for Site-Specific Seismic Hazard Analysis

The seismic secondary data is then processed to minimize systematical error and to obtain reliable result of seismic hazard parameters. A probabilistic seismic hazard analysis (PSHA) and local site effect analysis are then performed to develop recommended site-specific response spectra. Generally, these procedures are illustrated in Figure 1.

LITERATURE REVIEW

T.G Sitharam and P Anbazhagan (2006) have conducted seismic hazard analysis for Bangalore region. The paper presents the determination of maximum credible earthquake (MCE) and generation of synthetic acceleration time history plot for the Bangalore region. MCE has been determined by considering the regional seismotectonic activity in about 350 km radius around Bangalore city.

The seismotectonic map has been prepared by considering the faults, lineaments, shear zones in the area and historic earthquake events of more than 150 events. Shortest distance from the Bangalore to the different sources is measured and then peak ground acceleration (PGA) is calculated for the different source and moment magnitude.

J. Shukla and D. Choudhury (2011) conducted deterministic seismic hazard analysis for various sites of the major cities (Ahmedabad, Surat, Bhuj, Jamnagar and Junagadh) of the Gujarat region in India to compute the seismic hazard exceeding a certain level in terms of peak ground acceleration (PGA) and to estimate maximum possible PGA at each site at bed rock level. Because the instrumental records of India specifically in the Gujarat region are far from being satisfactory for modeling the seismic hazard using the probabilistic approach, an attempt has been made in this study to accomplish it through the deterministic approach. In this regard, all small and large faults of the Gujarat region were evaluated to obtain major fault systems.

The empirical relations suggested by earlier researchers for the estimation of maximum magnitude of earthquake motion with various properties of faults like length, surface area, slip rate, etc. have been applied to those faults to obtain the maximum earthquake magnitude. For the analysis, seven different ground motion attenuation relations (GMARs) of strong ground motion have been utilized to calculate the maximum horizontal ground accelerations for each major city of Gujarat.

C. Shreyasvi et al. (2019) performed seismic hazard analysis for Mangalore and its surrounding area by adopting state -of-the -art classical Cornell–McGuire approach. In order to predict the seismic hazard in a probabilistic manner, all the possible seismic sources in the form of tectonic features were considered along with the up-to-date database of seismic activity in the region.

The uniform hazard spectrum developed at the bedrock level and the one generated from topography were compared with the design spectrum of IS 1893 and it was found that the majority of the study area needs an appraisal in terms of seismic zonation. Further, the seismic zoning map recommended by the Indian code is Intensity-based and not an effective standard for comparing the seismic hazard estimated using a probabilistic approach.

In summary, the site-specific uniform hazard spectrum and seismic hazard maps developed from this study are believed to be of immense use for the performance-based seismic analysis and design of structures.

Masyhur et al. (2007) developed the seismic design spectra for each usage and performance of the structure. Conceptually, different performance targets means different safety requirements and relate to different failure conditions. Upon obtaining the PSHA result for the site for each level of risk considered, further study is required to derive the design tools needed by the structural engineers.

The result of the PSHA will be used to develop recommendation values of ground accelerations and corresponding design spectra. The computed surface spectral accelerations obtained from local site effect analysis are use to develop recommended design spectra. Based on surface spectral accelerations, the average and average plus one standard deviation response spectral acceleration are calculated.

The recommended site-specific response spectrum is then determined based on average plus one standard deviation spectral acceleration.

Praveen K. Malhotra (2003) presented a procedure to select and scale strong-motion records for site-specific analysis. The procedure matches records' smooth response spectra with the site response spectrum by scaling of the acceleration histories. The parameters defining the smooth spectrum of various records are computed and tabulated to allow easy selection of records. Hazard de-aggregation is used to identify closer and distant seismic events, which are simulated by the scaled ground motion histories. The procedure can also be used to obtain ground motion pairs in orthogonal directions for multidimensional dynamic response analysis.

M. A James et al. (2006) We compare four methods, all based on Bayesian regressions, to predict response spectra at instrumented sites, located at the hill and lakebed zones in Mexico City, that have recorded several recent earthquakes. The regressions are built as functions of magnitude and closest distance to the rupture area of the earthquake, using more than 20 subduction earthquakes (thrust-faulting mechanism) recorded since 1964.

The four methods are:

(a) a regression on observed response spectra;

(b) a regression on observed Fourier amplitude spectra and use of random vibration theory to estimate the response spectra,

(c) a regression on observed response spectra at the reference hill- zone station multiplied by response spectral ratios; and

(d) a regression on Fourier amplitude spectra at the reference hill zone,

Multiplied by Fourier spectral ratios and use of the random vibration theory to estimate response spectra. From the results presented here, Method 1, the direct Bayesian regression of response spectra, is the best choice since it has shown the smallest errors and deviations. The problem with Method 1 is that it needs a wide set of records (response spectra) to be reliable, and this is not the case for most sites. It is only true for the sites presented in this work (CU, SCT and CD); for any other site Method 1 simply cannot be applied. Method 2 is based on Fourier amplitude spectra and the use of the random vibration theory together with the strong motion duration, a step that introduces approximations that may reduces its reliability. Standard deviations computed for this method are usually the largest.

P. Anbazhagan and G. Silas Abraham (2020) Region-specific seismic hazard analysis was carried out for Krishna Raja Sagara Dam site in Karnataka, India. Seismic event data and seismic source data within a 500 km radius were collected.

Deterministic seismic hazard analysis was conducted for different methods of earthquake magnitude and location estimation. It was observed that the ground motion estimates vary widely with different methods of Mmax estimation and that the rupture based method, which calculates Mmax based on fault dimensions, can give a reliable estimate of the possible maximum magnitude in regions of low to moderate seismicity. Based on this study, the greatest median ground motion at the dam site is estimated as 0.43 g and the ground motion required to be tolerated without catastrophic failure is considered as 0.11 g. In Stable Continental Regions across the world, where earthquake data is scarce, the methodology followed here can be adopted to conduct region-specific seismic hazard analysis.

Satish C. Bhatia et al. (1999) This paper presents the results of an exercise carried out under GSHAP, over India and adjoining regions bound by 0°N-40°N and 65°E-100°E. A working catalogue of main shocks was prepared by merging the local catalogues with the NOAA catalogue, and removing duplicates, aftershocks, and earthquakes without any magnitude. Eighty-six potential seismic source zones were delineated based on the major tectonic features and seismicity trends. Using the probabilistic hazard assessment approach of McGuire, adopted by GSHAP, the Peak Ground Accelerations (PGA) were computed for 10% probability of exceedance in 50 years, at locations defined by a grid of 0.5° x 0.5°. Since no reliable estimates of attenuation values are available for the Indian region, the attenuation relation of Joyner and Boore (1981) was used.

The PGA values over the grid points were contoured to obtain a seismic hazard map. The hazard map depicts that a majority of the Northern Indian plate boundary region and the Tibetan plateau region have hazard level of the order of 0.25 g with prominent highs of the order of 0.35-0.4 g in the seismically more active zones like the Burmese arc, Northeastern India and Hindukush region.

In the Indian shield, the regional seismic hazard, covering a major area, is of the order of 0.05-0.1 g whereas some areas like Koyna depict hazard to the level of 0.2 g. The present map can be converted into a conventional seismic zoning map having four zones with zone factors of0.1 g, 0.2 g, 0.3 g and 0.4 g respectively.

T G Sitharam et al. (2012) presents a detailed study on the seismic pattern of the state of Karnataka and also quantifies the seismic hazard for the entire state. In the present work, historical and instrumental seismicity data for Karnataka (within 300 km from Karnataka political boundary) were compiled and hazard analysis was done based on this data.

Geographically, Karnataka forms a part of peninsular India which is tectonically identified as an intraplate region of Indian plate. Due to the convergent movement of the Indian plate with the Eurasian plate, movements are occurring along major intraplate faults resulting in seismic activity of the region and hence the hazard assessment of this region is very important. Apart from referring to seismotectonic atlas for identifying faults and fractures, major lineaments in the study area were also mapped using satellite data.

The earthquake events reported by various national and international agencies were collected until 2009. Declustering of earthquake events was done to remove foreshocks and aftershocks. Seismic hazard analysis was done for the state of Karnataka using both deterministic and probabilistic approaches incorporating logic tree methodology.

The peak ground acceleration (PGA) at rock level was evaluated for the entire state considering a grid size of 0.05◦×0.05◦. The attenuation relations proposed for stable continental shield region were used in evaluating the seismic hazard with appropriate weightage factors. Response spectra at rock level for important Tier II cities and Bangalore were evaluated. The contour maps showing the spatial variation of PGA values at bedrock are presented in this work

OBJECTIVES

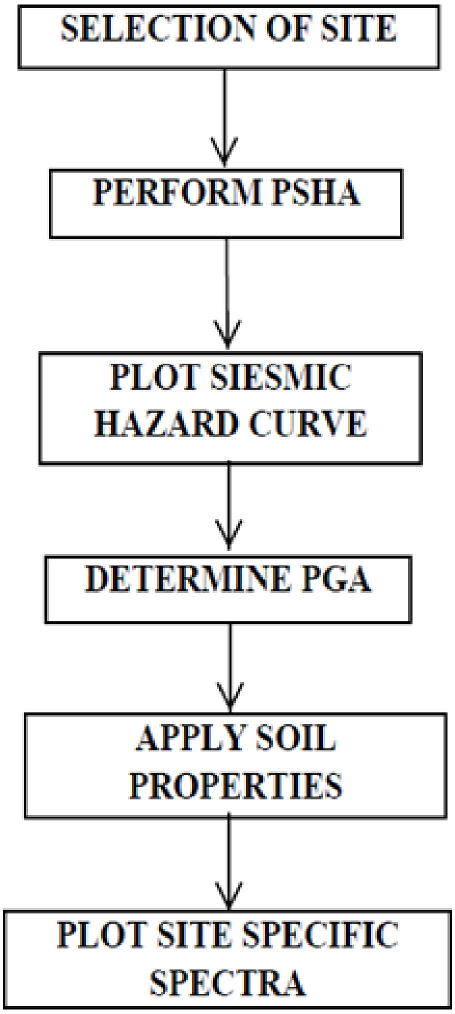
The main objectives of the study are,

a. Determining the reliable past historic earthquakes for the site.

b. Collect the soil properties and layer data based on the past research conducted.

c. Perform Non-linear site-specific spectral analysis.

Methodology



DEEPSOIL SOFTWARE

DEEPSOIL is a unified 1D equivalent linear and nonlinear site response analysis platform developed by University of Illinois at Urbana. Main functions of the software include Strength-controlled nonlinear model, Frequency-independent damping formulation, Porewater pressure generation and dissipation models, Graphical user interface, Parallel-processing capability. Hashash et al. (2017) published the user manual of the software for better understanding and implementation of the software and the recent advances in the nonlinear site response analysis.

Consider an example soil profile made of 5 layers of the soil. The soil properties and layers are entered as shown in the figure 2 extracted from the software,

Layer Number	Layer Name	Thickness (m)	Unit Weight (KN/m^3)	Shear Wave Velocity (m/s)
1	Layer 1	4	20	250
2	Layer 2	4	20	250
3	Layer 3	4	20	250
4	Layer 4	4	20	250
5	Layer 5	4	20	250

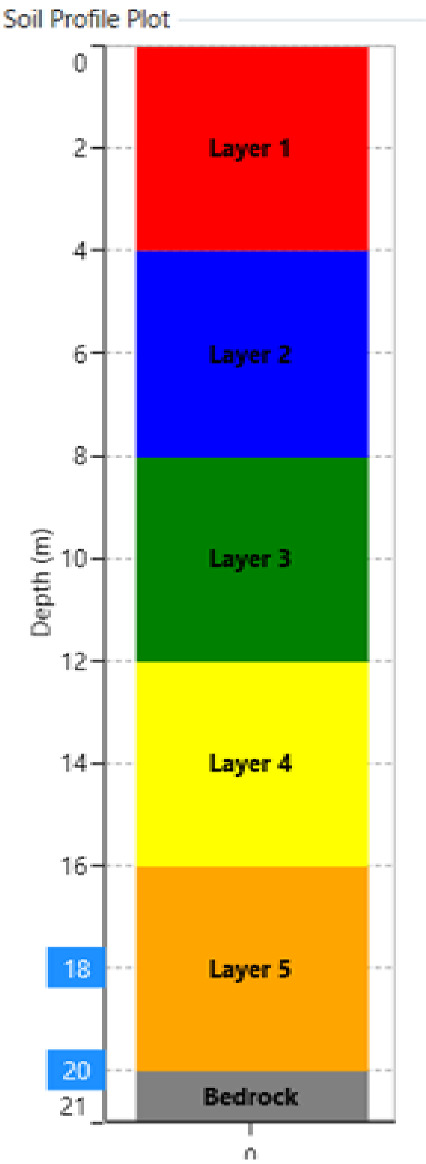
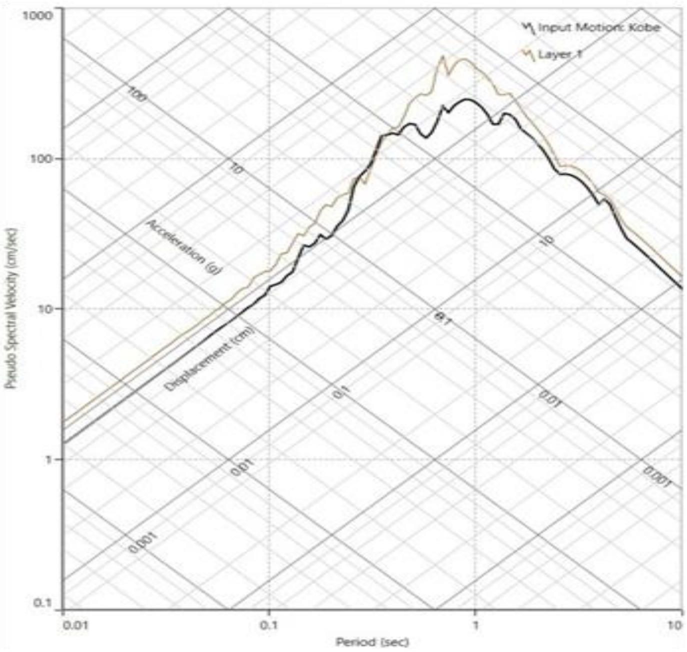


Figure 2: Soil layers and Soil properties

Nonlinear site-specific response analysis is carried out using the software. Kobe Earthquake data is taken from the Strong motion database and simulated for the considered soil layers and soil properties. Then the analysis is carried out to obtain the response spectrum graph for the site as shown in the figure 3. Time history plots, stress strain curve and animated displacement can be obtained after the analysis is carried out.



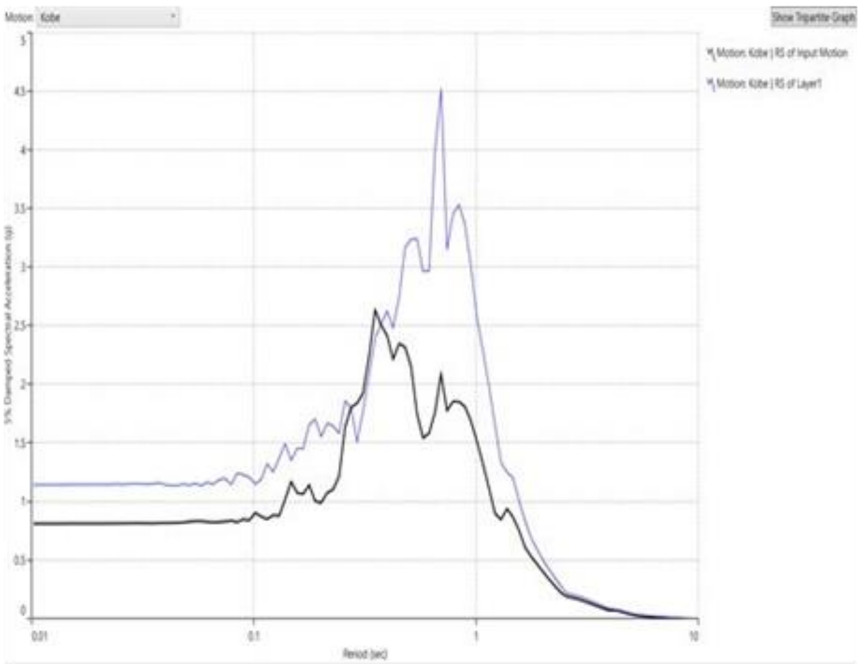


Figure 3: Response spectral plots obtained for the model

CONCLUSIONS

This paper concludes that to plot the site-specific spectra one has to carryout probabilistic analysis for the site. Hence various data such as seismic sources, fault details and also the previous earthquake data should be taken into consideration. Since the probabilistic analysis has already been carried out for entire state of Karnataka by T G Sitharam et al. (2012) the results can be derived from the conclusion drawn by the author and adopt the PGA and hazard curves for required cities in Karnataka. Site specific spectra can be obtained by considering the soil properties and derive the spectra for a specific spectrum. Derivation of site-specific spectra can be obtained by inputting the soil characteristics of the site.

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REFERENCES

1. T. G. Sitharam and P. Anbazhagan, "Seismic hazard analysis for the Bangalore Region," Nat. Hazards, vol. 40, no. 2, pp. 261–278, 2007, doi: 10.1007/s11069- 006-0012-z.

2. J. Shukla and D. Choudhury, "Estimation of seismic ground motions using deterministic approach for major cities of Gujarat," Nat. Hazards Earth Syst. Sci., vol. 12, no. 6, pp. 2019–2037, 2012, doi: 10.5194/nhess-12-2019-2012.

3. C. Shreyasvi, K. Venkataramana, S. Chopra, and M. M. Rout, "Probabilistic Seismic Hazard Assessment of Mangalore and Its Adjoining Regions, A Part of Indian Peninsular: An Intraplate Region," Pure Appl. Geophys., vol. 176, no. 6, pp. 2263–2297, 2019, doi: 10.1007/s00024-019-02110-w.

4. Masyhur Irsyam, Donny T Dangkua, Dyah Kusumastuti, and Engkon K Kertapati, "Methodology of Site-Specific Seismic Hazard Analysis for Important Civil Structure," Civ. Eng. Dimens., vol. 9, no. 2, pp. 103–112, 2007.

5. P. K. Malhotra, "Strong-Motion Records for Site- Specific Analysis," Earthq. Spectra, vol. 19, no. 3, pp. 557–578, 2003, doi: 10.1193/1.1598439.\

6. A. Kijko and N. H. Centre, "‘ Introduction to Probabilistic Seismic Hazard Analysis ’ (Extended version of contribution by A . Kijko , Encyclopedia of Solid Earth Geophysics , Harsh Gupta ‘ Introduction to Probabilistic Seismic Hazard Analysis ’ (Extended version of contribution b," no. January 2011, 2021.

7. M. A. Jaimes, E. Reinoso, and M. Ordaz, "Comparison of methods to predict response spectra at instrumented sites given the magnitude and distance of an earthquake," J. Earthq. Eng., vol. 10, no. 6, pp. 887– 902, 2006, doi: 10.1080/13632460609350622.

8. P. Anbazhagan and G. S. Abraham, "Region specific seismic hazard analysis of Krishna Raja Sagara Dam, India," Eng. Geol., vol. 268, no. February, p. 105512, 2020, doi: 10.1016/j.enggeo.2020.105512.

9. Musgrove, M., Harmon, J., Hashash, Y. M. A., Rathje, E. M. (2017). "Evaluation of the DEEPSOIL Software on the DesignSafe Cyberinfrastructure". Journal of Geotechnical and Geoenvironmental Engineering, Vol. 143, Issue 9.

10. Groholski, D., Hashash, Y., Kim, B., Musgrove, M., Harmon, J., and Stewart, J. (2016). "Simplified Model for Small-Strain Nonlinearity and Strength in 1D Seismic Site Response Analysis". J. Geotech. Geoenviron. Eng., 10.1061/(ASCE)GT.1943-5606.0001496, 04016042.

11. Strong MotionDatabase: www.strongmotioncenter.org

