Uniform Hazard Spectrum at SVNIT in Surat City

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Abstract. The present research paper reviews on the different seismic hazards variations in the country. All the thirty - two source zones of country covered into seven geological regions. A brief highlights of return period along with a review of past probabilistic seismic hazard analysis effects for estimating seismic hazard in India. Consider the Surat city under zone III with the Z value of 0.16 and the result have been compared with the analysis done by many researchers in the same region. Earthquake catalogue containing all unknown events of medium to large magnitudes are 4≤Mw<5, 5≤Mw<6, 6≤Mw<7, 7≤Mw<8 and 8≤Mw<9. After collecting earthquake raw data following process carried out to the preparation of earthquake data, Z - map used for declusturing the data, completeness of the catalogue and recurrence relation of Gutenberg-Richter's derived a frequency- magnitude recurrence relationship. Seismic hazard analysis describes the potential for earthquake related natural phenomena such as ground shaking, rupture of fault and soil liquefaction, Seismic hazard may be assessed deterministic and probabilistic approach. Seismic Hazard Analysis (SHA) involves the development of a particular seismic scenario consisting of an earthquake of a specified size occurring at a specified location/region in other words provides a straightforward frame work for evaluation of ground motion. The Peak Horizontal Acceleration (PHA), Uniform Hazard Spectrum (UHS) and Peak Ground Acceleration (PGA) values obtained in the past study matches well with the values obtained by other authors studied for different area of the country.

Keywords: Earthquake, DSHA, PSHA, PHA and PGA

1 Introduction

Earthquake disaster is created by the severity of the earthquake ground motion, the size and distribution of population, economic development and degree of disaster preparedness [3, 15]. Seismic hazard analysis provides the expected ground motion at a site of interest. Proper implementation of comprehensive earthquake risk reduction programme is essential to prevent an earthquake transforming into a disaster. Earthquake disasters occur mainly due to failure of structures and facilities such as buildings and lifelines (dams, bridges, transportation systems, power plants, etc.) apart from earthquake induced landslides, liquefaction and tsunami. The Western India (WI) is one of the stable continental regions (SCR), situated in the interior of the Indian plate. Major earthquakes such as the Killari [moment magnitude (Mw) 6.2, 1993], Jabalpur (Mw 5.7, 1997) and Bhuj (Mw 7.7, 2001) have initiated seismic hazard studies in many regions of the Peninsular India. Earthquake-resistant buildings are essential to reduce the seismic risk. The goal of earthquake-resistant design is to produce a structure or facility that can withstand a certain level of shaking without excessive damage. Seismic hazard analysis involves the quantitative estimation of ground-shaking hazards at a particular site [12, 13, 14].

Ground response analysis is then carried out with the knowledge of the local soil conditions to obtain the design ground motion parameters at surface level. The expected ground motion at a site is represented in terms of quantitative measures that describe the characteristic or intensity of ground motion. In this study performed probabilistic seismic hazard analysis (PSHA) is to identify a design response spectrum to use for geotechnical or structural analysis. One approach for developing a spectrum is to compute a uniform hazard spectrum. Uniform hazard spectrum is PSA ordinates having a same probability of exceedance for a considered time period with PGA values for Return period of 475 and 2475 years.

2 Literature review

A critical appraisal of the reviewed literature relevant to the subject of present investigation is given and the need for the present study is identified. To understand the evolution of seismic hazard estimation or the peak ground acceleration estimation, mathematical theories used in order to simulate or represent the seismic wave propagation, the past researches were studied. Efficient work has been done by many researchers using deterministic and probabilistic seismic hazard estimation has been reviewed in this literature. Geological observations point out the existence of a NNE trending strike slip fault, passing through Koyna [6, 9, 10]. The Koyna fault striking approximately in a NNE direction passes very close to the Koyna reservoir. Son-Narmada Fault (SNF) has witnessed an earthquake of magnitude Mw 5.2 respectively. Seismic hazard of Gujarat, Mumbai and Western India region is controlled by SNF Seismicity of India has been addressed by many researchers in particular Kaila et al. (1972), Chandra (1977), Ramalingeswara Rao and Sitapathi Rao (1984), Tandon (1992), Khattri (1992), Parvez et al. (2003), and Iyengar and RaghuKanth (2004). As per IS 1893 (2016), seismic study area falls in the zones II and III in the seismic zonation map of India.

3 Earthquake catalogue

Past available earthquake events in India is not properly arranged and it is necessary to do the proper manner for the estimate seismic hazard analysis. Earthquake data were collected between the intervals of 1819 to 2015, data was collected from various sources like Institute of Seismological Research (ISR), Gandhinagar , India Meteorological Department (IMD) earthquake report etc. Declustering and Completeness Analysis of magnitude two main methods have been used. The first method is Cumulative Visual interpretation (CUVI) method it is also known as graphical technique and second is Stepp's Method. About more than 400 earthquake events were collected, after declustering process with the minimum magnitude of 3.0 and maximum >=7. The data set events between magnitude 3-4M, 4-5M, 5-6M, 6-7M and greater than 7, the no of each earthquakes represented in histogram of each decade are as shown in figure 1[2].

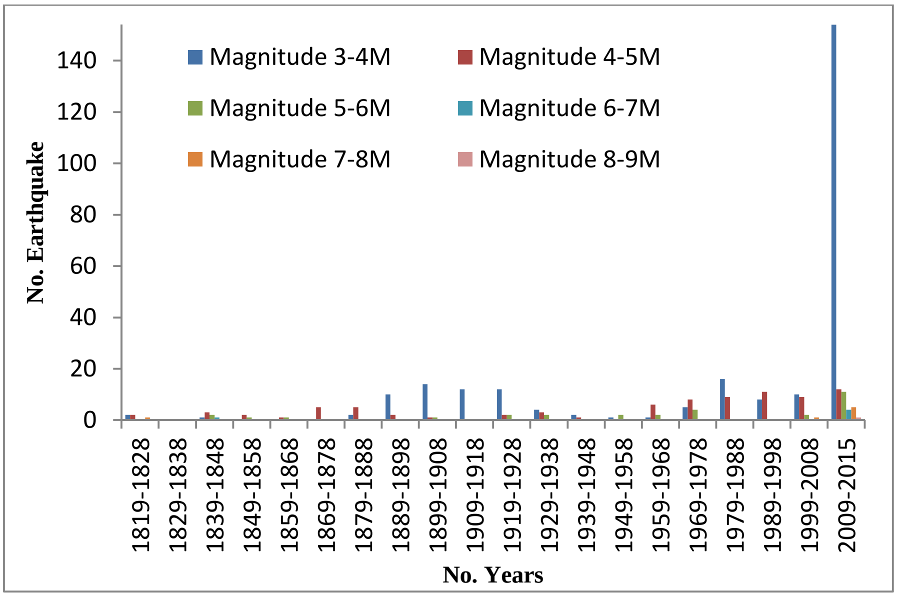

Fig. 1. Histogram of earthquakes in Gujarat, WI region

4 Seismicity parameters

A Western Indian is a taken as study region of 400 km radius with its centre at Somnath Temple Complex, Gujarat. Earthquake catalogues constitute the first essential input for the delineation of seismic source zones and their characterization. The preparation of a unified working catalogue for a region under consideration is an important task. The composite earthquake catalogue for Western India region includes around 3115 earthquakes with Mw ≥3 from 1819 to 2015 A.D as plotted in Figure 2

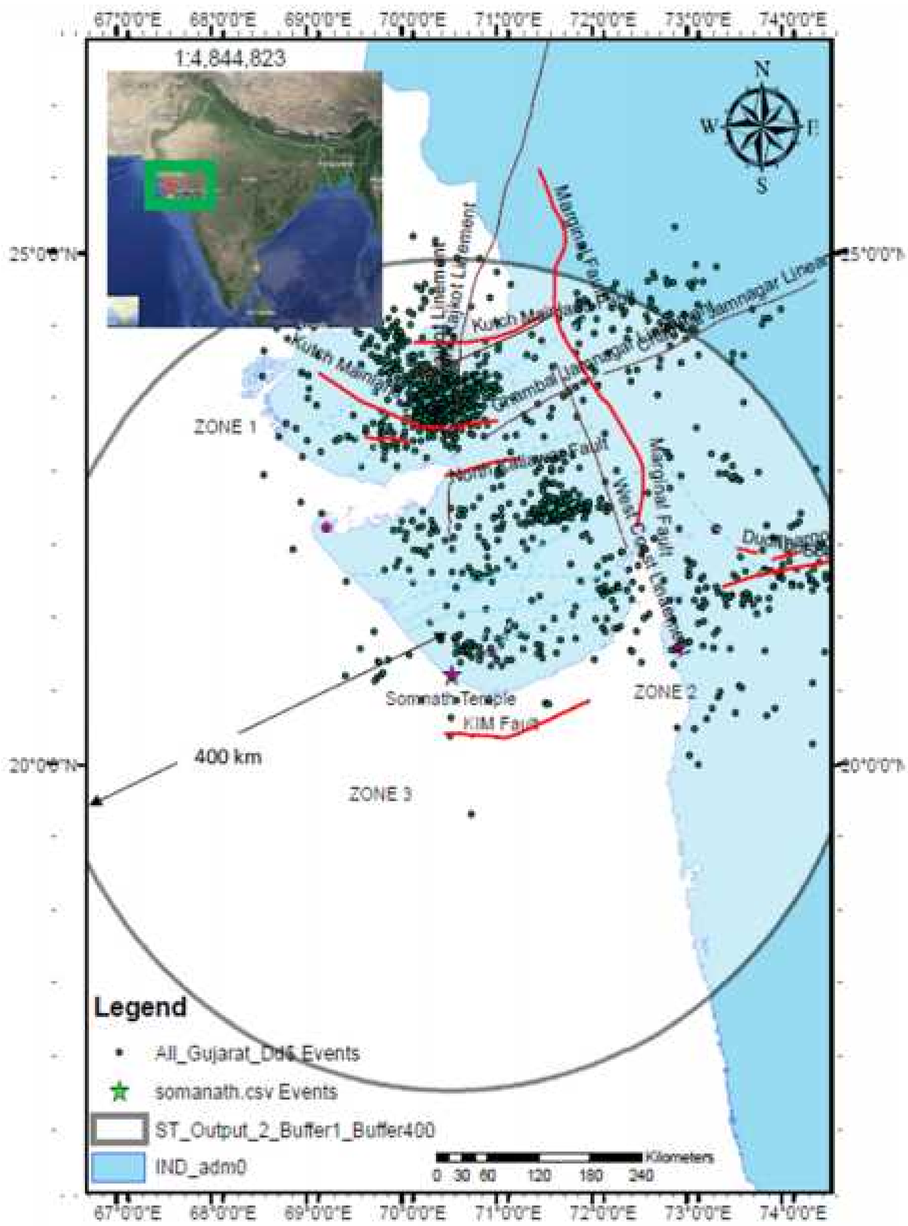

Fig. 2. Maps Showing Seismicity of the Gujarat Region from 1819 to 2015 A.D.

5 Derive Gutenberg-Richter (G-R) Recurrence Law

The cumulative annual rates of occurrence of earthquakes are also tabulated for different magnitude classes are 3≤Mw<4, 4≤Mw<5, 5≤Mw<6, 6≤Mw<7 and 7≤Mw<8 using CUVI method for the given region in Tables 1. The recurrence relationships that are established for the Gujarat region using CUVI method

Table 1. Cumulative annual rate of occurrence of earthquakes for Gujarat region using CUVI method

Magnitude range	Mean magni-tude (Mw)	No. of events	Complete-ness period	Annual rate	Cumula-tive annu-al rate, λm	log(λm)
3≤Mw<4	3.5	193	1970-2016	4.196	4.196	0.623
4≤Mw<5	4.5	55	1962-2016	1.019	5.214	0.008
5≤Mw<6	5.5	25	1934-2016	0.305	5.519	-0.516
6≤Mw<7	6.5	5	1844-2016	0.029	5.548	-1.537
7≤Mw<8	7.5	1	1819-2016	0.005	5.589	-2.294

A core element in the assessment of seismic hazard in the conventional method is the estimation of the recurrence intervals of earthquakes of different magnitudes. completeness year and period with the different rang of magnitude. The cumulative annual rates of occurrence of earthquakes are also tabulated for different magnitude classes are 3≤Mw<4, 4≤Mw<5, 5≤Mw<6 and 6≤Mw<7. The derived equation 1 from the completeness analysis for the earthquake catalogue of the study region.

CUVI, $y = -0.570x + 2.564$ (1)

6 Seismic hazard analysis

Seismic hazard analysis (SHA) is performed to quantify the expected ground shaking that a structure or facility will be subjected during its useful lifetime at a particular site. The degree of loss resulting from earthquakes is within human control in comparison to the control on earthquake occurrence. Safe design of a structure or facility is possible with the knowledge of the seismic hazard at a particular site or the region. In the present study, probabilistic seismic hazard analysis is carried out to estimate the design ground motion parameters for the Sardar Vallabhbhai National Institute of Technology (SVNIT) campus facilities being established at Surat region, Gujarat, West India. The following are the main steps involved in the PSHA:

Step 1 is define the of earthquake sources, which range from small faults to large seismotectonic provinces within the seismicity region. Step 2 is the derive the seismicity recurrence characteristic for the given sources, where each source is described by an earthquake probability distribution or recurrence relationship. A recurrence relationship indicates the chance of an earthquake of a given size to occur anywhere inside the source during a specified period of time. A maximum range of earthquake is chosen for each source, which is represents, the maximum event to be considered. Because these earthquakes are assumed to occur anywhere within the earthquake source, distances from all possible location within that source to the site must be considered. Step 3 is the assessment of the earthquake effects, which is similar to the deterministic approach apart from that in the probabilistic analysis, the range of earthquake sizes considered requires a family of earthquake attenuation, each relating to a ground motion parameter, such as peak acceleration, to distance for an earthquake of a given size. Step 4 is the determination of the hazard at the site, which is substantially dissimilar from the procedure used in arriving at the deterministic hazard [4,5,8, 9, 10]. In this case the effects of all the earthquakes of different sizes occurring at different locations in different earthquake sources at different probabilities of occurrence are integrated into one curve that shows the probability of exceeding different levels of ground motion level (such as peak acceleration) at the site during a specified period of time.

7 Hazard computation

Quantitatively assessment of the PSHA, the nature of earthquake ground motions at a selected site due to future earthquakes occurring in and around the site within an influence region in a specified time period. In this chapter describes PSHA methodology aimed to produce the probabilistic hazard curve, uniform hazard spectrum (UHS) for reference return periods (i.e., 95, 475, 975 and 2,475 years) and spectrum compatible accelerograms on stiff and level ground for Temple complex by using the attenuation relationship of Abrahamson et al, (2014). The main feature of this study is the usage of new seismogenic sources and most recent Ground Motion Prediction Equations (GMPE). The standard Cornell-McGuire approach has been used, which was first formalized in late 1960s by Cornell 1968 and generalized by McGuire 1976. The Cornell-McGuire method is a zone dependent method in which seismotectonic and geological data are used along with earthquake catalogue to identify seismogenic zones within which earthquakes have equal probability of occurrence at any location within the zones. The seismogenic zones are usually represented as faults or area sources. The rate of seismic activity of the identified source is to be characterized with respect to time, that is, annual rate of occurrence of different magnitude earthquakes. The Gutenberg- Richter (G-R) relation law, in which seismicity of the source is expressed with activity rate, b-value (frequency-magnitude slope) and maximum magnitude value at which curve is condensed. After the seismic source is characterised, ground motion prediction equations (GMPEs) or attenuation relations evaluate the ground motion intensity measure due to the identified seismogenic source. In this study describes PSHA methodology aimed to produce the probabilistic hazard curve, uniform hazard spectrum for reference return periods (i.e., 475, and 2,475 years) and spectrum compatible accelerograms on stiff and level ground for specified region of SVNIT campus by using the attenuation relationship [1]. At the final the influence of all the sources are combined and annual frequency of exceedance is obtained for different values of ground motion parameters. Later on the spectral ordinates are evaluated for other time periods; this annual probability of exceedance can be obtained by simply adding the individual annual probabilities of exceedance corresponding to each of the considered seismic sources.

8 Seismic hazard curves

The hazard estimation can be done based on the past earthquake data of the region and it is important to prepare a comprehensive earthquake catalog for the study area. The seismicity parameters such as b-value and recurrence rate are estimated through the procedure called the analysis of completeness. The seismicity parameters obtained from the present study and fitted the frequency formula and estimated reliable Gutenberg-Richter (G-R) parameters to quantify seismic hazard for all Gujarat region [2, 7, 10, 11]. Distribution of hazard estimates allows the statistical uncertainty in hazards to be quantified for the site, such that hazard estimates can be expressed as the mean or the 50th percentile of a distribution. Figure 3 show the hazard curves for the SVNIT campus to return periods of 475 and 2475 years by using the attenuation relationship [1].

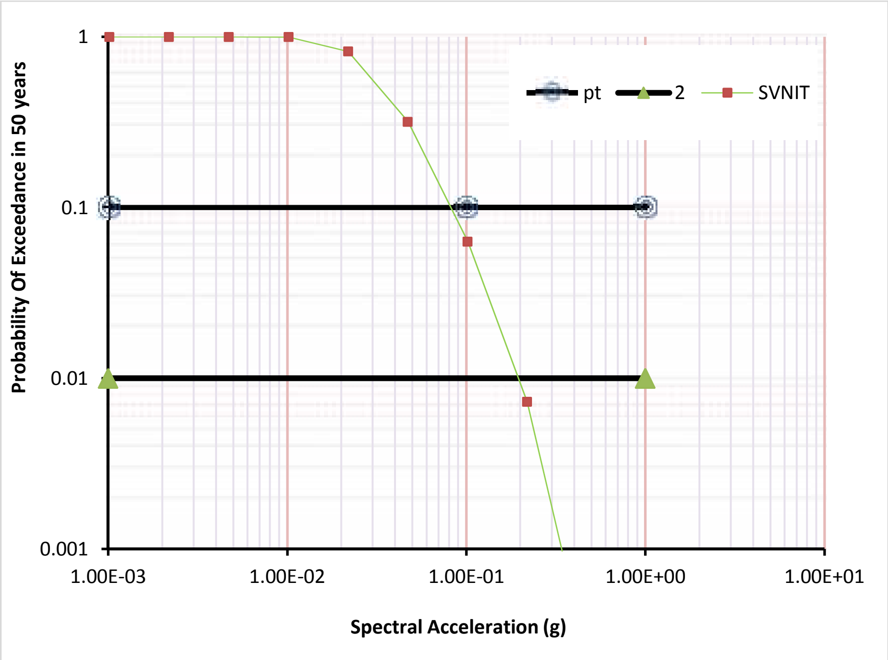

Fig. 3. Mean seismic hazard curves for Western India region at a SVNIT Campus site.

9 Uniform hazard spectrum

Uniform hazard spectrum (UHS) is PSA ordinates having a same probability of exceedance for a particular considered time span. The Uniform hazard spectrum is a common result of PSHA, often being used in response spectrum method of analysis for structures or as the target spectrum for acceleration time history scaling. The uniform hazard spectra (UHS) for 5% damping with return periods (RP) of 475 years at level and stiff or rock ground conditions for horizontal component of ground motions are derived from hazard curves (Figure 3). PGA values for return period of 475 and 2475 (10% PE in 50 yr, 2% PE in 50 yr) years are found to be between 0.082 and 0.107g respectively. 475-year RP hazard level is considered representative of moderate events that are reasonably likely to affect the structure in its design life, which is often represented as design basis earthquake (DBE). The RP of 2475-year hazard level represents the most severe earthquake effects considered for important structures, which is often represented as maximum considered earthquake (MCE). According to Indian seismic code (IS: 1893 Part 1 2016), SVNIT, Surat, Gujarat lies in Zone III. For DBE and MCE, the expected PGAs are 0.08g and 0.16g respectively. Figure 4, 5 are compares the UHS for 475, 2475 yr return period at the site with the DBE spectrum respectively, The PGA values compare well. At longer structural periods, IS code recommends higher spectral accelerations. Similar observations can be drawn from comparing UHS of 2475 yr return period with MCE.

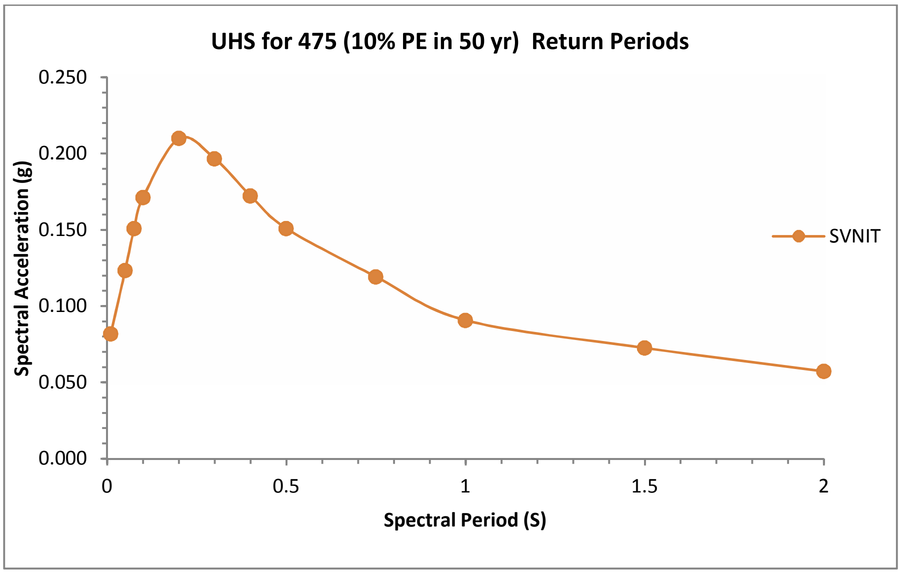

Fig. 4. Horizontal components of UHS for 475 (10% PE in 50 yr) return periods at Sardar Vallabhbhai National Institute of Technology

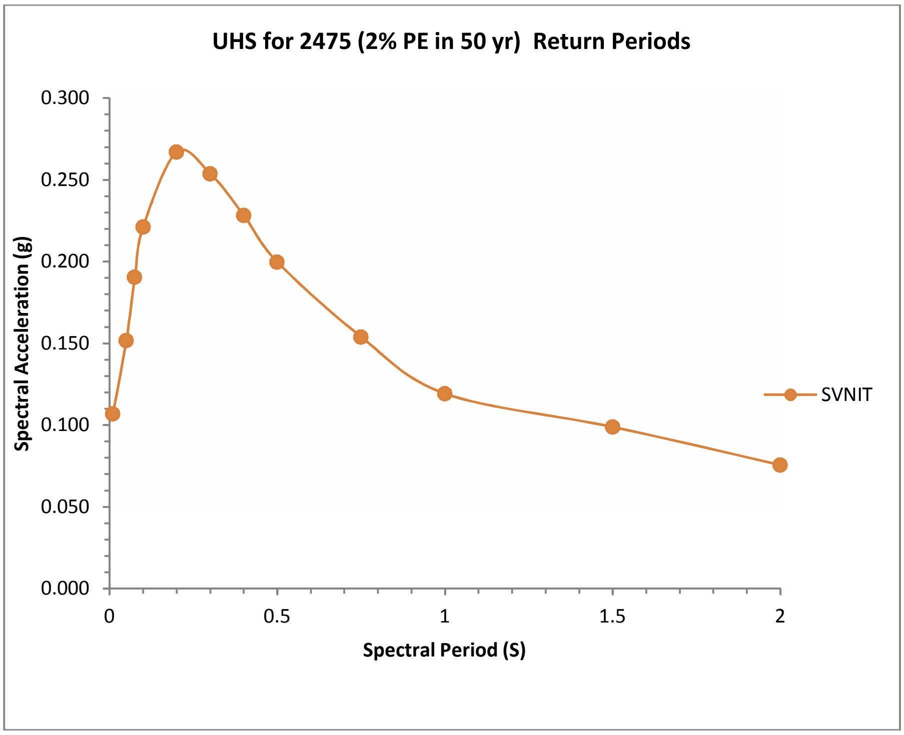

Fig. 5. Horizontal components of UHS for 2475 (2% PE in 50 yr) return periods at Sardar Vallabhbhai National Institute of Technology

10 Conclusions

The probabilistic methodology is the essential tool for quantifying tectonic hazards, as it considers all potential sources in a region, allows uncertainty to be fully quantified and provides hazard estimates for a spectrum of return periods. The results of the hazard analysis are provided in the form of peak ground acceleration (PGA), uniform hazard spectrum (UHS) and acceleration time-histories at bedrock level. The hazard curve gives probability of exceedance for a suite of PGA levels from all sources. The PGA value obtained PSHA approach for SVNIT, Surat, Gujarat region is for 475, 2475 years return period. This value compares well with the published results for the Gujarat region. The horizontal PGA expected in SVNIT (from the mean hazard curve), on stiff ground, with a 10% probability of exceedance in 50 years is 0.082g, whereas, that with a 2% probability of exceedance in 50 years is 0.107g.

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