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Ground Motion Selection Considering Seismicity of the Area and Response of the Structure

Ayon Das[1], Varun Patel[2] and Avishek Ghosh[3]
[1]Postgraduate Student (Structural), [2]Postgraduate Student (Structural) and [3]Postgraduate Student (Geotechnical)
Department of Civil Engineering, Indian Institute of Technology Bombay, Mumbai 400076, India

***Abstract*— In assessing the risk of any civil structure, ground motion selection plays a significant role. When looking at the risk assessment of any structure in a region, it is helpful to have ground motion time histories which are representative of the seismicity of that region. When actual ground motion records doesn't exist, ground motion of the similar nature from other parts of the world needs to be used or else synthetic ground motions need to be used for carrying out the analysis. Earthquake time history data is an important part of any dynamic analysis. The present study focuses on the selection on the selection of ground motions to reflect the regional seismicity as well as the frequency of the structure. This paper describes how to select an earthquake in Indian region using IS code.**

Keywords*— Ground Motion; Earthquake; Magnitude, Mean Time Peiord.

1. INTRODUCTION

Earthquakes in the past years have caused great damages to the structures. This has led the people to think and design earthquake resistant structures. In designing these earthquake resistant structures, a lot of research has been going on and a number of analysis methods have been investigated. Analysis can be static or dynamic. Also by using only static analysis it's difficult to solve the large structure problems where the dynamic analysis provides flexibility to solve the problem using specific and non-linear dimension of force (Bagheri, Firoozabad, and Yahyaei 2012) . Hence, dynamic analysis gives a better picture of the earthquake force than static analysis. To achieve a reliable estimation of the probabilistic distribution of the structural response, different ground motions are required in dynamic analyses (Nielson 2005). Incremental dynamic analysis (IDA) is also a newly developed analysis to estimate structural performance under seismic loads profoundly. It involves subjecting a structural model to one or more ground motion records, each scaled to numerous levels of intensity, thus producing one or more curves of response parameterized versus intensity level (Vamvatsikos and Allin Cornell 2002). The seismic response properties depends on the severity and the intensity of the earthquake, it is important to choose appropriate earthquakes.

2. GROUND MOTION SELECTION CRITERIA

The selection of earthquake ground motion is based on number of factors(FEMA P695). It is included following parameters.

- Magnitude of the source
- Types of source
- Condition of the site
- Site to source distance
- Number of records per even
- Strong Motion Instrument Location

2.1 Magnitude of the source

Large magnitude earthquake releases more energy and have greater duration of strong shaking causing greater risk of the collapse of the structures. While small magnitude earthquakes have smaller area of influence and also the duration of the shaking is small.

The NDMA report (NDMA,2011) has an earthquake catalogue and many historical and instrumental earthquake sources in India as well as the overseas are compiled in that catalogue. The catalogue dates from BC2474 to AD2008 with MW ≥ 4.0 collected from (Ghosh et al. 2012) is shown in Figure 1.Hence magnitude range 4-8 should be is used to take care of all the possible ground shaking in the region.

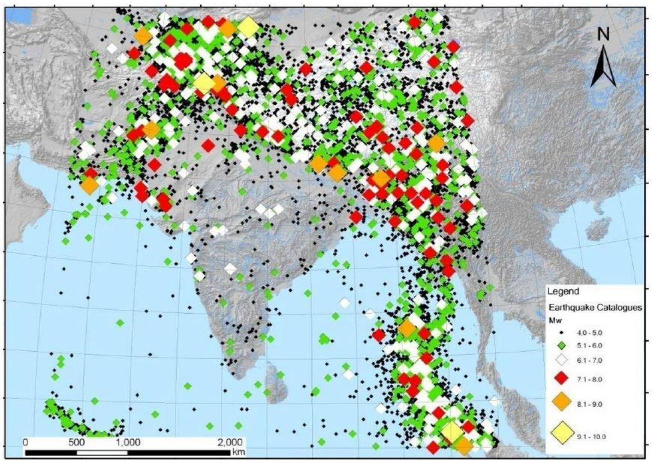

Figure 1: Earthquake catalogue from NDMA from BC2474 to AD2008 with Mw ≥ 4.0

2.2 Types of source

Source type is related to the type of the fault in this region. The reason of earthquake is the fault of break in the earth's crust along which the movement of the earth takes place. Faults are several types.

- Normal fault
- Reverse fault
- Strike-slip fault
- Strike-slip & Normal fault
- Strike-slip & Reverse fault
- Normal-Reverse fault

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Faults that move is the direction of gravity normally are called normal faults, faults that move is the reverse direction of gravity normally are called reverse faults and strike-slip fault shift on either side of a reverse or normal fault slide up or down along a dipping fault surface.(Figure 2)

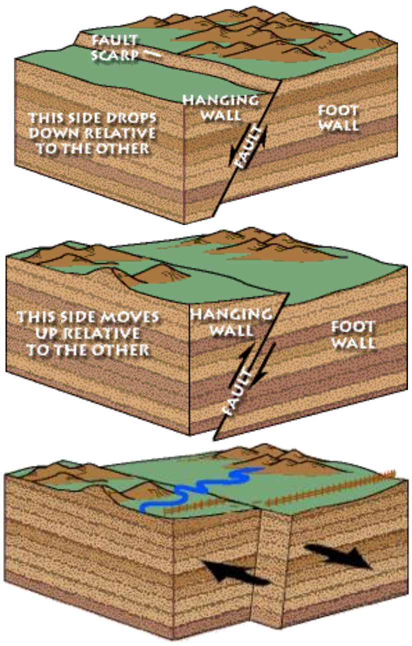

Figure 2: Normal fault, reverse fault and strike-slip fault (http://www.geo.mtu.edu/KeweenawGeoheritage/The_Fault/Fault_types.html)

2.3 Condition of the site

The amplitude, frequency and duration of earthquake ground motions are significantly influenced by soil material beneath a site and thereby affect the phenomenon and degree of damage to buildings and other structures (Idriss 1991).

The major types of soils found in India are: Laterite Soil, Mountain Soils, Black Soil, Red Soil, Alluvial Soil, Desert Soil, Saline and Alkaline Soil, Peat Soil. All types of soil are grouped into three types on the basis of SPT value in IS 1893 (Part 1), 2002.

- Type I: Rock or hard soil (SPT > 30)
- Type II: Medium soil (10 < SPT < 30)
- Type III: Soft Soil (SPT < 10)

2.4 Site to source distance

Depending on the site to source distance ground motion are two types- “Far-Field” record and “Near-Field” record. In Far-Field record set are the ground motion records where sites situated greater than or equal to 10km from fault rupture. When the distance between sites to fault rupture less than 10 km, it is referred as Near-Field record.

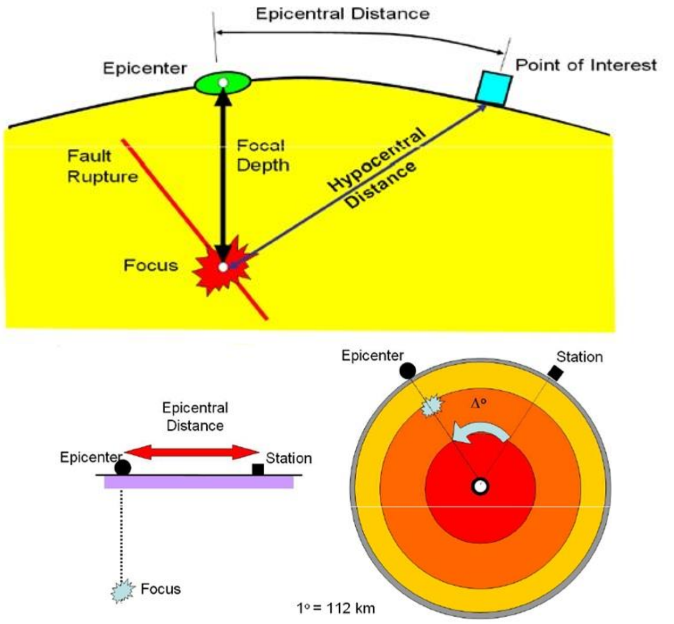

Figure 3: Focus, focal depth, epicenter & epicentral distance (http://mzsengineeringtechnologies.blogspot.in/2015/08/element-of-civil-and-environmental.html)

The starting rupture point of any ground motion, where elastic wave energy is first transformed from strain energy is called focus. Mainly Focus or Hypocenter is the the point on the fault rupture where slip begins. Epicenter is the point on Earth’s surface directly above an earthquake’s focus. Focal depth is the depth of focus from the epicenter, is an significance factor in defining the damaging capacity of an earthquake. Distance from the epicenter to any point of interest like any structure is called epicentral distance. For earthquakes at large distances, sometimes epicentral distance is measured as an angle subtended at the center of the Earth. For our study epicentral distance keeps 15 to 1000 km.

2.5 Number of records per event

Strong-motion detecting instruments are not equally located across seismically potential regions. Due to the insufficient number of instruments at different location, at the time of the earthquake some large magnitude earthquake generates many records, while others produce only a few. To avoid this potential bias in record data, not more than three records are taken from any one earthquake for a record set**.**

2.6 Strong motion instrument location

Strong-motion instruments are sometimes located inside buildings (e.g., ground floor or basement) that, if large, can influence recorded motion due to soil-structure-foundation interaction. Instead, instruments should be set up in open-field location or on ground floor of a small building should be used (Xu et al. 2016).

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3. EARTHQUAKE DATABASE

Considering the above parameters, the Pacific Earthquake Engineering Research Centre (PEER) ground motion database and COSMOS database are used to select the earthquake (Table-2) .These database provide options for searching, selecting and downloading ground motion data. Those have application for getting the records of the required property.

4. DESIGN RESPONSE SPECTRA

It is the plot of maximum response (Spectral acceleration) versus the time period. The design response spectra is obtained from IS 1893 (Part 1), 2002.

Figure 4 shows the proposed 5 precent spectra for different types of soil sites and Table-1 gives the multiplying factors for obtaining spectral values for various other damping.

For rocky, or hard soil sites,

$$\frac{S_a}{g} = \begin{Bmatrix} 1 + 15\,T & 0.00 \le T \le 0.10 \\ 2.50 & 0.10 \le T \le 0.40 \\ 1.00/T & 0.40 \le T \le 4.00 \end{Bmatrix}$$

(1)

For rocky, or hard soil sites,

$$\frac{S_a}{g} = \begin{Bmatrix} 1 + 15\,T & 0.00 \le T \le 0.10 \\ 2.50 & 0.10 \le T \le 0.55 \\ 1.36/T & 0.55 \le T \le 4.00 \end{Bmatrix}$$

(2)

For rocky, or hard soil sites,

$$\frac{S_a}{g} = \begin{Bmatrix} 1 + 15\,T & 0.00 \le T \le 0.10 \\ 2.50 & 0.10 \le T \le 0.67 \\ 1.67/T & 0.67 \le T \le 4.00 \end{Bmatrix}$$

(3)

Above equations are used to derive the spectra shown in figure-4.

Table 1: Multiplying Factors for Obtaining Values for other damping

Damping %	0	2	5	7	10	15	20	25	30
Factors	3.2	1.4	1.0	0.9	0.8	0.7	0.6	.55	0.5

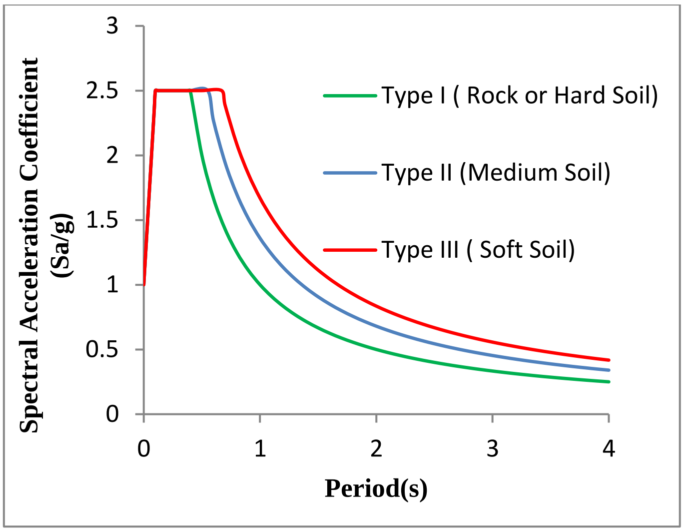

Figure 4: Response spectra for rock and soil sites for 5 precents damping (IS 1893 Part 1, 2002)

5. MATCHING OF SPECTRA

Records obtained from the database are the unscaled or original records. Hence it is important to match spectra of earthquake with the design spectra of the region. Sometimes, it is necessary to scale the records in order to match the design response spectrum of the region. This task was achieved with the help of the software named 'SeismoMatch'. SeismoMatch is an software application developed by Seismosoft which can adjust earthquake accelerograms to match a defined response spectrum, using the wavelets algorithm proposed by Abrahamson [1992] and Hancock et al. [2006].For our study Type-II medium soil spectra has used for study and searched in PEER database. Later, that earthquake time history data are scaled to match the spectra.

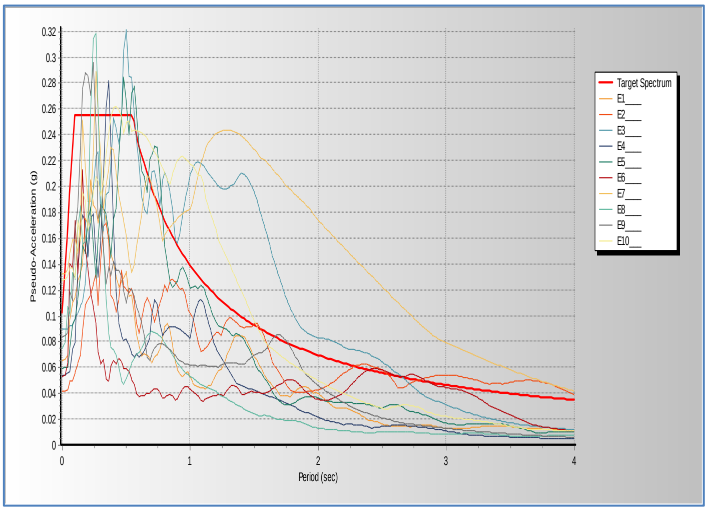

Figure 5: Original spectra and design spectra

Table 2: Details of ground motion records

No.	Earthquake Event	Station	Year	Fault Types	Mw	PGA (g)	Database
E-1	Borrego	El Centro Array #9	1942	Strike slip	6.50	0.065	PEER
E-2	Kern Country	LA Hollywood Stor FF	1952	Reverse	7.36	0.042	PEER
E-3	Kern Country	Santa Barbara Courthouse	1952	Reverse	7.36	0.089	PEER
E-4	Northern Calif-02	Ferndale City Hall	1952	Strike slip	5.20	0.054	PEER
E-5	Hollister-01	Hollister City Hall	1961	Strike slip	5.60	0.058	PEER
E-6	Parkfield	Cholame Shandon Array #12	1966	Strike slip	6.19	0.053	PEER
E-7	Borrego Mtn	El Centro Array #9	1968	Strike slip	6.63	0.132	PEER
E-8	San Fernando	Fairmont Dam	1971	Reverse	6.61	0.074	PEER
E-9	San Fernando	Gormon-Oso Pump Plant	1971	Reverse	6.61	0.083	PEER
E-10	Point Mugu	Port Hueneme	1973	Reverse	5.65	0.127	PEER

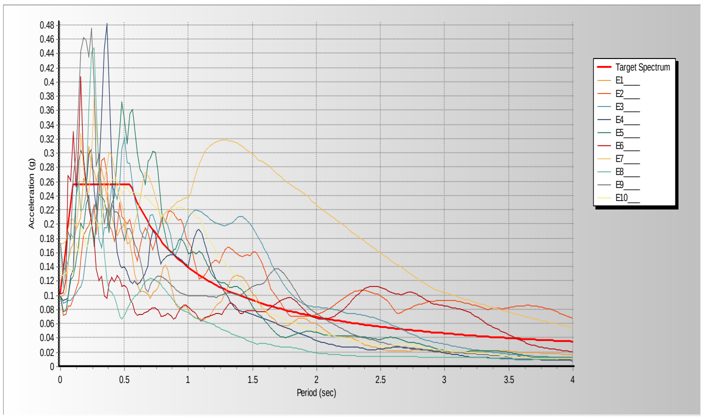

Figure 6: Scaled spectra and design spectra

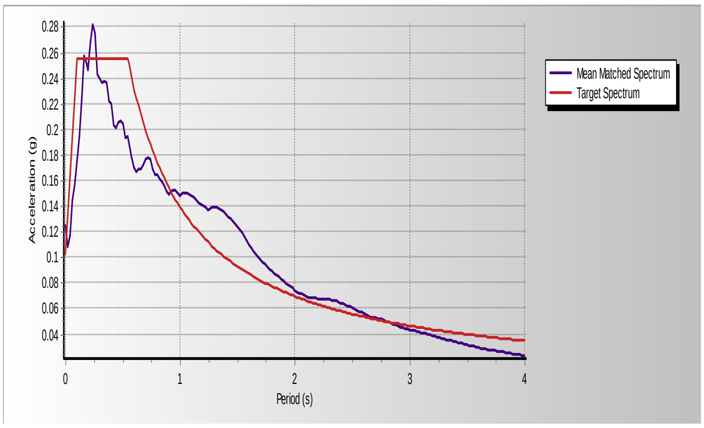

Figure 7: Mean spectra and design spectra

6. FREQUENCY CONTENT

The input earthquake ground motion has great effect in the dynamic behaviour of any structural systems subjected to earthquake ground shaking. When the amount of frequency an earthquake ground motion becomes close to the natural period of a structural system (e.g., building) the dynamic response is increased, larger forces are applied on the system, and significant loss can occur (Chopra 1981). That's why, it is important to assess the frequency parameter of an earthquake ground motion and evaluate its effect on the dynamic response of a structure.

Rathje et al. (2004) examined four scalar parameters that define the frequency quantity of strong ground motions are described below.

1. The mean period (T_m)
2. The average spectral period (T_{avg})
3. The smoothed spectral predominant period (T_o) and
4. The predominant spectral period (T_p)

Mean period (T_m) is the average time period having weightage as square of the Fourier amplitude. Average spectral period (T_{avg}) is the average of periods in acceleration in acceleration response spectra where discrete periods equally spaced on an arithmetic axis. Smoothed spectral predominant period (T_o) is the average of periods in acceleration in acceleration response spectra where discrete periods equally spaced on a log axis. Predominant spectral period (T_p) is the period at which response spectrum is maximum.

T_m and T_{avg} differentiate the lower frequency content of ground motions, while T_o is influenced most by the high frequency content. T_p does not clearly narrate the frequency content of a strong ground motion and is not preferred. This study concludes that T_m is the best frequency content parameter for earthquake records.

$$T_m = \frac{\sum_i {C_i}^2 \left(\frac{1}{f_i}\right)}{\sum_i {C_i}^2} \qquad (4)$$

for $0.25\text{Hz} \le f_i \le 20$ Hz, with $\Delta f \le 0.05$ Hz

Where C_i are the Fourier amplitude coefficients, f_i are the discrete fast Fourier transform (FFT) frequencies between 0.25 and 20 Hz, and Δf is the frequency interval used in the FFT computation.

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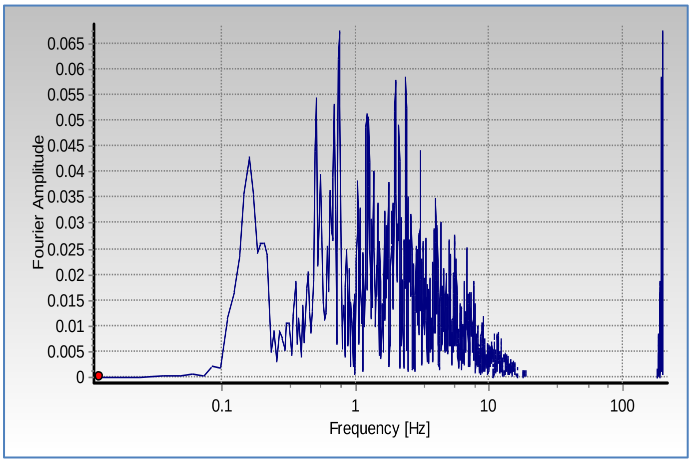

Figure 8: Fourier amplitude spectra for Borrego earthquake

This task was achieved with the help of the software named 'SeismoSignal'. SeismoSignal constitutes an easy, yet potential, package for the processing of earthquake data. It helps to develop elastic and constant ductility inelastic response spectra, computation of Fourier amplitude spectra, filtering of high and low frequency record content. Meantime period are described in Table-3.

Table 3: Mean period (T_m) of original ground motion records

No.	Earthquake Event	Mean Period (s)
E-1	Borrego	0.58
E-2	Kern Country	1.01
E-3	Kern Country	0.88
E-4	Northern Calif-02	0.60
E-5	Hollister-01	0.67
E-6	Parkfield	0.71
E-7	Borrego Mtn	1.33
E-8	San Fernando	0.33
E-9	San Fernando	0.50
E-10	Point Mugu	0.71

Meantime period or frequency of any earthquake ground motion should be close to frequency to the structure to get maximum response.

7. CONCLUSIONS

This project explained how to select earthquake records from the online ground motion database like PEER and COSMOS considering different parameters of selection. Further it described how to define the design spectrum and scale the natural records to match the target spectrum**.** Later, It is described how to relate time period of the earthquake ground motion with the time period of any defined structure. Time period or frequency of any earthquake has a great impact on the analysis of any structure. So, we should select the ground motion data that are related with geographical data of the areas as well as create maximum response of the structure.

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