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DEVELOPMENT OF ELASTIC SPECTRUM FOR INDIAN CONTEXT

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ABSTRACT

Response spectrum is a central and widely accepted concept in earthquake engineering to estimate lateral force on the structure. It is an envelope of maximum response of various Single Degree of Freedom (SDOF) systems to a specified earthquake ground excitation. The response spectrum can't be used uniformly to design any structure since it is very much ground motion dependent. Apart, it is very much jagged in nature and required to be smoothen out. In order to utilize them for designing the structure uniformly it is converted to Elastic Design Spectrum. Elastic design spectrum is a by enlarge derived from response spectrums of ensembles of earthquake ground motions. The elastic design spectrum can be readily used for designing new as well assessing existing structure for seismic capacity. The elastic design spectrum is globally used to determine lateral force due to earthquake in seismic code of most of the countries.

In the present paper, elastic design spectrum is developed for Indian subcontinent. About 184 earthquake ground motion records are compiled. Out of this 67 earthquake ground motions are established as Strong Ground Motion records to develop response spectrum. The response spectrums are converted to elastic spectrum through statistical analysis. Mean response spectra for East and North regions are very much similar to each other, while mean response spectra for West and South-East regions are similar. East and North region has wide velocity sensitive region as compared to West and South-East regions.

1. INTRODUCTION

Response spectrum is the maximum response of linear single degree of freedom system for the available time histories. The response spectrum cannot be used directly used to determine the lateral force in design, since the response of a given structure for future earthquake will be very much differing from the past earthquakes. Elastic design spectrum is the smooth spectra developed from the response spectra by removing the jaggedness of the response spectra. The design spectrum is based on statistical analysis of the response spectra for the ensemble of ground motions.

Chopra[1] has developed the response spectrum as well as design spectrum for El-centro ground excitation. The procedure for developing the design spectrum from the response spectrum by considering Newmark & Hall amplification factors has been explained. Newmark and Hall[2] has considered 14 horizontal and 7 vertical ground motions for different soil condition for San Fernando seismic event to develop design spectrum. Amplification factors for different probabilities were developed by deriving ad/v^2 ratio and the same has been used to generate design spectrum. Malhotra[3] has suggested the method of constructing a smooth-response spectrum from peak values of ground acceleration, velocity, and displacement (PGA, PGV, and PGD). Functional form of amplification factors is presented for various values of damping unlike the procedure mentioned by Newmark & Hall[2].

H.Ghasemi, M.Zare and F. Sinaeian[4]has developed the smooth spectra of horizontal and vertical ground motions for Iran. The main concern of the study has been to propose a practical procedure for constructing smooth response spectra from the peak values of ground motion. The dynamic amplification factors has been calculated for horizontal and vertical components and functional form of amplification factors for horizontal and vertical spectra has been developed in line with the procedure followd by Malhotra[3]. Freeman[7]traces the development of building code provisions and the relationship to response spectra. A response spectra has been developed for the ground motion recorded at the ground level of the Holiday Inn hotel structure during the Northridge earthquake of January 1994 in California, U.S.A. The method to smooth out the curve by removing jaggedness from the response spectrum has been discussed.

2. DEVELOPMENT OF DESIGN SPECTRUM

The design spectrum is used to design new structure and to determine the seismic capacity of existing structure. By removing the sharp peek and valleys from the response spectrum and smoothen out the curve by statistical approach, elastic design spectrum can be developed. Following are the steps to develop design spectrum:

- All ground motion data has been normalized by considering peak ground acceleration as one.
- Mean of normalized peak ground acceleration, ground velocity and ground displscement has been derived for four regions (East, west, North, South-East).
- Mean response spectrum for four regions has been developed on four way logerithmic paper.
- Amplification factors, α_A=2.12, α_V=1.65 and α_D=1.59 for 5% damping ratio (ζ) and 50% non-exceedance probabilities has been selected which is given by N. M. Newmark and W. J. Hall.
- As per N. M. Newmark and W. J. Hall, time period between 0.125 sec and0.349 sec is considered as acceleration sensitive region. So multiplying peak ground acceleration by amplification factor α_A, constant value of pseudo acceleration A is obtained.
- Time period between 0.349 sec and 3.135 sec is considered as velocity sensitive region. So multiply peak ground velocity by amplification factor α_V, constant value of pseudo velocity V is obtained.
- Time period between 3.135 sec and 10 sec is considered as displacement sensitive region. So multiply peak ground displacement by amplification factor α_D, constant value of deformation D is obtained.
- For period shorter than 0.125 sec consider pseudo acceleration A is equal to peak ground acceleration and for period more than 10 sec consider pseudo displacement D is equal to peak ground displacement.

3. DESIGN SPECTRUM FOR INDIAN CONTEXT

Various earthquake excitations recorded at various places of the country, India are compiled from authentic earth recording stations, web portal. Most of the time history data are available from NICEE, at IIT Kanpur. A set of 184 Indian time histories (23 earthquake events) has been collected from different regions of the country for the detailed study. Out of this 67 earthquake ground motions are established as Strong Ground Motion records based on Duration of motion, RMS acceleration and PGA to develop design spectrum.

The country is divided into four regions: East, West, North and South-East. In East region, 43 ground motions, West region 1 ground motion, North 21 ground motion and South-East 2 ground motions are identified as strong ground motion. These strong ground motions are listed in Table 1.

Table: 1 Strong Ground Motion stations and PGA

Region	RecordingStation	PGA (m/sec^2)	RecordingStation	PGA (m/sec^2)
East	Nongkhlaw	0.539	Umsning	1.2
	Pynursla	0.91	Baithalangso	0.603
	Satisama	1.11	Berlongfer	1.42
	Ummulong	1.11	Diphu	0.898
	Bamungao	0.194	Saitsama	0.61
	Berlongfer	0.706	Berlongfer	0.707
	Diphu	0.843	Diphu	0.79
	Hatikhali	0.305	Hatikhali	0.437
	Saitsama	0.364	Katakhal	1.05
	Mawphlang	0.796	Nongpoh	0.476
	Nongkhlaw	1.05	Nongstoin	0.469
	Pynursla	0.487	Pynursla	0.279
	Ummulong	0.553	Tinsukia	0.023
	Umsning	0.39	Guwahati	0.184
	Baithalongso	1.51	Jorhat	0.0393
	Berlongfer	2.95	Naogaon	0.3211
	Hajadisa	0.902	Golaghat	0.09
	Khliehriat	0.688	Kokhrajhar	0.0592
	Panimur	1.65	Golaghat	0.147
	Saitsama	2.07	Golaghat	0.1625
	Ummulong	0.886	Jorhat	0.0901
	Umrongso	0.748		
West	Ahmedabad	1.04		
North	Bhatwari	2.48	Rakh	0.29
	Rudraprayag	0.523	Gopeshwar	1.95
	Srinagar	0.654	Ghansiali	0.714
	Uttarkashi	2.37	Roorkee	0.554
	Nathpa	0.049	Ukhimath	0.891

	Roorkee	0.0191	Chamoli	0.411
	Ukhimath	0.371	Roorkee	0.0234
	Bhawarna	0.365	Champawat	0.0168
	Jawali	0.149	Munsiari	0.0946
	Shahpur	2.00	Pithoragarh	0.0344
	Chamba	1.43		
South-East	Portblair 2008	0.2251	Portblair 2010	0.0407

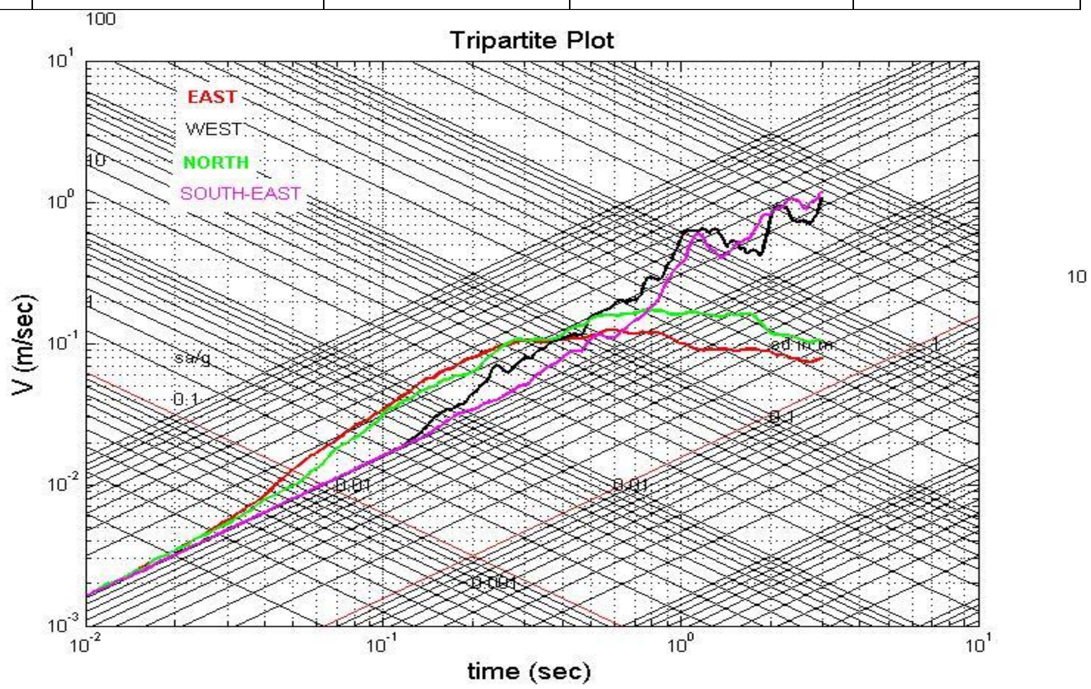

Fig:1 Mean Response Spectrum for four regions

Fig.1 shows mean response spectrum developed for East, West, South-East and North region of the country. It is cleare from the above figure that seismic demand offered by North and East response spectrum is similar while same observation is valid for West and Sourth-East response spectrum. The response spectrum shown in Fig. 1 is used to develop design spectrum for four different regions of the country. The response spectrum and design spectrum are developed through MATLAB based programming. Fig. 2 shows design spectrum developed usingamplification factor suggested by Newmark & Hall [ ] for East region.

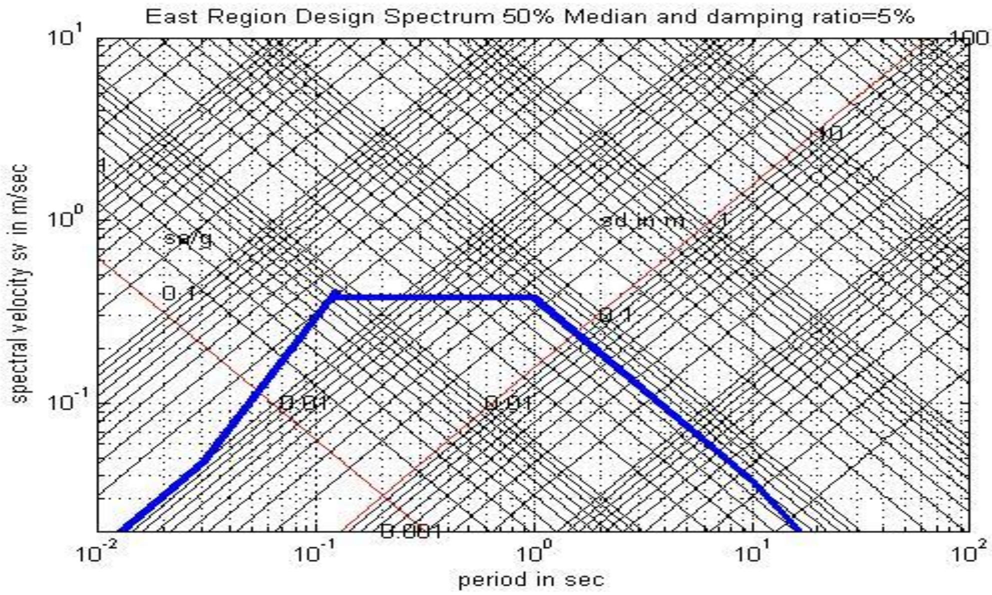

Fig:2 Design spectrum for East region

Similarly, Fig. 3, Fig. 4 and Fig. 5 shows design spectrum developed for West, North and South-East region of the country, respectively.

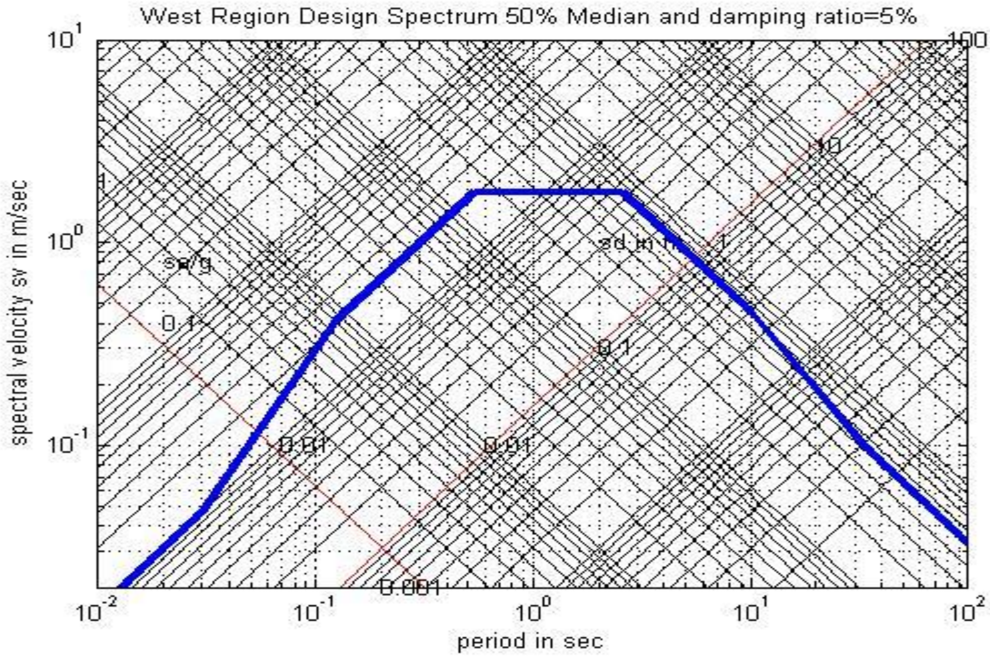

Fig:3 Design spectrum for West region

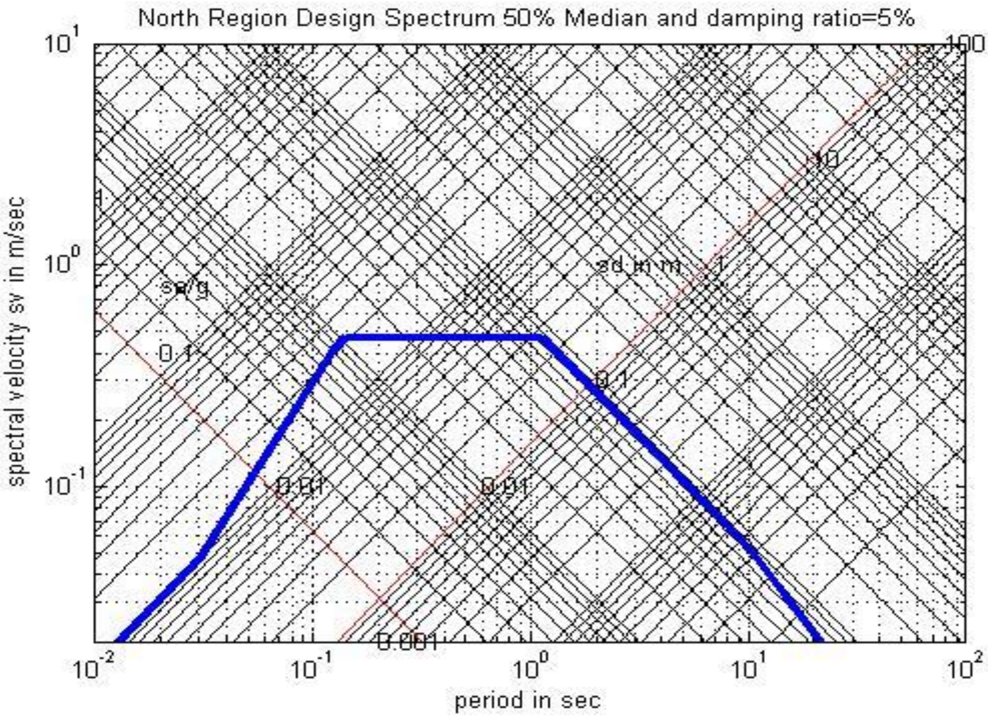

Fig:4 Design spectrum for North region

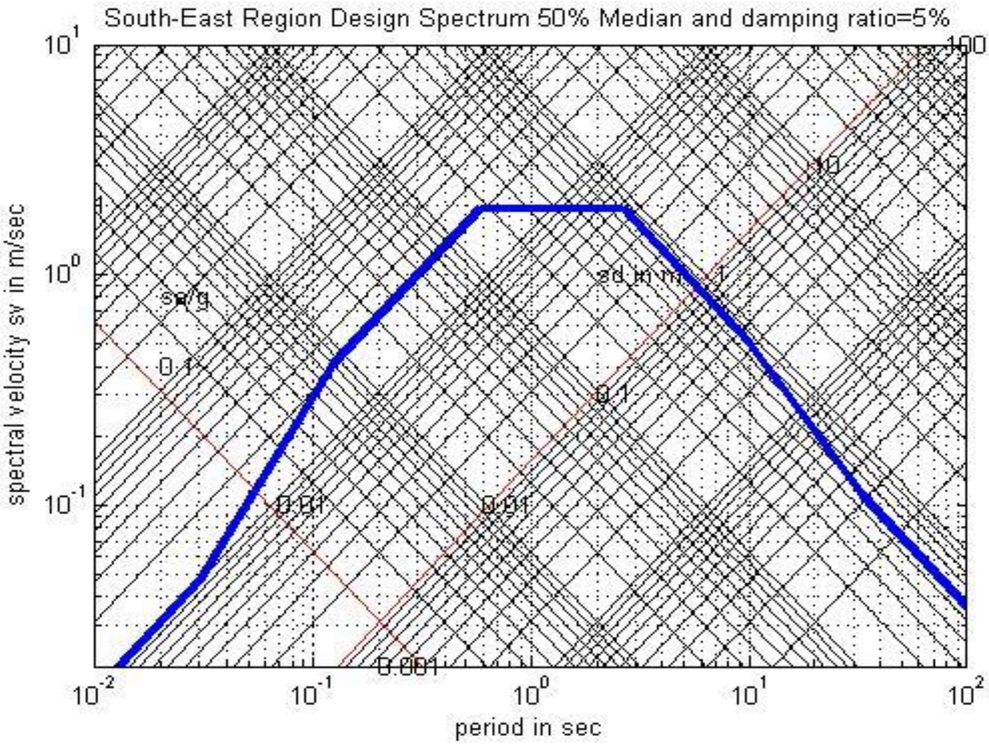

Fig:5 Design spectrum for South-East region

4. CONCLUSION

Use of response spectrum and design spectrum plays a vital role in estimating lateral force for the structures. In the current paper response spectrum is developed for four different region of the country based of selected 67 strong ground motion. Using amplification factors suggested by Newmark and Hall, design spectrum are developed for four region of the country. It is observed that seismic demand posed by North and East region and South-East and West region are quite similar. However, note that later has very limited time history data. The design spectrum developed can be compared with design spectrum provided by IS:1893-2002 (Part-I) in order to establish the efficacy of the former.

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