A STUDY ON SITE SPECIFIC SPECTRUM OF RECORDED EARTHQUAKES IN INDIA

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Abstract: Earthquake is natural calamity, results from ground movement which causes damage or sometimes complete collapse of structures. It is important to understand the response of structures subjected to strong ground motions. Maximum response of structure under strong ground motion is important for earthquake resistant design. Present paper attempt to develop site specific spectrum for recorded earthquakes in India. Efforts to develop response spectrum for a particular structure and to compare it with developed response spectrum also highlights in the paper. This response spectrum is developed by solving equation of Single Degree of Freedom system (SDOF).

Index Terms: **Earthquake, Response Spectrum, Site Specific Spectrum**

I. INTRODUCTION

Earthquake is a disastrous natural force that causes damages to manmade structures. There are so many small earthquakes occur in various countries everyday. The fundamental of earthquake should be recognized so structures can be protected. It is important to know the characteristics of an earthquake as numbers of earthquakes are so weak which can be only observed by measuring instruments and cannot be felt.

Buildings collapse in an earthquake because of the vibration of the ground. Strong ground motion has enough strength to affect people and damage structures. Strong ground motions produced by earthquakes are random in nature and contain energy of different magnitudes.

The main objective of the paper is to develop the site specific spectrum for different earthquake events of India. The present paper also contains development of response spectrum for a particular structure and to compare it with developed response spectrum.

II. DATA OF VARIOUS GROUND MOTIONS FOR INDIA

A set of 139 Indian time histories (12 earthquake events) has been collected from different regions of the country for the study. Out of them, 49 strong ground motions from 12 earthquake events for different regions of India classified. Table 1 shows all these strong ground motion earthquake records.

Table 1: Available Indian Strong Ground Motion Earthquake Records

Events	Recording Station	Magnitude	PGA (m/s^2)	PGA at time (sec)
Bhuj (26/01/2001)	Ahmedabad	7.0	1.0382	46.94
Chamoli (28/03/1999)	Ghansiali	6.6	0.71419	13.56
	Gopeshwar		1.9507	4.8
	Joshimath		0.69554	5.62
	Ukhimath		0.89061	0.48
India-Burma border 1997 (08/05/1997)	Jellalpur	5.6	1.1519	7.02
	Katakhal		1.0531	9.44
	Silchar		0.93317	9.26
	Ummulong		1.5209	10.32
Xizang-India border (26/03/1996)	Ukhimath	4.8	0.37079	1.96
India-Burma border 1995 (06/05/1995)	Baigao	6.4	0.55919	2.36
	Berlongfer		0.70707	27.48
	Diphu		0.78998	1.5
Chamba (24/03/1995)	Chamba	4.9	1.4284	2.86
	Rakh		0.29033	3.42
Uttarkashi (19/10/1991)	Barkot	7.0	0.932	6.06
	Bhatwari		2.48	4.26
	Ghansiali		1.16	6.4
	Uttarkashi		2.37	6.22
India-Burma border 1990 (09/01/1990)	Berlongfer	6.1	1.42	27.92
	Diphu		0.898	4.92
	Maibang		0.624	0.72

	Panimur		0.753	1.74
	Saitsama		0.61	2.64
India-Burma border 1988 (06/08/1988)	Baigao	7.2	2.17	23.32
	Baithalongso		1.51	26.94
	Berlongfer		2.95	29.58
	Bokajan		1.48	22.84
	Dauki		1.06	20.32
	Diphu		2.77	21.04
	Mawphlang		1.17	21.76
	Nongkhlaw		1.39	31.2
	Panimur		1.65	27.1
	Saitsama		2.07	28.22
	Umsning		1.2	29.96
India-Bangladesh border 1988 (06/02/1988)	Mawphlang	5.8	0.796	13.66
	Nongkhlaw		1.05	14.74
	Pynursla		0.487	12.58
	Saitsama		0.646	0
	Ummulong		0.553	12.78
India-Burma border 1987 (18/05/1987)	Berlongfer	5.9	0.706	15.62
	Diphu		0.843	15.86
	Gunjung		0.414	1.06
	Hajadisa		0.769	2.02
	Laisong		0.415	2.16
NE-India (10/09/1986)	Pynursla	4.5	0.91	5.26
	Saitsama		1.11	5.3
	Ummulong		1.11	4.68
	Umsning		0.995	6.24

Source: https://strongmotioncenter.org/vdc/scripts/earthquakes.plx#IND

III. SITE SPECIFIC SPECTRUM

Site specific response spectrum developed using SIREN and MATLAB software for earthquakes of different regions of India.

Oasys SIREN Version 8.3

Siren is a site response analysis program, which calculate the soil response attributable to specified movement in the bedrock. This is achieved by modelling the soil as a non-linear one-dimensional soil column with an earthquake motion input at its base.
In this program, the following can be calculated for a specified soil column and bedrock movement,

- Displacement, velocity and acceleration time response for any node
- Stress-Strain curve for any element in the soil profile
- Relative displacement at various elevations at any time
- Base response spectrum and surface response spectrum
- Spectral ratio (surface/bedrock)

To assess the ground movement affecting a specific structure or to review the peak ground acceleration to be considered during design SIREN can be used.

Procedure

- For dynamic soil property, Oasys SIREN Version 8.3 software used.
- From that time history data of various earthquakes acquired which entered in MATLAB software.
- For the interval of 0.001 sec acceleration value acquired.
- In order to develop response spectrum for earthquake, graph of Pseudo-acceleration (g) Vs. Time (sec) is drawn.
- Value of response spectrum function entered in ETABS for 10 storey building and acquired structural parameters such as base reaction, maximum storey drift and maximum displacement.

Table 2 and 3 show properties of non-plastic soil.

Table 2: Properties of Soil Material

Degradation Curve	Shear Strain Amplitude (%)	G/Go	Shear Stress/Go	Hysteretic Damping Ratio
Defaults	0	1		
1	2.00E-05	1	2.00E-07	0
2	5.50E-05	0.992	5.46E-07	0.00186692
3	0.0001	0.98	9.80E-07	0.00485909
4	0.001	0.95	9.50E-06	0.00206051
5	0.01	0.5	5.00E-05	0.0573349
6	0.1	0.1	0.0001	0.257515
7	1	0.025	0.00025	0.201287

Source: Singh J. P., Ph. D. Thesis, "Site Response of an Instrumented Building including Soil-Structure Interaction", Indian Institute of Technology Roorkee, 2008 retrieved from http://shodhbhagirathi.iitr.ac.in:8081/jspui/image/pdf/web/viewer.html?file=/jspui/bitstream/123456789/851/1/SEISMIC%20RESPONSE%20OF%20AN%20INSTRUMENTED%20BUILDING%20INCLUDING%20SOIL-STRUCTURE%20INTERACTION.pdf

Table 3: Properties of Soil Elements

Element	Elevation at top (m)	Material		Density (kg/m^3)	Unload Factor	Visc Damp Ratio	Frequency (Hz)	Shear Wave Velocity (m/s)
		Go (Pa)	Degradation curve					
Defaults	0	0	1	0	1	0		
1	30	326682000	1	1830	1	0.05	29.8865	422.51
2	25.5	288445000	1	1788	1	0.05	42.6164	401.65
3	22.5	206987000	1	1840	1	0.05	35.587	335.4
4	19.5	77688600	1	1515	1	0.05	24.0271	226.45
5	16.5	122161000	1	1580	1	0.05	29.5031	278.06
6	13.5	114136000	1	1510	1	0.05	29.171	274.93
7	10.5	146401000	1	1550	1	0.05	32.6088	307.331
8	7.5	151164000	1	1525	1	0.05	33.4056	314.84

Source: Singh J. P., Ph. D. Thesis, "Site Response of an Instrumented Building including Soil-Structure Interaction", Indian Institute of Technology Roorkee, 2008 retrieved from http://shodhbhagirathi.iitr.ac.in:8081/jspui/image/pdf/web/viewer.html?file=/jspui/bitstream/123456789/851/1/SEISMIC%20RESPONSE%20OF%20AN%20INSTRUMENTED%20BUILDING%20INCLUDING%20SOIL-STRUCTURE%20INTERACTION.pdf

IV. Generation of Site Specific Response Spectrum

Figs. 1 to 12 show site specific response spectrum for 12 recorded earthquake events of India using SIREN and MATLAB software.

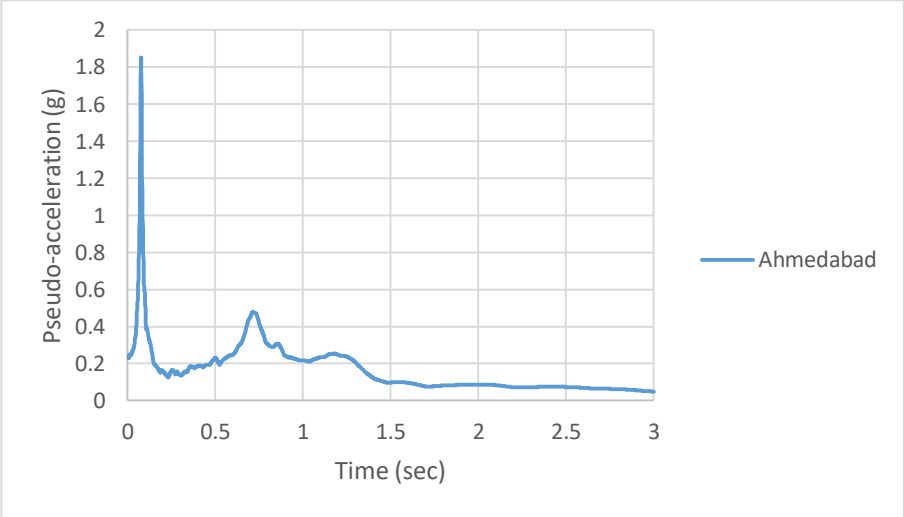

Fig. 1: Site Specific Response Spectrum for Bhuj Earthquake

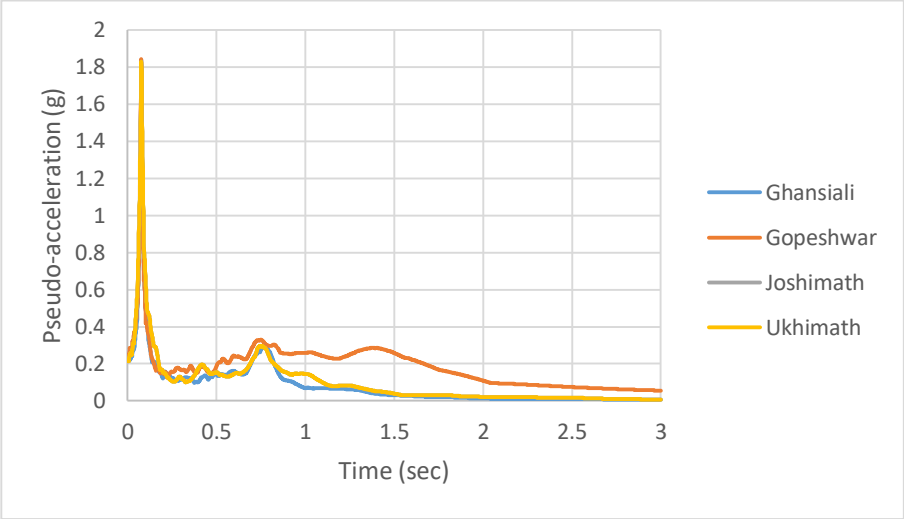

Fig. 2: Site Specific Response Spectrum for Chamoli Earthquake

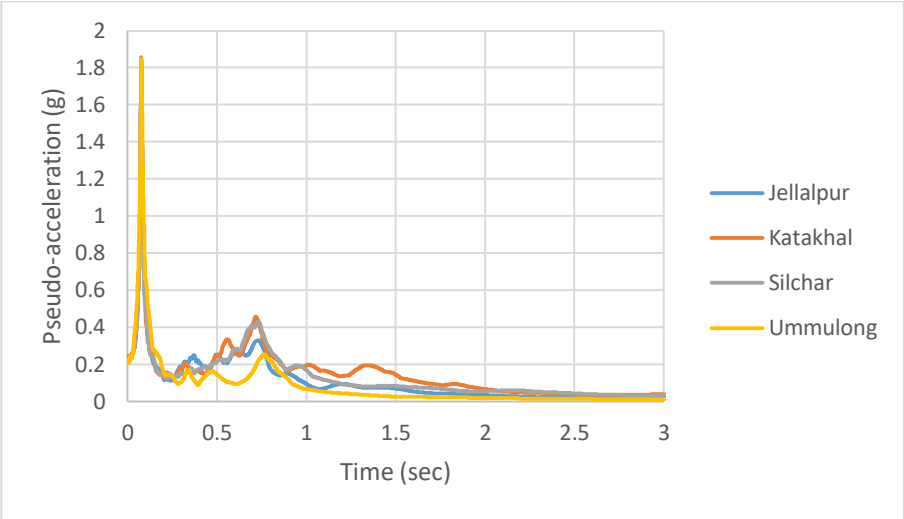

Fig. 3: Site Specific Response Spectrum for India-Burma Border 1997 Earthquake

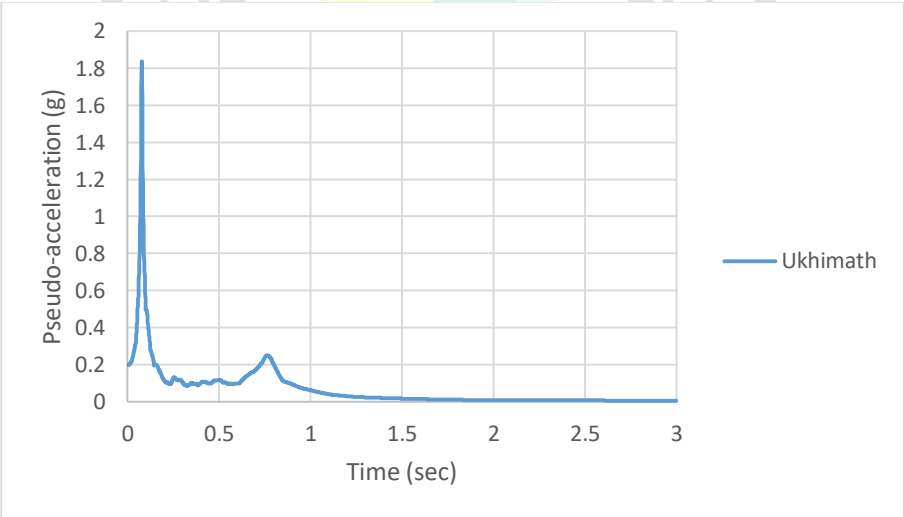

Fig. 4: Site Specific Response Spectrum for Xizang-India Border Earthquake

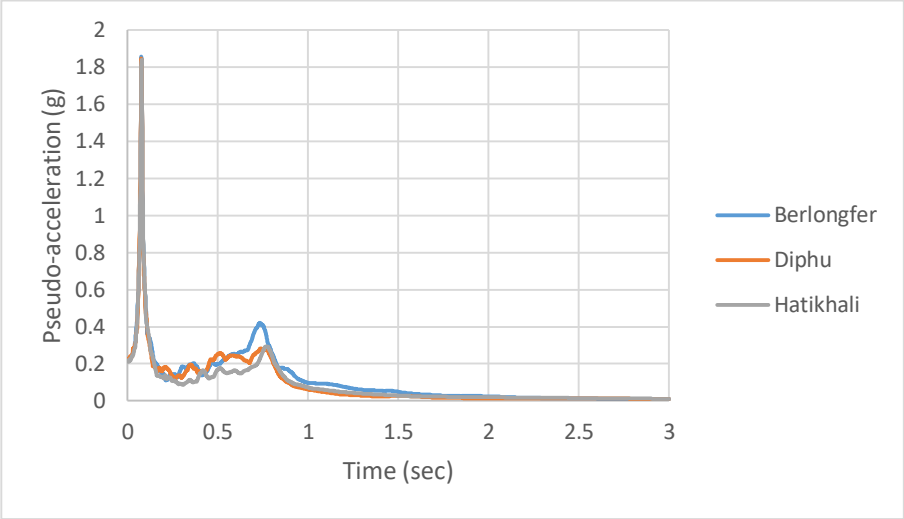

Fig. 5: Site Specific Response Spectrum for India-Burma Border 1995 Earthquake

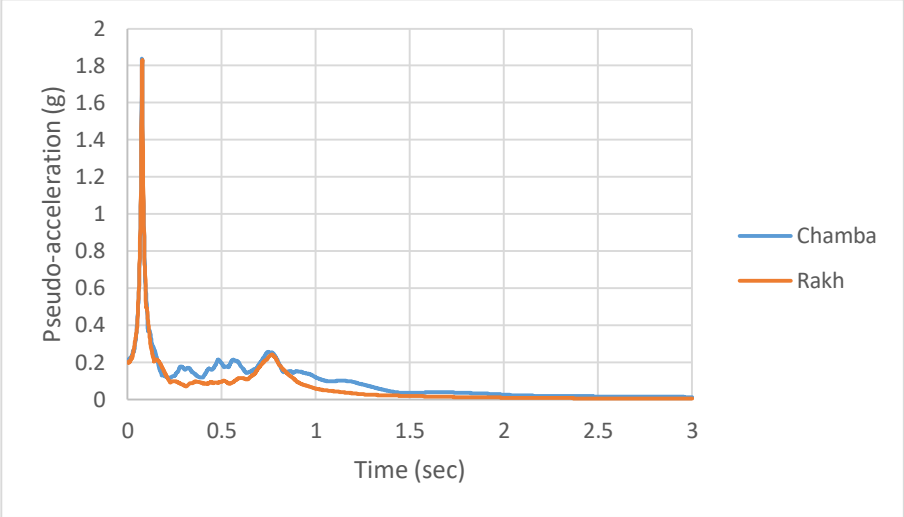

Fig. 6: Site Specific Response Spectrum for Chamba Earthquake

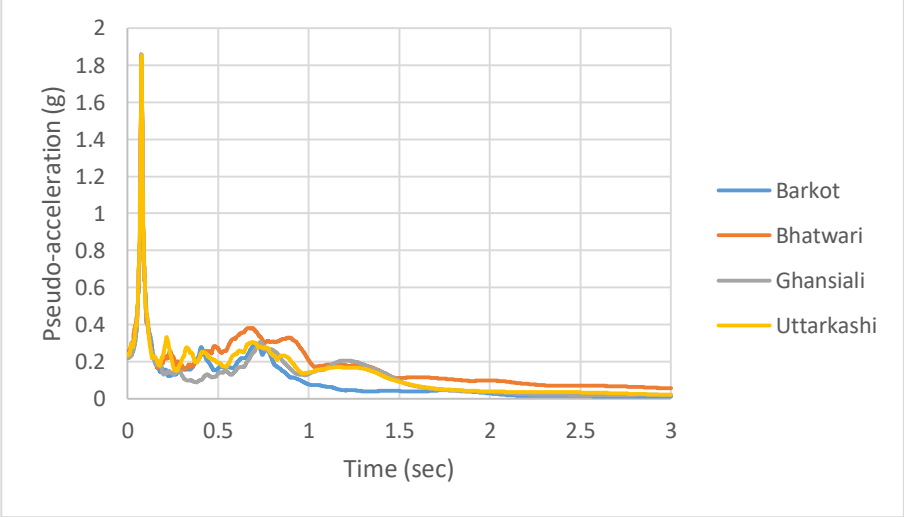

Fig. 7: Site Specific Response Spectrum for Uttarkashi Earthquake

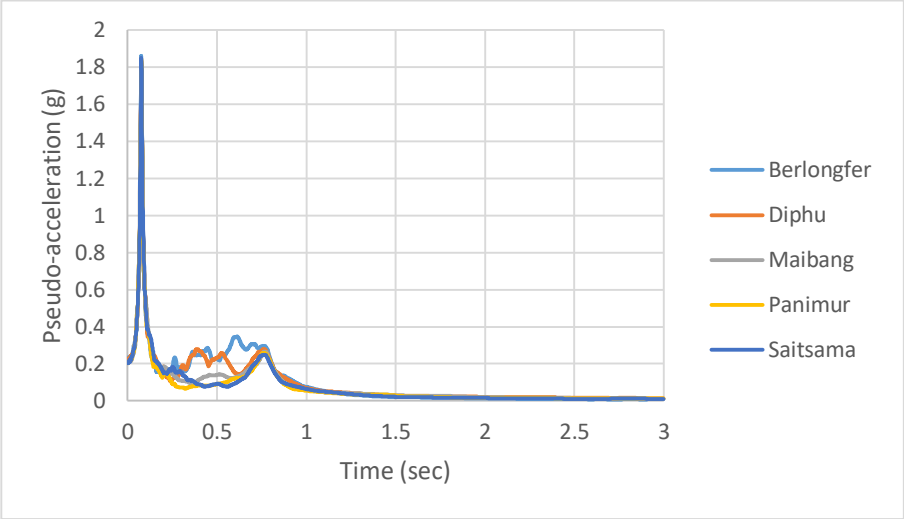

Fig. 8: Site Specific Response Spectrum for India-Burma Border 1990 Earthquake

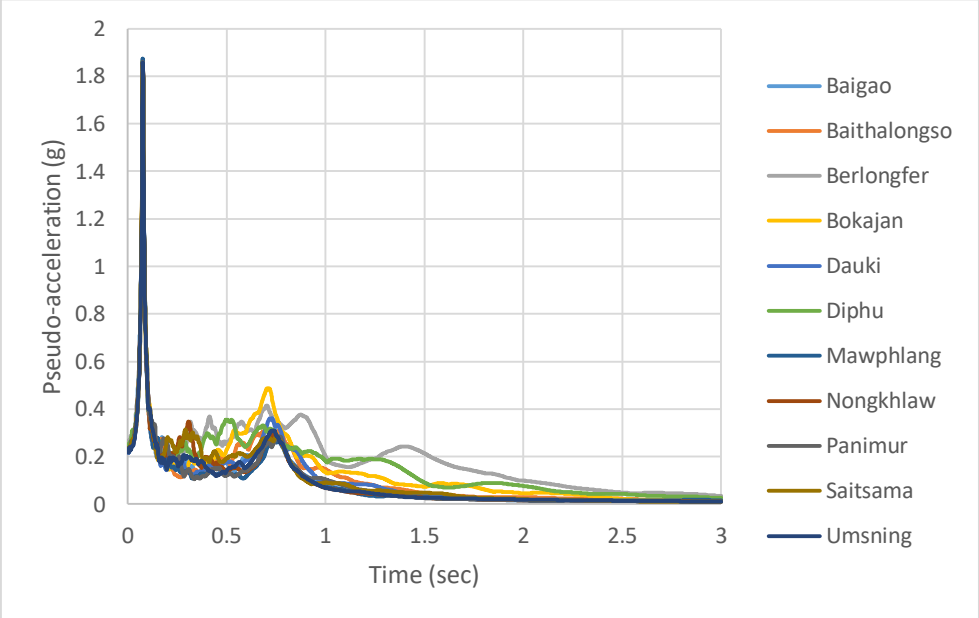

Fig. 9: Site Specific Response Spectrum for India-Burma Border 1988 Earthquake

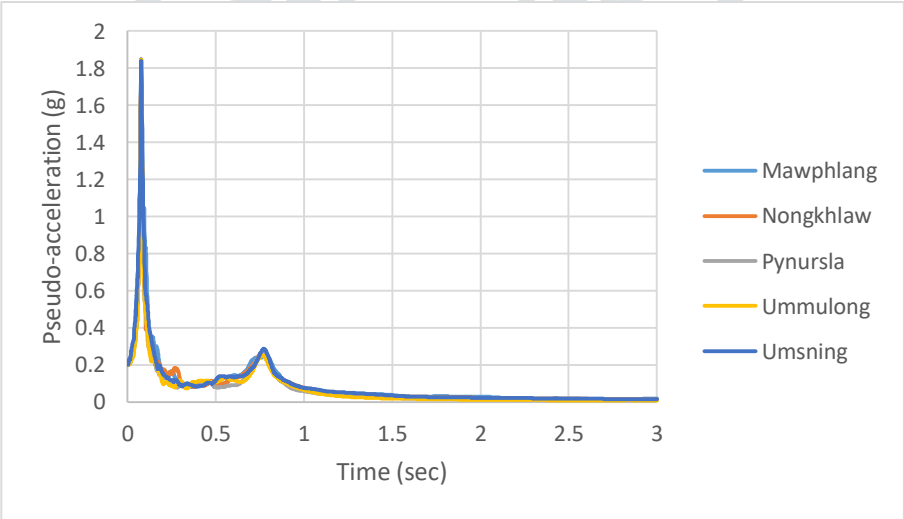

Fig. 10: Site Specific Response Spectrum for India-Bangladesh Border 1988 Earthquake

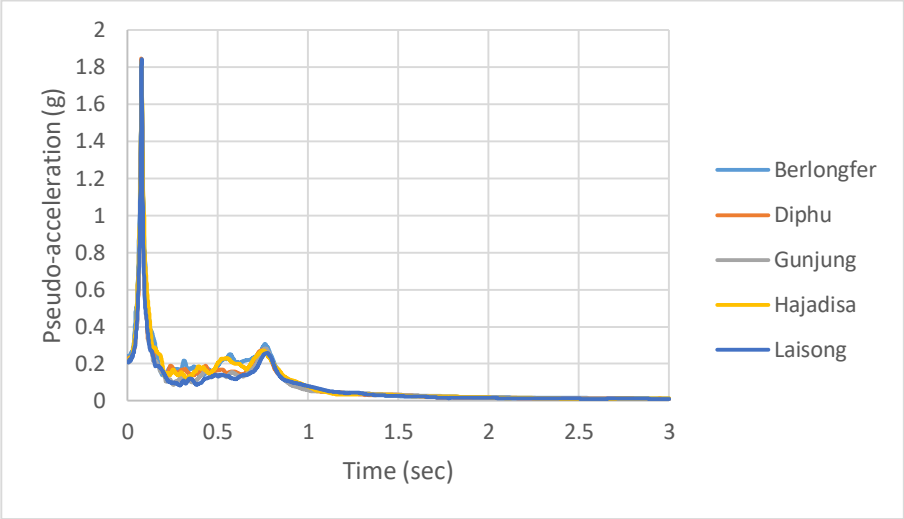

Fig. 11: Site Specific Response Spectrum for India-Burma Border 1987 Earthquake

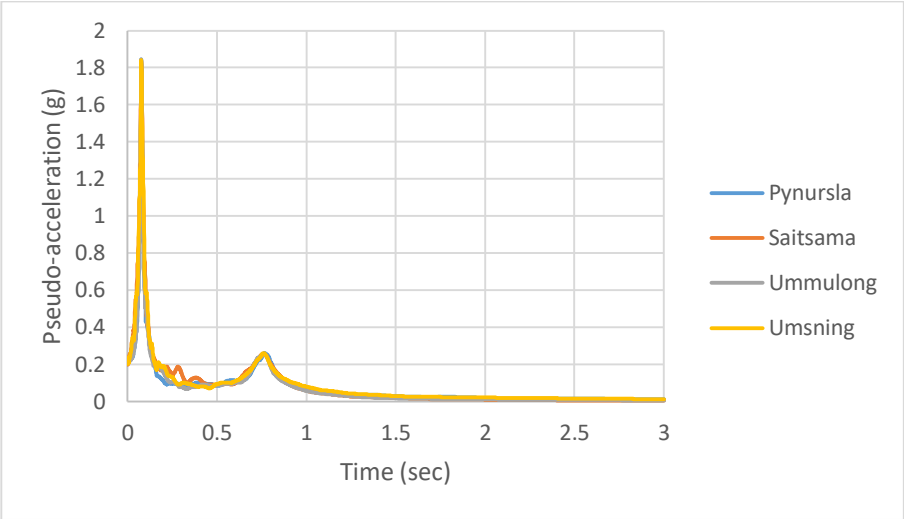

Fig. 12: Site Specific Response Spectrum for NE-India Earthquake

V. Specifications of the Model

Specifications of the model are as follows:

- Number of Storey : 10
- Storey height : 3 m
- Live load : i. 4.0 kN/m^2 at typical floor
  ii. 1.5 kN/m^2 on terrace
- Floor finish : 1.0 kN/m^2
- Water proofing : 2.0 kN/m^2
- Terrace finish : 1.0 kN/m^2
- Location : Ahmedabad (i.e., Seismic zone III)
- Type of soil : Type II, Medium as per IS: 1893
- Ground beams : To be provided at 100 mm below G.L.
- Plinth level : 0.6 m
- Walls : 230 mm thick brick masonary walls only at periphery
- Beams : 300 x 600 at all floors
- Secondary beams : 200 x 600
- Columns : i. 500 x 500 at all typical floors
  ii. 600 x 600 below ground level
- Slab : 7500 x 7500, 100 mm thick
- Grade of Concrete : M25 grade, however higher M30 grade concrete is used for central columns up to plinth, in ground floor and in the first floor.
- Grade of Steel : Fe 415

VI. Results for 10 Storey Building

Analysis of 10 storey building according to design spectrum of IS 1893 using ETABS and site specific spectrum of various earthquakes using SIREN and ETABS.

IS 1893

Table 4 shows result of base reactions of 10 storey building according to IS 1893 using ETABS. The base reaction value is 1621.043 kN.

Table 4: Base Reactions according to IS 1893

Sr. No.	Load Case	Base Reaction (kN)
1	EXTP	905.29
2	IS1893_X Max	1621.043

Table 5: Maximum Storey Drift according to IS 1893

Storey	Drift (mm)
10	1.743
9	2.947
8	3.941
7	4.7
6	5.308
5	5.83
4	6.314
3	6.749
2	6.951
1	6.147
Plinth	1.987

Table 5 shows maximum storey drift value is 6.951 mm at 2nd storey.

Table 6: Maximum Storey Displacement according to IS 1893

Storey	Displacement (mm)
10	48.446
9	47.166
8	44.941
7	41.79
6	37.816
5	33.104
4	27.707
3	21.666
2	15.045
1	8.131
Plinth	1.987

Table 6 shows maximum storey displacement value is 48.446 mm at 10th storey.

Site Specific Spectrum of Various Earthquakes

Table 7 shows result of base reactions of 10 storey building using SIREN. Maximum base reaction value is 1460.6876 kN for Chamoli earthquake at Gopeshwar station.

Table 7: Base Reactions using SIREN

Sr. No.	Load Case	Base Reaction (kN)
1	EXTP	905.2896
2	Bangladesh Mawphlang	507.5964
3	BANGLADESH Nongkhlaw	539.0002
4	BANGLADESH Pynursla	506.2849
5	BANGLADESH Ummulong	455.3894
6	BANGLADESH Umsning	529.7494
7	BHUJ Ahmedabad	1394.338
8	BURMA_87 Berlongfer	580.9126
9	BURMA_87 Diphu	550.3991
10	BURMA_87 Gunjun	532.3455
11	BURMA_87 Hajadisa	554.9831
12	BURMA_87 Laisong	474.3761
13	BURMA_88 Baigao	638.4261
14	BURMA_88 Baithalongso	649.7501
15	BURMA_88 Berlongfer	1234.899
16	BURMA_88 Bokajan	961.2408
17	BURMA_88 Dauki	670.5834
26	BURMA_90 Maibang	500.9682
27	BURMA_90 Panimur	508.8088
28	BURMA_90 Saitsama	484.7533
29	BURMA_95 Berlongfer	791.8581
30	BURMA_95 Diphu	569.7393
31	BURMA_95 Hatikhali	530.5547
32	BURMA_97 Jellapur	702.1864
33	BURMA_97 Katakhal	1009.977
34	BURMA_97 Silchar	1115.981
35	BURMA_97 Ummulong	495.0878
36	CHAMBA Chamba	551.7337
37	CHAMBA Rakh	412.075
38	CHAMOLI Ghansiali	517.69
39	CHAMOLI Gopeshwar	1460.6876
40	CHAMOLI Joshimath	631.9018
41	CHAMOLI Ukhimath	631.9018
42	NE Pynursla	471.2929

18	BURMA_88 Diphu	948.9503
19	BURMA_88 Mawphlang	548.8267
20	BURMA_88 Nongkhlaw	607.9141
21	BURMA_88 Panimur	539.5458
22	BURMA_88 Saitsama	599.8102
23	BURMA_88 Umsning	626.5377
24	BURMA_90 Berlongfer	581.4079
25	BURMA_90 Diphu	595.3388

43	NE Saitsama	462.8545
44	NE Ummulong	466.1436
45	NE Umsning	512.6327
46	UTTARKASHI Barkot	515.5711
47	UTTARKASHI Bhatwari	1305.083
48	UTTARKASHI Ghansiali	662.1994
49	UTTARKASHI Uttarkashi	778.916
50	XIZANG-INDIA Ukhimath	432.3788

Table 8: Maximum Storey Drift using SIREN

Storey	Drift (mm)
10	1.807
9	3.129
8	4.15
7	4.644
6	4.84
5	5.173

Storey	Drift (mm)
4	5.556
3	6.008
2	6.261
1	5.548
Plinth	1.792

Table 8 shows maximum storey drift of 10 storey building using SIREN. The value is 6.261 mm at 2nd storey.

Table 9: Maximum Storey Displacement using SIREN

Storey	Displacement (mm)
10	43.131
9	41.963
8	39.935
7	37.098
6	33.591
5	29.496

Storey	Displacement (mm)
4	24.81
3	19.497
2	13.575
1	7.337
Plinth	1.792

Table 9 shows maximum storey displacement of 10 storey building using SIREN. The value is 43.131 mm at 10th storey.

VII. Comparison of Results

Table 10 shows comparison of results of design spectrum of IS 1893 and site specific spectrum.

Table 10: Comparison of Results

Parameter	Comparison		Difference (%)
	IS 1893	Site Specific Spectrum	
Base Reaction (kN)	1621.043	1460.6876	9.892
Maximum Storey Drift at 2nd Storey (mm)	6.951	6.261	9.926
Maximum Storey Displacement (mm)	48.446	43.131	10.970

VIII. Conclusion

Total 12 earthquakes event recorded at 49 stations are studied and response spectrum is generated for all strong ground motions. For Chamoli earthquake at Gopeshwar station, value of base reaction is reduced by 9.892% in site specific spectrum compared to design spectrum of IS 1893. The value of maximum storey drift is reduced by 9.926% in site specific spectrum compared to design spectrum of IS 1893. The value of maximum storey displacement is reduced by 10.970% in site specific spectrum compared to design spectrum of IS 1893. The value of base reaction, storey drift and storey displacement is less for site specific spectrum in compare to IS 1893. So, if structure is design using site specific spectrum, it will be economical.

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