Site Specific Response Spectrum Analysis of Building with Different Shear Wall Position

Dipak K. Jivani and Paresh V. Patel
Department of Civil Engineering, Institute of Technology, Nirma University, Ahmedabad 382481

***Abstract*—Shear walls have been the most common structural systems used in building structures to resist horizontal forces caused by wind or earthquakes. The shear walls tend to be laterally much stiffer than the moment resisting frames. The extent to which a wall will contribute to the resistance of earthquake forces depends on its geometric configuration, orientation and location within the plan of a building. The seismic forces on multi storeyed building depend on peak ground acceleration and time period of building. Peak ground acceleration depends on soil conditions on which building is resting and time period of building depends on its structural planning. Therefore to select an efficient structural system for better performance during earthquake site conditions and structural planning should be considered.**

In this paper site specific response spectrum analysis of multistorey shear wall buildings with different positions of shear wall is presented. Symmetrical shear wall building with different positioning of shear walls are taken. 10, 15, 20, 25 and 30 storey buildings are considered for study purpose. For site specific response spectrum analysis, response spectra are developed at various sites of Ahmedabad. One dimensional equivalent linear approach based software ProSHAKE is used for development of response spectrum. Based on the acceleration time history recorded at passport office building of Ahmedabad on 26th January 2001 Bhuj earthquake, response spectra are developed at various sites. Comparisons between site specific response spectra and standard response spectra given in IS 1893:2002 are carried out. ETABS is used for dynamic analysis of shear wall building. The parametric study is made to understand the behavior of different buildings in terms of time period, storey displacement and Base shear of building on various soil sites of Ahmedabad.

***Keywords*—Shear Wall Position, Site Specific Response Spectrum, Time Period, Base Shear**

I. INTRODUCTION

One of the most important aspects in earthquake geotechnical engineering is the evaluation of site specific response to earthquakes. Through site response analyses one can predict ground surface motions for developing design response spectra. For earthquake resistant design of structures, use of spectral acceleration of the site is considered as most important data. Generally most of the structures are designed considering IS: 1893 (Part I)-2002 specified standard response spectrum for different soil types, irrespective of local soil conditions. But, local soil condition has a great influence on seismic motion. Therefore, Site specific ground response analysis is essential for accurate estimation of earthquake forces, which includes characterization of site, selection of input motion, ground response analysis and development of site specific response spectrum.

In the present study, site specific study of various sites of Ahmedabad city is carried out to obtain site specific response spectra. Site specific investigation is necessary as the responses of the soil obtained at various sites due to earthquake are different. The design response spectra obtained for these sites vary from each other. In IS-1893 (Part-I) : 2002, the response spectra for soil sites for 5% damping is given as the standard design acceleration spectrum for calculating the effect of ground motion on response of the structures. Shear walls have been the most common structural systems used in the past for stabilizing building structures against horizontal forces caused by wind or earthquakes. With the advent of reinforced concrete, shear wall systems are widely adopted efficiently for the tallest building structures. In this paper usefulness of shear walls in structural planning of multistory buildings has been presented. Different symmetrical buildings with 10, 15, 20, 25 and 30-storey and with different positioning of shear walls have been taken. The parametric study has been carried out considering the position of the shear wall, the height of the building and site specific response spectrum. Software ProSHAKE and ETABS are used for the present study.

II. METHODS USED FOR SITE SPECIFIC GROUND RESPONSE ANALYSIS

Various methods to carry out Site Specific Ground Response Analysis are one-dimensional, Two-dimensional and Three-dimensional ground response analysis [1].

In present study site specific response spectrum analysis has been carried out using one dimensional equivalent linear ground response analysis. One-dimensional ground response analysis are based on the assumption that the ground surface and all material boundaries below the ground surface are horizontal and response of a soil deposit is caused by seismic waves propagating in the vertical direction below the bedrock. Various factors such as rupture mechanism at the origin of earthquake, propagation of seismic waves through the crust to the top of the bedrock are difficult to quantify and thus complete ground response analysis becomes highly complicated. Therefore, one dimensional ground response analysis is preferred over other analysis methods due to simplicity. The method is based on the lumped mass model of sand deposits resting on rigid base to which seismic motions are applied [2].

III. Ground Response Analysis using ProSHAKE Software

The software ProSHAKE is based on a one-dimensional, equivalent linear seismic ground response analysis of horizontal layered soil deposits. ProSHAKE provides the results of acceleration time history, ground response spectra and depth plots of various sites [3]. Site specific ground response analysis of following sites is performed:

- Indian Institute of Management (I.I.M.) Site.
- Maninagar-Sukhipara Site.
- Passport Office Site.
- Nirma Institute of technology (N.I.T) Site.
- Thaltej site.

The ground motion data of Ahmedabad, recorded at Passport Office Site on 26th January 2001, Bhuj earthquake is collected. This ground motion data consist of acceleration time history. Considering soil profile at Passport office these acceleration time histories are transferred at 15 m depth using ProSHAKE software and subsequently they are considered as input motion for various sites of Ahmedabad (Govinda Raju et al. 2004). The data of soil profile of the sites corresponding to various parameters such as number of layers, thickness of each layer, unit weight and shear wave velocity are obtained from borehole data and geophysical tests. The soil profiles for IIM, Maninagar, Passport Office, NIT, and Thaltej sites of Ahmedabad are presented in Tables 1, 2, 3, 4 and 5 [4].

TABLE 1: SOIL PROFILE-IIM SITE

Layer No	Material Name	Thick.(m)	Vs(m/sec)
1	Brown clayey sand	1	190
2	Brown clayey sand	1.5	300
3	Brown clayey sand	0.2	300
4	Very stiff brown clayey silt	1.8	420
5	Medium brown sandy silt	2.5	420
6	Dense brown silty sand	1.5	350
7	Dense brown silty sand	1.5	350
8	Dense brown silty sand	1	190
9	Dense brown silty sand	1.5	190
10	Dense brown silty sand	2.5	250
11	Hard brown clayey silt with sand kankar	1.5	330
12	Hard brown clayey silt with sand kankar	1	330
13	Hard brown clayey silt with sand kankar	2.5	360
14	Hard brown clayey silt with sand kankar	3	400

TABLE 2: SOIL PROFILE- MANINAGAR SUKHIPARA SITE

Layer No	Material Name	Thick. (m)	Vs (m/sec)
1	Yellow clayey silt	1.00	210
2	Yellow clayey silt with sand	1.00	210
3	Yellow clayey silt with sand	0.70	210
4	Yellow silty sand	0.30	210
5	Yellow silty sand	1.00	240
6	Yellow silty sand	1.00	240
7	Yellow clayey silt with sand	1.00	280
8	Yellow clayey silt with sand	1.25	280
9	Yellow silt with fine sand	2.75	310
10	Yellow silt with fine sand	2.50	330
11	Yellow silt with fine sand	1.50	400

TABLE 3: SOIL PROFILE-PASSPORT OFFICE SITE

Layer No.	Material Name	Thick. (m)	Vs m/sec
1	Fill up soil	1.7	203
2	Stiff yellow clayey silt sand and kankar	1.4	213
3	Stiff yellow clayey silty sand and less kankar	0.4	223
4	Dense yellow silty sand with little clay	3.2	289
5	Dense yellow medium to fine silty sand	8.3	351

TABLE 4: SOIL PROFILE- N.I.T SITE

Layer No	Material Name	Thick. (m)	Vs (m/sec)
1	Yellow Clayey Silt with sand and kankar	2.5	240
2	Yellow Clayey Silt with sand and kankar	2.5	460
3	Medium Stiff Brownish Black Clayey Silt+Sand	2.5	300
4	Medium Stiff Brownish Black Clayey Silt+Sand	2.5	250
5	Medium Stiff Brownish Yellow Clayey Silt with Sand +kankar	2.5	270
6	Medium Stiff Brownish Yellow Clayey Silt with Sand +kankar	2.5	310
7	Medium Stiff Brownish Yellow Clayey Silt with Sand +kankar	2.5	400
8	Medium Stiff Brownish Yellow Clayey Silt with Sand +kankar	2.5	400
9	Stiff Brownish Yellow Clayey Silt with Sand +kankar	2.5	480
10	Stiff Brownish Yellow Clayey Silt with Sand +kankar	2.5	480
11	Stiff Brownish Yellow Clayey Silt with Sand +kankar	2.5	480
12	Stiff Brownish Yellow Clayey Silt with Sand +kankar	2.5	600

TABLE 5: SOIL PROFILE- THALTEJ SITE

Layer No.	*Material Name*	*Thick.(m)*	*Vs m/sec*
1	Dark brownish, fine to medium grained, filled up clayey sand with debris	1	186
2	Dark brownish, fine to very fine grained, silt of intermediate compressibility	0.8	204
3	Yellowish brownish, fine to very fine grained, silt with some gravels	0.7	217
4	Yellowish brownish, fine to very fine grained, silt with occasional gravels	2.3	252
5	Brownish, fine to very fine grained, clayey sand(SC)	2.2	278
6	Brownish, medium grained, silty sand	2	299
7	Brownish, medium grained, silty sand	2	317
8	Brownish, medium grained, silty sand`	2	333
9	Brownish, medium grained, silty sand	2	348

From ground response analysis, acceleration time history on ground and response spectra in longitudinal direction are obtained. Acceleration time history graphs of I.I.M, Maninagar-Sukhipara, Passport Office, NIT and Thaltej sites are shown in Fig. 1. Normalized response spectra at all the five sites are obtained by dividing ordinates of response spectrum by peak ground acceleration. They are further compared with similar plot (Sa/g → Time period) given in IS 1893:2002 (Part-1) and are shown in Fig 2.

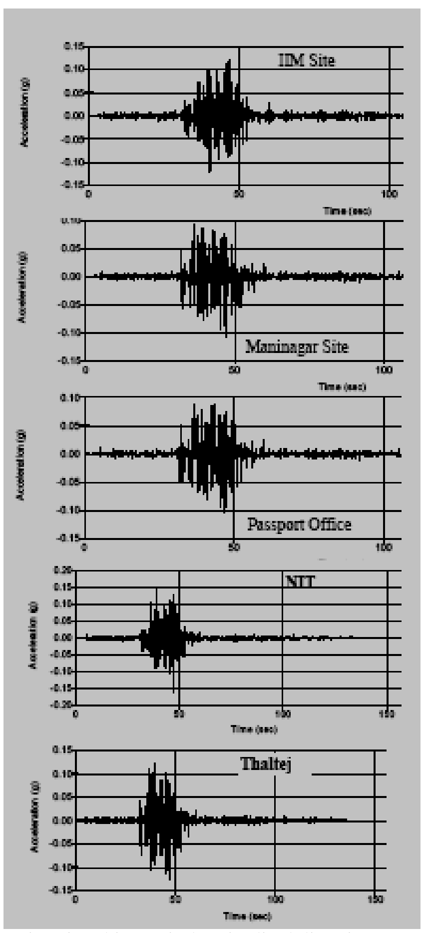


Fig. 1 Acceleration time history in longitudinal direction on ground surface

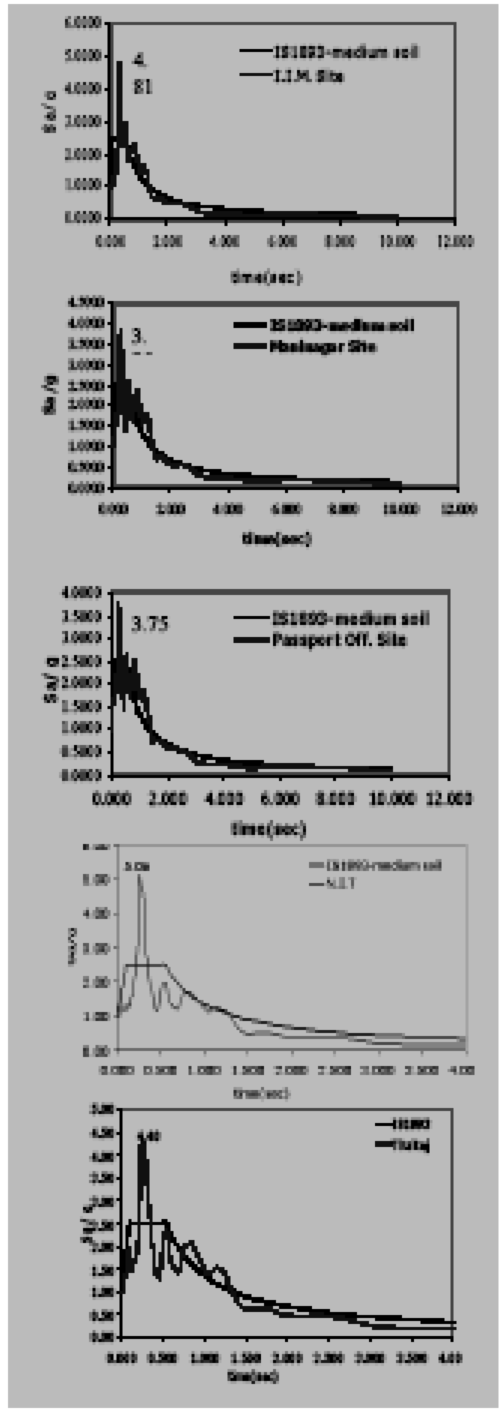


Fig. 2: Comparison of Response Spectrum at Various Sites

IV. SITE SPECIFIC RESPONSE SPECTRUM ANALYSIS

In this section effect of site specific response spectrum on building is discussed.

Structural Data

To understand effect of site specific response spectrum on analysis of multistoried building a shear wall building is considered in this study. When walls are situated in advantageous position in a building, they can form an efficient lateral load resisting system, while simultaneously fulfilling other functional requirement. Following four geometric positions of shear walls, which are central, middle sided, outer sided and corner sided, are shown in figure 3. Further the height is considered for 10, 15, 20, 25 and 30 storey symmetrical buildings. Plan of building is shown in Fig 3. Height of each story is considered as 4 m. The dimensions of various structural elements are given in Table 6. Live load of 4 kN/m^2 is considered in all the buildings.

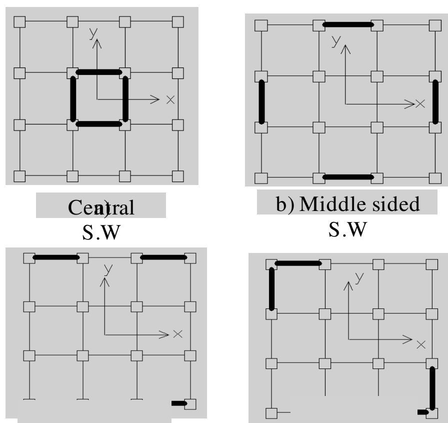


Fig. 3: Geometric positions of shear wall in 10, 15, 20, 25 and 30 storey symmetrical buildings

TABLE 6: SHEAR WALL FRAME BUILDING PROPERTIES

Building Type	*Bay Size m × m*	*Storey Height m*	*Beam Size m × m*	*Column Size m × m*	*Slab Thickness m*	*Shear wall Thickness m*
10-storey	6 × 6	4	0.4 × 0.6	0.55 × 0.55	0.15	0.17
15-storey	6 × 6	4	0.4 × 0.6	0.65 × 0.65	0.15	0.17
20-storey	6 × 6	4	0.4 × 0.6	0.75 × 0.75	0.15	0.20
25-storey	6 × 6	4	0.4 × 0.6	0.9 × 0.9	0.15	0.25
30-storey	6 × 6	4	0.4 × 0.6	1 × 1	0.15	0.30

The dynamic analysis of the multi-storey buildings is carried out using ETABS software [5]. The results are obtained in terms of time period, base shear and lateral displacement considering IS 1893 response spectrum [6] and site specific response spectrum.

Time Period

Comparisons of time period obtained from dynamic analysis and as per formula given in IS 1893:2002 are carried out. From these comparisons, it has been observed that IS 1893:2002 gives same time period for a particular building with different positioning of shear wall. It means that there is no effect of shear wall positioning on time period given by IS 1893:2002. While in case of dynamic analysis, it is observed from the Figure 4 that the shear wall position in center for all different high-rise buildings has the minimum time period in their first mode. Eventually it will attract more earthquake forces and it will be the critical case among the other shear wall positions. The maximum time period is observed in the case of buildings with the shear wall position at outer side.

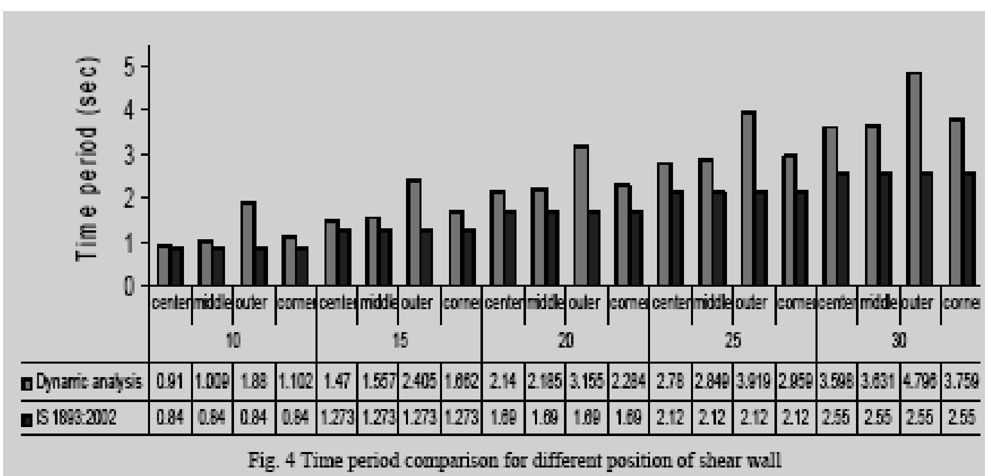


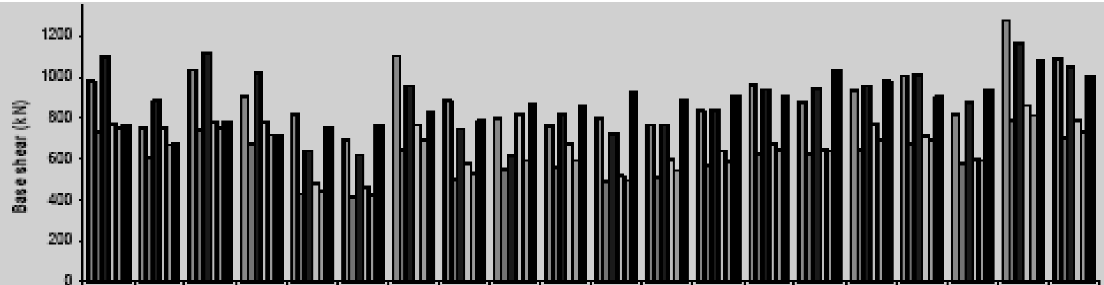
Fig. 4: Time period comparison for different position of shear wall

Base Shear

The total seismic force on building is obtained in terms of base shear. Base shear is obtained for 10, 15, 20, 25 and 30 storied building by site specific response spectrum analyses. Comparisons of base shear in different shear wall position are carried out in X-direction considering site specific response spectra and IS 1893 response spectrum, the same is presented in Figure 5.

V. RESULTS AND DISCUSSIOS

Site specific response analysis for five sites of Ahmedabad city is carried out using ProSHAKE software. From the available data of sub-soil strata and input motion of acceleration time history recorded during Bhuj earthquake of 26th January 2001, response spectra for five sites are obtained. Comparison of response spectrum plot for



	10				15				20				25				30			
	center	middle	outer	corner	center	middle	outer	corner	center	middle	outer	corner	center	middle	outer	corner	center	middle	outer	corner
IM	978.15	751.52	1033.1	905.11	818.98	687.6	1102.1	879.54	802.59	756.73	799.11	768.58	833.71	964.62	874.78	928.54	1010.1	819.76	1274.7	1088.7
Maninagar	730.23	603.67	736.88	678.46	426.46	411	649.11	503.25	552.68	555.69	486.69	513.19	564.08	627.07	629.09	646.82	674.63	582.25	785.01	703.35
Passport	1095.1	885.99	1114.5	1018.6	638.78	620.36	961.05	746.35	612.88	822.99	725.01	763.18	833.74	935.41	944.55	960.8	1014.3	873.58	1167.8	1047.4
NIT	770.64	753.83	775.93	782.69	486.2	462.58	768.94	580.1	820.76	678.45	516.35	597.97	643.93	677.95	647.5	772.95	707.08	602.46	860.77	787.91
Thaltej	752.99	667.62	753.22	714.35	442.39	423.26	689.12	531.77	592.39	593.48	498.22	543.94	586.85	647.33	638.06	688.21	689.76	590.48	811.45	730.31
IS1893	762.92	679.19	779.71	716.53	750	766.76	824.67	789.15	868.34	858.36	921.2	883.14	908.96	907.05	1028.2	981.55	902.93	934.61	1072.9	1001.8

Fig. 5 Comparison of Base shear for different SW position

longitudinal direction for above sites is shown in Figure. 2. From comparison of normalized response spectra, it is found that IS 1893 response spectrum is having lower values for structure having lower time periods and higher values for structure having higher time periods compared to site specific response spectrum. This affects base shear of multistoried buildings and design forces in shear walled building. The parametric study is carried out for different shear wall position which includes comparison of time period, storey displacements, and Base shear of building for different sites. Results have been presented in graphical form to understand the behavior of building with increasing storey height. The study highlights the importance of site specific response spectrum analysis of buildings.

VI. Conclusions

From the above study the following conclusions can be made

- Acceleration time histories on ground and response spectra are influenced by local sub soil characteristics.
- There is no effect of shear wall positioning on time period specified by IS 1893:2002. Dynamic analysis of the R.C.C. shear wall framed structures gives higher time period as compared to the time period obtained from formula of IS:1893-2002 (Part-1). Center shear wall position gives less time period, while outer sided shear wall building gives higher time period.
- IS 1893-2002 gives lower value of base shear for 10, 15 storey and 30 storey building in comparison to site specific response spectrum. While IS 1893-2002 gives higher value of base shear for 20 and 25 storey buildings in comparison to site specific response spectrum.
- In most of cases outer shear wall positioning in building gives higher value of Base shear. While, middle side position gives lower value of Base shear.

VII. Acknowledgements

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