Estimation of Seismic Force in Shear Walled Building Using Site Specific Response Spectrum

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Earthquakes are major natural disasters and increased seismic activity has attained greater importance for analysis of building considering seismic forces. Dynamic analysis is generally believed to provide the most realistic predictions of structural response induced by earthquake ground motions. The forces on building depend on peak ground acceleration and time period of building. Subsoil condition is responsible for the amplification of ground motion and amplification may increase or decrease the value of spectral acceleration coefficient. So, analysis using code specified response spectra may underestimate or overestimate seismic forces. An attempt has been made in this work to study the effect of site specific response spectrum on estimation of seismic forces on shear wall building. For site specific response spectrum analysis, response spectra are developed at seven sites of Ahmedabad. One dimensional equivalent linear approach based software ProSHAKE is used for development of response spectrum. Acceleration time history recorded at passport office building of Ahmedabad on 26th January 2001 Bhuj earthquake is considered as an input motion. The response of different multi–storied regular shear wall frame structures on various sites are obtained in terms of base shear and are compared with that obtained using IS 1893 specifications.

Introduction

Earthquakes are major natural disasters, responsible for loss of life and damage to property. Prediction of the earthquake is not possible. In this decade, the increased seismic activity, attained greater importance on analysis of structure for seismic forces. The seismic forces depend on peak ground acceleration and time period of structure. In India, during Bhuj earthquake 2001, Ahmedabad experienced a heavy damage in some parts, in spite of its greater distance from epicenter. During an earthquake, there is release of energy, which reaches to the ground surface and to the structures by means of seismic waves. These seismic waves originate from the point of occurrence of the earthquake and travel through bedrock and soil strata below the structure. When these waves travel through the soil profile, their properties such as amplitude, velocity, acceleration, frequency etc. get altered due to various soil parameters. This means that intensity of ground shaking or peak ground acceleration at different sites can be different during a particular seismic event.

Site specific ground response analysis is required to determine the response of a soil deposit to the motion of the bedrock immediate below the soil and also to determine the effect of local soil conditions on amplification of seismic waves. It is also required for estimation of the ground response spectra for future design purposes (Kramer, 1996).

The estimation of strong motion characteristic in terms of peak ground acceleration and spectral ordinates is important for any engineering design. Loading condition is the main input in structural design, which must satisfy certain condition regarding their level and frequency of occurrence during the lifetime of a structure. Generally, various important structures and buildings are designed for seismic forces specified in IS 1893 (Part I): 2002. The response spectra of codal provisions are applicable for general soil conditions but not reflecting local sub soil characteristics. Sub soil condition plays an important role in response of ground surface under specified bed rock motion and thus in development of response spectra for a specific site. For the important structures, response spectrum obtained from site specific ground response analysis is recommended rather than that of code specified response spectrum.

In present paper site specific ground response analysis is carried out for Ahmedabad soil sites. For development of site specific response spectrum ProSHAKE software is used while for dynamic analysis of multistoried wall frame buildings ETABS software is used. ProSHAKE is based on one dimensional geotechnical site response model and ETABS is widely used software for three dimensional structural analysis of buildings.

In highrise structures shear wall is widely used to resist earthquake forces. Earthquake forces produce large displacement, vibration and large stresses in building which leads to building an unsafe and causing discomfort to the occupants. The concrete shear walls are quite stiff in their own plane. Therefore, shear wall frame building of varying no. of storey are considered to understand effect of site specific response spectrum in this paper. Seismic forces in shear wall building is estimated considering site specific response spectrum and are compared with that obtained considering IS 1893 response spectrum.

Site Specific Response Analysis

Site specific ground response analysis is required to determine the response of a soil deposit to the motion of the bedrock immediate below the soil. It is also used for determining the effect of local soil conditions on amplification of seismic waves and hence estimating the ground response spectra. The term site specific is used because as the seismic waves travel from bedrock to the surface, the soil deposits that they pass through change certain characteristics of the waves, such as amplitude and frequency content. Site specific response analysis is considered the most important part as the obtained response spectra of various sites is required for dynamic analysis of the structures. Following are the steps performed to generate site specific response spectrum (Govind Raju et al. 2004).

1. Characterization of Site
2. Selection of input bedrock motions
3. Ground response analysis for specific soil site
4. Site specific response spectra for structural analysis

Characterization of Site

The local characteristics of soil such as shear wave velocity, shear modulus of the soil deposits, unit weight of soil, thickness of soil layers are obtained from the geotechnical and geophysical investigations.

Selection of input bedrock motions

Appropriate rock motions i.e. natural acceleration time histories or synthetic acceleration time histories are selected to represent the design rock motion for the site. For the present study the strong motion recorded at Ahmedabad during 26th January 2001 Bhuj earthquake is selected as input bedrock motions.

Ground response analysis for specific soil site

Evaluation of ground response is one of the most important parts to be carried out for ground response analysis. Ground response analysis is used to predict surface ground motions for development of design response spectra. Ground response analysis are performed for the site specific soil profiles using rock motions as input motion to calculate the time histories at the ground surface and design response spectra.

Site specific response spectra for structural analysis

Response spectra of calculated ground surface motion are statically analyzed to develop the design spectrum for the site. The response spectrum describes the maximum response of a single degree of freedom (SDOF) system to a particular input motion as a function of the natural period and damping ratio of the SDOF system. The response is expressed in terms of acceleration, velocity or displacement is referred as the spectral acceleration (Sa), spectral velocity (Sv), and spectral displacement.

Methods Used for Site Specific Ground Response Analysis

Based on dimensionality Site Specific Ground Response Analysis can be classified as:

- One-dimensional ground resp–onse analysis
- Two-dimensional ground resp–onse analysis
- Three-dimensional ground resp–onse analysis

One-dimensional ground response analysis

This method is widely used for site specific ground response analysis. The methods of one-dimensional ground response analysis are useful for level or gently sloping sites with parallel material boundaries. Such conditions are not uncommon and one-dimensional analysis are widely used in geotechnical earthquake practice. The 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 soil and bedrock are assumed to extend infinitely in all lateral horizontal directions. The second assumption is that inclined incoming seismic rays are reflected to a near-vertical direction, because of decrease in velocities of surface deposits. Therefore the response of the soil deposit is caused by shear waves propagating vertically from the underlying bedrock. During a strong earthquake motion, the stress waves, from the earthquake focus propagate vertically when they arrive at the earth's surface. These vertical ground motions are not as important as horizontal ground motions from the structural design point of view.

A complete ground response analysis should consider various factors such as rupture mechanism at the origin of earthquake, propagation of seismic waves through the crust to the top of the bedrock and are difficult to quantify thus, complete ground response analysis becomes highly complicated. Therefore, one dimensional ground response analysis is preferred over other analysis methods due to simplicity and also it is believed to provide conservative result.

Based on number of techniques available for ground response analysis, one dimensional ground response analysis is carried out using following method

1. Linear analysis
2. Equivalent linear analysis
3. Non–linear analysis

In the present study, ground response analysis is carried out using one dimensional equivalent linear analysis. The method is based on the lumped mass model of the soil layer system connected by linear shear dashpot element.

Ground Response Analysis Using ProSHAKE Software

The effect of local soil conditions on ground response during earthquake is evaluated using computer software ProSHAKE, software based on one-dimensional, equivalent linear seismic ground response analysis. ProSHAKE provides the results of acceleration time history, ground response spectra and depth plots of various sites (Edu Pro.2003). 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
- Bodakdev Site
- Sola Site
- Chandkheda Site

The ground motion data in terms of acceleration time history recorded at Passport office building during the earthquake of 26th January 2001 is used to get acceleration time history and response spectra of the sites. 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.

The data of soil profile of the sites corresponding to various parameters such as number of layers of soil, thickness of each layer, unit weight, shear modulus are obtained from borehole data and geophysical testing. The soil profiles for I.I.M. Maninagar, Passport Office, NIT, Bodakdev, Sola and Chandkheda Site are shown in Tables 1, 2, 3, 4, 5, 6 and 7.

Using ProSHAKE software ground response analysis is performed and various results are obtained. Acceleration time history graphs of I.I.M Site, Maninagar-Sukhipara Site, Passport Office Site, N.I.T Site, Bodakdev Site Sola Site and Chandkheda Site are shown in Figure 1. Normalized response spectra at all the seven 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) as shown in Figure 2.

From ground response analysis various parameters like peak ground acceleration, velocity and displacements are obtained for all the three components of the ground motion. But as the longitudinal direction is critical these parameters are compared for all the seven sites as shown in Table 8.

Table 1: Soil Profile - IIM Site

Layer No.	Material Name	Thickness (m)	Vs m/sec
1	Brown clayey sand	1	190
2	Brown clayey sand	1.5	300
3	Brown clayey sand	2.2	300
4	Very stiff brown clayey silt	1.8	420
5	Medium brown sandy silt	2.5	420
6	Dense brown sandy silt	1.5	350
7	Dense brown sandy silt	1.5	250
8	Dense brown sandy silt	1	190
9	Dense brown sandy silt	1.5	190
10	Dense brown sandy silt	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	1	400
15	Hard brown clayey silt with sand kankar	1	400

Table 2: Soil Profile - Maninagar - Sukhipara Site

Layer No.	Material Name	Thickness (m)	Vs m/sec
1	Yellow clayey silt	1	210
2	Yellow clayey silt with sand	1	210
3	Yellow clayey silt with sand	2.7	210
4	Yellow silty sand	2.3	210
5	Yellow silty sand	1	240
6	Yellow silty sand	1	240
7	Yellow clayey silt with sand	1	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	2.5	330
11	Yellow silt with fine sand	1.5	400
12	Yellow silt with fine sand	1	400
13	Yellow silt with fine sand	Infinite	400

Table 3: Soil Profile - Passport Office Site

Layer No.	Material Name	Thickness (m)	Vs m/sec
1	Fill up soil	1.7	203.14
2	Stiff yellow clayey silt sand and kankar	1.4	213.88
3	Stiff yellow clayey silt sand and kankar	3.4	223.61
4	Dense yellow silty sand with little clay	3.2	269.76
5	Dense yellow medium to fine silty sand	8.3	301.24
6	Dense yellow medium to fine silty sand	Infinite	301.24

Table 4: Soil Profile - N.I.T. Site

Layer No.	Material Name	Thickness (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	480
3	Medium stiff brownish black clayey silt + sand	2.5	380
4	Medium stiff brownish black clayey silt + sand	2.5	250
5	Medium stiff brownish yellow clayey silt + sand	2.5	270
6	Medium stiff brownish yellow clayey silt + sand	2.5	310
7	Medium stiff brownish yellow clayey silt + sand	2.5	480
8	Medium stiff brownish yellow clayey silt + sand	2.5	480
9	Medium stiff brownish yellow clayey silt + sand	2.5	480
10	Medium stiff brownish yellow clayey silt + sand	2.5	480
11	Medium stiff brownish yellow clayey silt + sand	2.5	480
12	Medium stiff brownish yellow clayey silt + sand	2.5	580

Table 5: Soil Profile - Bodakdev Site

Layer No.	Material Name	Thickness (m)	Vs m/sec
1	Loose to medium dense yellow silty sand with kankar	3.1	188.2
2	Medium dense yellow silty sand	1.4	200
3	Medium dense to dense yellow clayey silty with sand	3	247.8
4	Medium dense to yellow clayey silty with sand	2	271.2
5	Medium dense to yellow clayey silty with sand	2	293.9
6	Medium dense to yellow clayey silty with sand	2	311.2
7	Medium dense to yellow clayey silty with sand	1.5	322.6

Table 6: Soil Profile - Sola Site

Layer No.	Material Name	Thickness (m)	Vs m/sec
1	Dark brown clay sand	0.9	214.2
2	Brown fine clay gravel	1.8	245.7
3	Yellowish brown clay gravel	1.1	259.2
4	Brownish fine silt gravel	0.7	266.3
5	Brownish fine silty sand	0.7	273.1
6	Light brown silty sand	0.8	280.5
7	Brownish fine silty sand	2	299.1
8	Brownish fine silty sand	2	314.2
9	Brownish fine silty sand	2	329.3
10	Brownish fine silty sand	3	343.3
11	Brownish fine silty sand	0	343.3

Table 7: Soil Profile - Chandkheda Site

Layer No.	Material Name	Thickness (m)	Vs m/sec
1	Brownish silty sand	2.8	252.3
2	Yellowish Brown Gravel	0.8	263.7
3	Reddish brown clay gravel	3.2	303.1
4	Brownish fine clay sand	0.2	305.3
5	Brownish clay sand	2	325.3
6	Brownish clay sand	2	337.5
7	Brownish clay sand	2	348.1
8	Brownish clay sand	2	357.3
9	Brownish clay sand	0	357.3

Response Spectrum Analysis of Shear Wall Frame Building

This study has been carried out to understand the effect of local soil conditions on response of shear walled building with 10, 15, 20, 25 and 30 storey. Shear walled frame building is chosen for study purpose because shear wall is an efficient way of stiffening the structure. Shear walls have been the most common structural systems used in building to resist horizontal forces caused by earthquakes. The shear wall frame buildings considered are three by three bays with fixed base resting on different sub soil condition. Plan of the shear wall frame building is shown in Figure 3. Story height of building is considered as 4m. The dimension of various structural elements is given in Table 9.

The response spectrum analysis of the multi–storey shear wall frame buildings is carried out

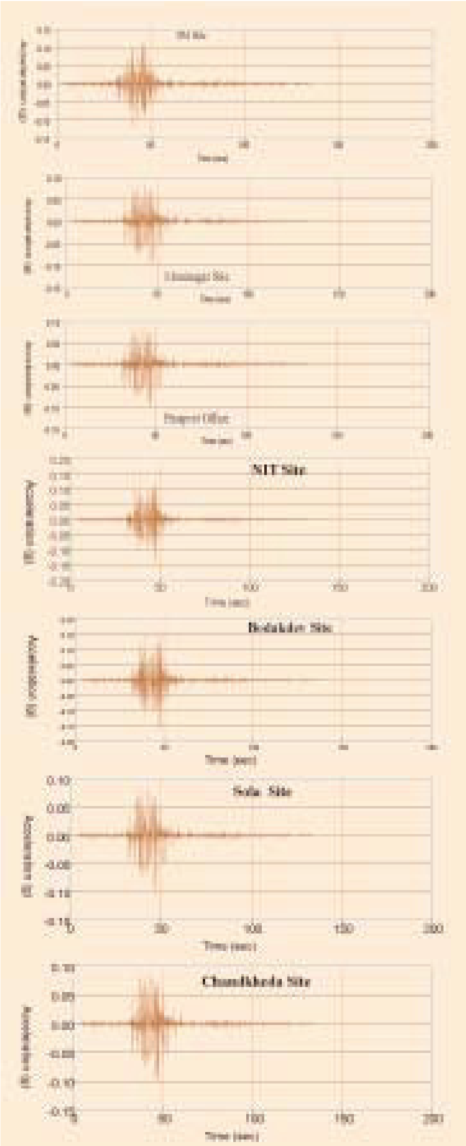


Figure 1: Acceleration time history at various sites

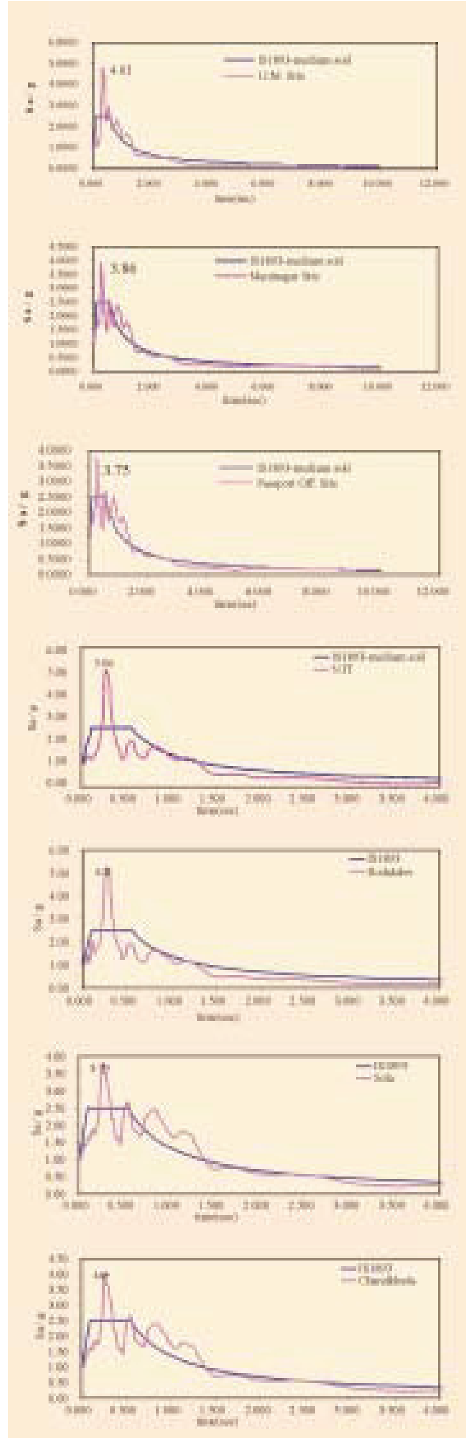
using ETABS software. The response spectra obtained from ProSHAKE for all the seven sites are provided in ETABS for response spectrum analysis (Wilson et al. 2002). Response spectrum analysis is carried out considering the IS 1893:2002 Response Spectrum (medium soil) as well as for the Site Specific Response Spectrum. The response spectrum corresponding to 5% damping is considered which is reasonable for concrete structure.

The time period of all the buildings are obtained using dynamic analysis and are compared with that of empirical formula given in IS1893-2002. The same is shown in Figure 4.

From Response spectrum Analysis for all structures and various results are compared. The comparison of Spectral Acceleration Coefficient and Base Shear considering IS 1893:2002 response spectrum and site specific response spectrum are presented in Figure 5 and 6 respectively.

Results and Discussions

Site specific response spectra for seven sites of Ahmedabad city are developed by performing Site specific ground response analysis. From the available data of sub-soil strata and input motion data of acceleration time history during Bhuj earthquake of 26th January 2001, acceleration time histories on ground and response spectra for the sites are developed. With the help of these plots, peak ground acceleration (g), Spectral acceleration coefficient (Sa) are evaluated. The comparison of site specific response spectrum with that of IS 1893 (medium soil) indicates significant difference for lower time period range. This affects base shear of buildings. Subsequently, site specific response spectrum analysis and time history analysis of multistoried building shows



Fgure 2: Comparison of Response spectrum at various sites

Table 8: Comparison of Various Parameters of Sites					
Parameters	Peak Accln (g)	Peak Velocity	Peak Disp (m)	Spectral Accln (Sa)	Sa/g
I.I.M.	0.129	0.107	0.377	0.62	4.81
Manina-gar	0.112	0.111	0.369	0.43	3.86
Passport Office	0.106	0.113	0.369	0.40	3.75
N.I.T	0.160	0.136	0.369	0.81	5.06
Bodakd-ev	0.174	0.144	0.368	0.91	5.23
Sola	0.108	0.112	0.369	0.41	3.79
Chandk-heda	0.110	0.113	0.369	0.43	3.89

Table 9: Shear Wall Frame Building Properties				
Building Type	Beam Size m×m	Column Size m×m	Slab Thick-ness m	Shear wall Thick-ness m
10-storey	0.4×0.6	0.55×0.55	0.15	0.17
15-storey	0.4×0.6	0.65×0.65	0.15	0.17
20-storey	0.4×0.6	0.75×0.75	0.15	0.20
25-storey	0.4×0.6	0.9×0.9	0.15	0.25
30-storey	0.4×0.6	1×1	0.15	0.30

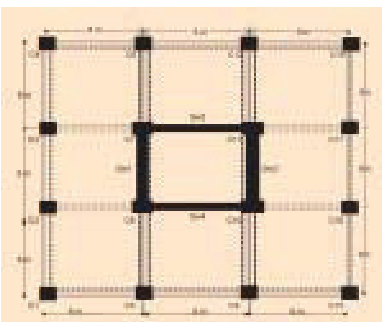
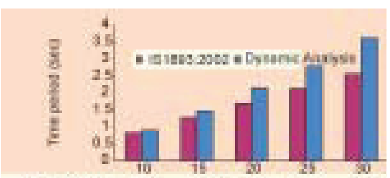


Figure 3: Plan of multistory building



	10	15	20	25	30
IS1893:2002	0.84	1.273	1.69	2.12	2.55
Dynamic Analysis	0.91	1.47	2.14	2.78	3.598

Figure 4: Time period comparison

difference in total seismic force on building. From Figure 5 it is observed that spectral acceleration coefficient is different for various

	10	15	20	25	30
IIM	2.489	1	0.617	0.5	0.238
Maninagar	2.119	1.2	0.545	0.45	0.219
Passport	3.361	1.1	0.867	0.55	0.35
NIT	1.522	0.8	0.382	0.3	0.156
Bodakdev	1.4	0.7	0.4	0.37	0.16
Sola	2.4	1	0.55	0.47	0.23
Chandkheda	2.3	1	0.62	0.55	0.25
IS1893	1.5	1.1	0.8	0.75	0.6

no of storey

Figure 5: Comparison of spectral acceleration coefficient

sites compared to that specified as per IS 1893. From Figure 6 it is observed that total seismic force on building expressed as base shear varies for various sites in comparison of IS 1893. For buildings having 10, 15, and 30 storey site specific response spectra gives higher base shear.

Conclusions

From the above study following conclusions can be made:

- Local sub soil characteristics have considerable effect on acceleration time histories on ground and response spectra
- Time period obtained from Dynamic analysis for all the R.C.C. shear wall framed structures is higher in comparison with the time period obtained from IS1893-2002
- IS 1893-2002 gives lower value of Sa/g coefficient for 10, 15 storey building in comparison to site specific response spectrum. While IS 1893-2002 gives higher value of Sa/g coefficient for 20, 25 and 30 storey buildings in comparison to site specific response spectrum.
- Base Shear obtained considering Site Specific response spectra is governing for 10, 15 and 30 stories buildings while in case of 20 and 25 storey building base shear considering IS 1893-2002 response spectra is governing.

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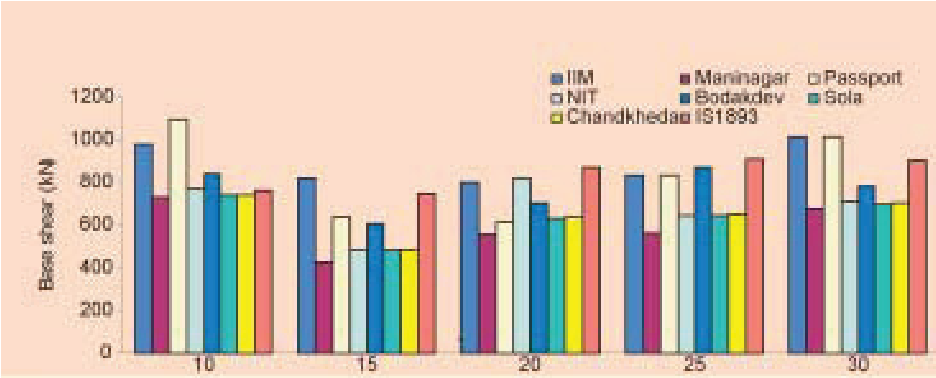

	10	15	20	25	30
IIM	978.15	818.98	802.59	833.71	1010.148
Maninagar	730.225	426.46	552.681	564.08	674.626
Passport	1095.108	638.78	612.882	833.74	1014.312
NIT	770.64	486.2	820.764	643.93	707.079
Bodakdev	840.32	607.8	703.51	868.13	783.15
Sola	741.29	482	631.21	647.61	699
Chandkheda	745.15	484.29	637	653.54	701.09
IS1893	762.92	750	868.335	908.96	902.931

Figure 6: Comparison of Base shear

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