SEISMIC ANALYSIS BY RESPONSE SPECTRUM METHOD IN ETAB

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Abstract- Earthquakes in various regions of the world demonstrated the terrible effects as well as vulnerability of inadequate structures. Many reinforced concrete (RC) framed structures located in zones of higher seismicity of India are built without thinking about the seismic codal provisions. The vulnerability of inadequately created structures belongs to seismic threat to occupants. Reinforced Concrete Frames would be the most often followed structures building methods in India. With growing economy, unavailability and urbanization of horizontal space increasing cost of need and land for agricultural land, high rise sprawling structures are becoming very more suitable in Indian buildings scenario, particularly in urban. With high rise buildings, not simply the structure must get started with gravity loads, but in addition to lateral forces. Lots of critical Indian metropolises fall under high threat seismic zones, thus strengthening of structures for lateral forces is a requirement. In this particular study the target is analyzing the response of a high rise structure to ground motion through the Response Spectrum Analysis. Different versions, that's, bare frame, brace frame as well as shear wall structure frame are considered in ETAB as well as change in time period, base shear, stiffness, storey drifts and top-storey deflection of the structure is observed.

Keywords- Earthquake, ETAB, Seismic Analysis, Response Spectrum Method

I. INTRODUCTION

1.1 Earthquake and Seismicity

An earthquake is the sudden, sometimes violent moment of the earth's surface from the release of energy in the earth's crust. This energy can be generated by a sudden dislocation of segments of the earth crust or by a volcanic eruption or magnetic activity. Most of the earthquakes, however are caused by the dislocations of the crust. An earthquake is also known as quake, tremor. The sudden release of the energy creates seismic waves. The seismicity, seismic or seismic activity of an area refers to the frequency, type and size of earthquakes experienced over a period of time.

1.2. Nature and occurrence of earthquake

When there is sudden localized disturbance in the rocks waves similar to those caused by a stone thrown into a pool spread out through the earth. An earthquake generates the same disturbance. The maximum effect of an earthquake is felt near its source, diminishing its distance from the source. The vibrations felt in the bedrocks are called shocks. Some of the earthquake are followed by the foreshocks and large earthquakes are followed by the aftershocks. Foreshocks are usually interpreted as being caused by the plastic deformation or small ruptures. Aftershocks are usually due to the fresh ruptures or readjustment of fractured rocks. The point of generation of an earthquake is known as focus, center or hypocenter. The point on the earth's surface directly above the focus is called the epicenter. The depth of focus from the epicenter is called the focal depth. Seismic destruction propagates from the focus through a limited region of the surrounding earth's body which is called the focus region.

1.3. Seismic Waves

The large strain energy released during an earthquake travels in the form of seismic waves in all directions through the earth's layers reflecting and refracting at each interface .These waves can be classified as body waves consisting of P waves (which is also known as primary, longitudinal, compressional waves) and S waves (which is known as secondary, transverse, shear waves) and another one is surface waves consisting of love waves and Rayleigh waves.

1.4. Causes of Earthquake

Earthquake are vibrations or oscillations of the ground surface caused by a transient disturbance of the elastic or gravitational equilibrium of the rocks at or beneath the surface of the earth. The disturbance and the consequent movements give rise to elastic impulses or waves. Two theories explains the causes of the earthquake

1.5 Objective

The objectives of present work are as follows:

a) To analyze the building with different ground motions, namely, IS code compatible ground motion.
b) To perform dynamic analysis of the building using response spectrum method in Etab
b) To model building with different lateral stiffness systems and study the change in response of the building
d) To compare and get a better and efficient lateral stiffness system

1.6 Scope

a) This study concerns analysis of reinforced concrete moment resisting open frame, open frame with braces and open frame with shear walls only, using Etab program. The effect of brick infill is ignored.
b) This study involves a theoretical 12 storey building with normal floor loading and no infill walls.in Etab.
c) The comparison of fundamental period, base shear, inter-storey drift and top-storey deflection is done by using Response Spectrum analysis, which is a linear elastic analysis in Etab.

II. LITERATURE SURVEY

Chandurkar, Pajgade et.al (2013) (1) evaluated the result of a 10 storey developing with seismic shear wall structure using ETAB v 9.5. Main focus was comparing the modification of response by modifying the location of shear wall structure in the multi storey structure. 4 models were studied- one to be a bare frame structural program as well as rest three were of dual style structural system. The results were good for shear wall in span that is short at corners. Larger dimension of shear wall was discovered to be inadequate in 10 or even under ten stories. Shear wall is an economical and effective choice for high rise structures. It was noticed that changing roles of shear wall was discovered to attract forces, thus correct positioning of shear wall structure is essential. Major quantity of horizontal forces have been taken by shear wall structure whenever the dimension is big. It was also found that shear walls at substantial locations decreased displacements as a result of earthquake.

Viswanath K.G et.al (2010) (7) investigated the seismic performance of reinforced concrete structures utilizing concentric steel bracing. Evaluation of a 4, 8, 12 as well as 16 storied building in seismic zone IV was completed using Staad Pro software, as per Is actually 1893: 2002 (Part I). The bracing was supplied for peripheral columns, as well as the usefulness of steel bracing distribution across the level of the structure, on the seismic functionality of the structure was studied. It was discovered that lateral displacements of the structures decreased after working with X type bracings. Steel bracings have been discovered to lessen flexure as well as shear demand on the beams as well as columns & transport lateral load by axial load mechanism. Building frames with X- category bracing have been discovered to have minimum bending as than various other kinds of bracing. Steel bracing technique was discovered to be a much better option for seismic retrofitting because they don't increase the entire mass of the structure considerably.

Chavan, Jadhav et.al (2014) (2) studied seismic evaluation of reinforced concrete with various bracing plans by equivalent fixed technique through the Staad Pro. Software. The plans considered were diagonal, V type, inverted X-type and V-type. It was noticed that lateral displacement reduced by fifty % to sixty % and maximum displacement reduced by utilizing X type bracing. Base shear of the structure was also found to boost from the bare frame, by using of X type bracing, indicating increased stiffness.

Esmaili et al. (2008) (3) analyzed the structural element of a fifty six stories high tower, located in an impressive seismic zone in Tehran. Seismic evaluation of the structure was done by nonlinear dynamic analysis. The current building had primary wall space and the side walls of it’s as shear walls, attached to the primary wall structure by coupling of beams. The conclusion was considering the time dependency of concrete. Steel bracing product must be supplied for energy absorption for ductility, but axial load is able to have undesirable impact on the performance of theirs. It's both economically and conceptually unacceptable to make use of shear wall structure as each gravity and bracing technique. Confinement of concrete in shear wall space is option that is good for offering stability and ductility.

Akbari et al. (2015)(4) assessed seismic vulnerability of steel X braced as well as chevron braced Reinforced Concrete by developing analytical fragility curve. Study of different parameters as level of the frame, the p delta impact as well as the portion of bottom shear just for the bracing technique was completed. For a certain created base shear, steel braced RC dual methods have very low injury probability as well as bigger capacity than unbraced phone system. Combination of more potent bracing and weaker frame cuts down on the damage probability on the whole system. Irrespective of height of the frame, Chevron braces are definitely more powerful than X type bracing. Just in case of X type bracing technique, it's far better to distribute foundation shear consistently between the brackets and also the RC frame, whereas in case of Chevron braced method it's acceptable to allot larger worth of share of base shear on the brackets.

Kappos, Manafpour et.al (2000)(5) presented brand new methodology for seismic design of RC developing based upon achievable partial inelastic type of the framework as well as performance requirements for 2 unique limit states. The procedure is developed to a format which may be incorporated with design codes as Eurocode eight. Time-History (Nonlinear dynamic) analysis as well as Pushover analysis (Nonlinear Static analysis) have been investigated. The adopted technique confirmed better seismic performance than regular code procedure, at minimum in case of typical RC frame building. It was discovered that behavior under "life safety" was simpler to manage than under serviceability earthquake due to the adoption of performance requirements affecting ductility needs of users for "life safety" earthquake.

Yamada et al.(2015) (6) studied, experimentally and also analytically, deformation & fracture qualities of lateral load resisting systems shear wall structure for RC frame and steel bracing for metal multi storey frame below earthquake, since versions having three various spans along with three, six as well as nine storeys. Deformations as well as facture outcomes for all of the 3 cases are compared and differences are clarified by normalization of suggested horizontal resisting proportions.

S.S. Patil et al.2013 (7) presented seismic evaluation of excessive rise building by using various lateral load resisting system which are one) bare frame, 2) brace frame, three) shear wall structure frame. This analysis is completed with Response Spectrum Method, and utilizing STAAD Pro application. Test outcome is based on parameters as base shear, story deflection and story drift. They realized that shear wall design provides a lesser amount of story deflection as well as story drift compared to bare frame and braced frame.

Hassaballa A.E. et al. (2013)(8) eight studied the seismic evaluation of a RC developing, and investigate the functionality of existing construction in case subjected to seismic loads. This particular building frame was examined by Response Spectrum Method as well as frame is computed via STAAD Pro application. For seismic evaluation of multistory structure they used static load as well as seismic load and get outcome which design based on reaction spectrum technique necessary large dimension of to resist huge displacement. And realized that drift resulting from nodal displacement as a result of mix of seismic loads and static load had been approximately two to three times the allowable drifts.

Mindaye et al, (2016)(9) nine analyzed the seismic effect of noncommercial G ten RC frame development is examined by the linear evaluation methods of equivalent fixed lateral forces as well as Response spectrum technique using ETAB primary 2015 software as per Is actually 1893:2002 part1. Various result like lateral force, displacement, story drift, overturning moment, base shear are plotted to evaluate the outcome of the dynamic and static analysis. They concluded that powerful story shear is under story shear for those instances. Equivalent static lateral force technique provides higher worth of force as well as moments that make creating uneconomical hence consideration of reaction spectrum strategy is necessary.

Padol S. et al (.2015)(10) studied the seismic evaluation of multistoried RCC construction with mass irregularity at various floor amount are performed. This paper highlights the impact of mass irregularity on various floor in RCC construction with Time History Method as well as analysis is accomplished by ETABS software. They realized that anytime system has various irregularity the impact of earthquake on structure could be reduce through shear wall, base isolation etc.

Patil A. S, et.al (2013) (11) studied nonlinear powerful evaluation of ten storied RCC developing considering various seismic intensities as well as analyzed seismic result of that structure. The structure under consideration is modeled with the aid of Sap 2000 15 software and five distinct time histories are used. The outcome of the research shows comparable variations design in seismic effect like base shear as well as storey displacements and realized that time past is practical technique employed for seismic analysis. It offers a much better check on the safety of system analyzed as well as created.

Bhagwat et al.(2014)(12) studied powerful evaluation of G twelve multistoried practiced RCC developing considering for Bhuj and Koyna earthquake is taken out. The time History Analysis and Response Spectrum Analysis along with seismic reactions of the structure are comparatively studied. The modeled with the aid of ETABS9.7.2 application. 2 time histories (i.e. Koyna and Bhuj) are already utilized to cultivate various criteria (base shear, storey displacement, storey shear), and also realized that, the valuation of base shear for Bhuj earthquake is 49.11 % much more than the Koyna earthquake, and Response Spectrum technique provides fifty % more outcome compared to Time History Analysis.

Dubey et al. (2015) (13)presented design of multistoried irregular construction with twenty accounts and modeled it with software STAAD PRO for seismic zone IV in India, powerful effect of creating under real earthquake, DELINA (ALASKA)2000 are deemed. This particular paper highlights the comparison of Time History Method and Response Spectrum Method. The story displacement effect continues to be acquired with each technique of powerful analysis, and also Concluded that Time History Analysis is discovered to be two to eight % above that of Response Spectrum Analysis in all kind of building i.e. irregular and regular, for excessive rise building it's essential to offer powerful evaluation due to nonlinear distribution of force. Storey displacement is found increased in THM as compared to RSM, and found the starting shear is increased in RSM as opposed THM. Thus it could be realized that time history examination is economically better for designing.

Rampure et al. (2016) (14) studied the powerful time history analysis as well as reaction spectrum evaluation associated with a concrete gravity dam by utilizing STAAD PRO. Finite component strategy is utilized to evaluate the dam along with a concrete gravity dam design is ready in STAAD PRO to do time history analysis and response spectrum evaluation as well as comparison is completed between both these techniques. They concluded that STAAD-PRO is very practical & less challenging for powerful analyses and it offers a computing setting to investigate modeling assumption as well as computational tasks associated with the fixed as well as seismic structural balance of gravity dam. It's essential to evaluate the framework by powerful evaluation of both these technique for below the level of dam 100m and above the height of dam 100m.

Hawaldar et al. (2015) (15)presented G+12 storey developing type with as well as without infill the time history analysis utilized for Koynaearthquake and Bhuj feature it's carried through in ETABS 2013 application. The seismic responses of story displacements, storey drifts are found. Time history plots of base force v/s time as well as roof displacement v/s period for each time history capabilities are compared and also analyzed. They realized the displacement values for bhuj functionality are bigger compared to the displacement value for koyna performance and also those for infill building are under that with no in filled building as well as drift importance of bhuj functionality had been far more in comparison with drifts for koyna function as well as infill drift values are comparatively much less than for without infill drift values for equally time history feature.

III. RESEARCH METHODOLOGY

To gather various types of work on seismic analysis of high-rise structures and increasing lateral stiffness of the system various papers, thesis and research articles were studied thoroughly and referred. The idea behind doing literature review was to collect data and have understanding on different methods and approaches that can be used, to clear understand the software requirement of the project. Literature review was done to have thorough guidelines during the entire project work.

3.1 Data Collection

The earthquake data's were obtained from the college. The earthquakes considered in this work are time history of ground motion as per IS 1893:2002 (Part-I), at particular location.

3.2 Methodology Adopted

As discussed in the scope of the work, the entire work is divided into three parts:

1. Analysis of bare frame
2. Analysis of the braced frames.
3. Analysis of the frame with shear wall

For analysis a 12 stories high building is modeled in Etab as a space frame. The building is does not represent any real existing building. The building is unsymmetrical with the span more along Z direction than along X direction. The building rises up to 42m along Y direction and spans 15m along X direction and 20 m along Z direction .The building is analyzed by Response Spectrum Analysis, which is a linear dynamic analysis. Dynamic Analysis is adopted since it gives better results than static analysis. The specifications of the frame are given in Table 1 and the plan and the model of the building is shown in Fig. 4 and Fig.5 respectively. In the entire course work X and Z are taken as the horizontal axes and Y as the vertical axes.

Table.1. Specifications of the building

Specifications	Data
Storey Height	3.5m
No. of bays along X direction	3
No. of bays along X direction	4
Bay Length along X direction	5m
Bay Length along Z direction	5m

Concrete grade used	M 30
Columns	0.45m X 0.25m
Longitudinal Beams	0.40m X 0.25m
Transverse Beams	0.35m X 0.25m
Slab Thickness	0.1m
Unit Weight of Concrete	25 kN/m3
Live Load	3.5 kN/m3
Zone	IV
Soil Conditions	Hard Soil
Damping Ratio	5%

3.3 Response Spectrum Analysis

Response Spectrum is a linear dynamic analysis. Response spectrum is a plot of the maximum response of a SDOF system to a ground motion versus time period. It is derived from time history analysis of ground motion by taking the maximum response for each time period.

The time periods of the bare frame up to 12^{th} mode calculated from MATLAB program is given below in Table 2.

Table 2 response spectrum analysis

Mode	Time Period (s)
1	2.4297
2	0.8145
3	0.4943
4	0.3592
5	0.286
6	0.2409
7	0.2112
8	0.1909
9	0.1769
10	0.1674
11	0.1613
12	0.1579

As given in IS 1893-2002 (Part-I), fundamental natural time period of a RC building without brick infill is given by

So, by IS code time period of the bare frame = 1.237 s

In Etab, Response Spectrum Analysis is done as follows:

1. After preparing the bare model, seismic definition for IS 1893-2002 was created by giving the required input of time period, zone factor, R factor, etc. Then under seismic definition self-weight and floor weights of 2.5kN/m2 and 3.5 kN/m2 were given.
2. Under Load Definition Earthquake load, Dead load, Live load and various load combinations were created.

3. Under Earthquake load, after assigning self-weight, floor load and live load in X, Y and Z directions, Response Spectra was defined. For Indian Code compatible earthquake already defined IS 1893-2002 is chosen.
4. The Sa/g is the response spectrum values that were taken from the results of MATLAB program for generating Response Spectrum from time history of ground motion of the earthquake considered. The time period and their corresponding acceleration values are given in the tables below.

Table 3. Time period vs. Acceleration

Time Period (s)	**Acceleration= Sa/g**
2.4297	1.61E+00
0.8145	2.31E+00
0.4943	2.14E+00
0.3592	1.47E+00
0.286	2.11E+00
0.2409	1.89E+00
0.2112	1.47E+00
0.1909	1.10E+00
0.1769	1.12E+00
0.1674	9.86E-01
0.1613	8.31E-01
0.1579	7.78E-01

4.The load combinations that were considered were according to IS 1893-2002 (Part-1) and are as follows:
1.5(DL+LL)
1.2 (DL+ LL+EL)
1.2 (DL+ LL-EL)
1.5 (DL+EL)
1.5 (DL-EL) 0.9DL + 1.5 EL 0.9DL -1.5 EL

Modelling of Braced Frame

For braces angle section ISA 60 X 40 X 6 is used. There are four trial locations in the building where braces are placed and analyzed for their effect on lateral stiffness. Braces are modeled as axial force members having pinned end connections. Bracings are of X-type modeled throughout the height of the building. The four locations are as follows:
Location 1: Bracing A- at the exterior side of the frame along X-direction. Location 2: Bracing B- at the exterior side of the frame along Y-direction. Location 3: Bracing AB- at the exterior side of the frame along X and Y-direction. Location 4: Bracing C- at the exterior side of the frame around the corners.
The figures of the models with different locations of braces are given in the tables below:

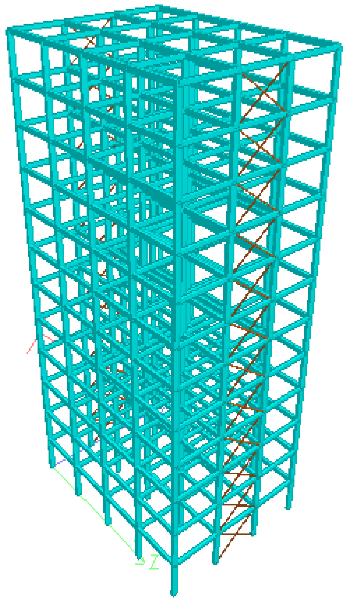


Fig. 01 3D Model of the building with braces at location 1

IV. RESULT AND DISCUSSION

The result is based on the responses of the bare frame model and the changes in the responses after using bracings and shear wall. The results include changes in time periods, base shear, inter-storey drifts and top-storey deflections for ground motions along X and Z direction considered individually. The results of time period, base shear, inter-storey drifts and top- storey deflection for bare frame, braced frame and shear wall frame were then compared with each other and a conclusion was then drawn.

4.1. Comparison of Time Period

In this study it was found that fundamental time period of the bare frame is longer than the time period of the braced frame and frames with shear wall. There is a gradual decrease in time period from bare frame to brace frame to frame with shear wall.

Table 4. Variation of time period

Cases	Time Period (s)
Bare Frame	3.51224
Bracing A	4.01208
Bracing B	3.53179
Bracing AB	3.73164
Bracing C	3.5124
Shear Wall A	3.59052
Shear Wall B	3.36548
Shear Wall AB	2.05164
Shear Wall C	1.70323

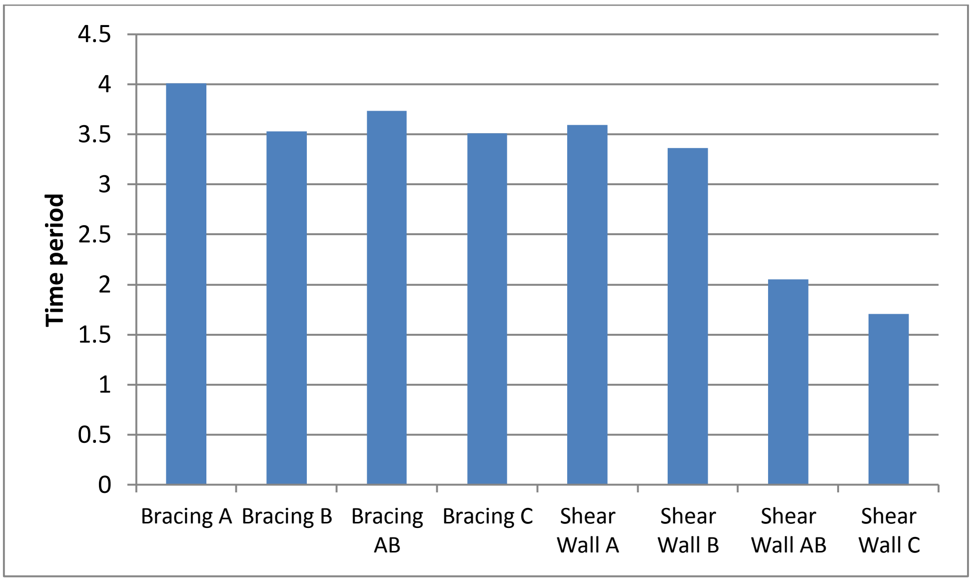


Fig.02 Variation of time periods

4.2 Comparison of Base Shear for ground motion in X- direction

The base shear was found to be increasing from bare frame to braced frame and is even more for frame with shear wall. In case of braced frame highest base shear is found in case of Bracing C in X-direction. In case of shear wall base shear is highest in case of Shear wall C in X-direction. Shear wall B shows the least base shear among all the shear wall cases because in case of Shear Wall B the frame is stiffened only along Y- direction and not along Z.

Table 14 shows the base shear for ground motion in X-direction for all the cases. Fig 7. Shows the variation of the base shear

Table 5. Base shear for ground motion in X-direction

Cases	Base Shear (kN)
Bare Frame	558.65
Case A	678.48
Case B	562.32
Case AB	681.95
Case C	740.62
Shear Wall A	895.7
Shear Wall B	658.36
Shear Wall AB	990.91
Shear Wall C	1227.99

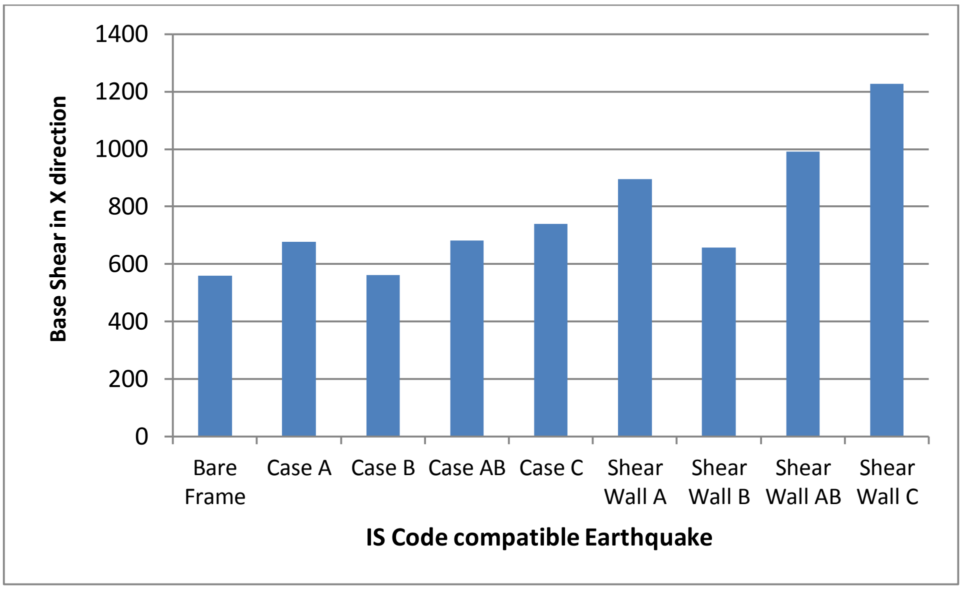


Fig 03. Variation of base shear for ground motion in X- direction

4.3 Comparison of Base Shear for ground motion in Z- direction

The base shear was found to be increasing from bare frame to braced frame and is even more for frame with shear wall. In case of braced frame highest base shear is found in case of Bracing C in Z-direction. In case of shear wall base shear is highest in case of Shear wall C in Z-direction. Shear wall A shows the least base shear among all the shear wall cases because in case of Shear Wall A the frame is stiffened only along X- direction and not along Z.

Table 15 shows the base shear for ground motion in X-direction for all the cases. Fig 8. Shows the variation of the base shear

Table 6. Base shear for ground motion in Z-direction

Cases	Base Shear (kN)
Bare Frame	519.54
Case A	519.36
Case B	514.35
Case AB	511.25
Case C	518.58
Shear Wall A	563.52
Shear Wall B	1145.63
Shear Wall AB	1221.58
Shear Wall C	1310.55

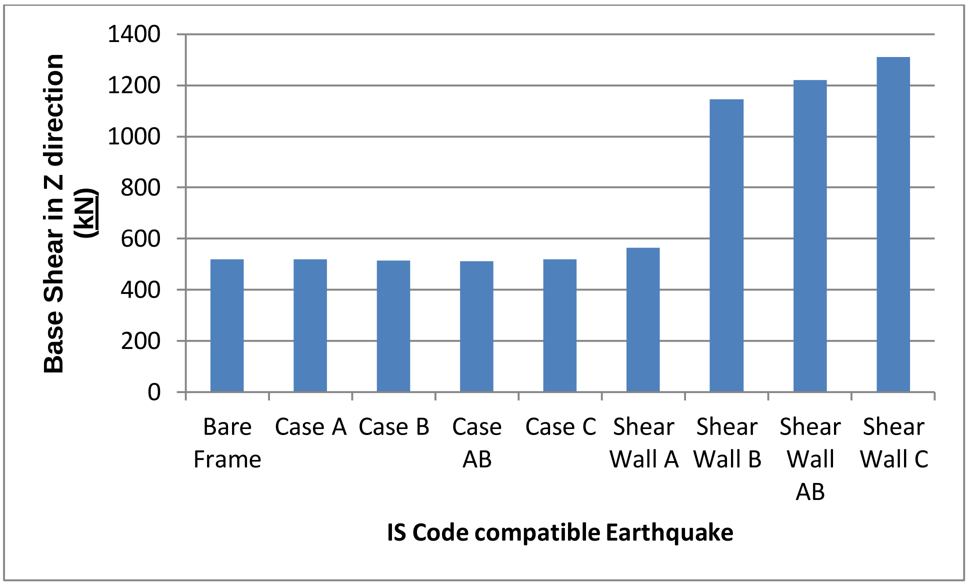


Fig 04. Variation of base shear for ground motion in Z- direction

4.4 Comparison of Inter-Storey Drift for ground motion in X- direction

As per IS 1893-2002 (Part-I) storey drift should be within 0.4% of storey height. For the building considered in this study the safe limit for storey drift is 14mm. Inter- storey drifts in bare frame was found to exceed this limit of 14mm. By using bracings and shear wall in the building the drift is found to be reduced. Inter storey drift decreases remarkably in case of shear walls. For ground motion in X-direction inter-storey drift is minimum in case of Bracing C and Shear Wall C. Shear Wall A shows the least inter- store drift in X-direction than Shear Wall B, because Shear Wall A is along X direction only whereas Shear Wall B is along Z direction only.

Table 16 shows the inter-storey drift for ground motion in Z-direction for all the cases.

Fig 9.Shows the variation of inter-storey drift.

Table 7. Inter-Storey Drift for ground motion in X- direction

Storey	Bare Frame	Bracing A	Bracing B	Bracing AB	Bracing C	Shear Wall A	Shear Wall B	Shear Wall AB	Shear Wall C
1	0	0	0	0	0	0	0	0	0
2	7.923	6.51	7.946	6.498	5.667	3.288	7.882	3.079	2.576
3	13.611	10.441	13.65	10.424	8.938	5.344	14.066	5.912	4.63
4	14.317	10.828	14.361	10.815	9.321	5.716	14.88	6.757	5.099
5	13.722	10.468	13.771	10.465	9.089	5.975	14.34	7.054	5.319
6	12.716	9.862	12.763	9.861	8.653	6.462	13.728	7.291	5.707
7	11.583	9.182	11.626	9.182	8.172	6.697	12.62	7.418	5.892
8	10.424	8.492	10.462	8.49	7.698	6.847	11.309	7.481	6.056
19	9.236	7.774	9.269	7.771	7.205	6.989	9.883	7.46	6.212
10	7.95	6.958	7.977	6.954	6.611	6.915	8.412	7.212	6.168
11	6.484	5.96	6.506	5.965	5.824	6.53	6.681	6.684	5.884
12	4.812	4.739	4.828	4.735	4.791	5.976	5.08	6.054	5.379
13	3.251	3.222	3.522	3.254	3.256	5.214	3.256	5.321	4.256

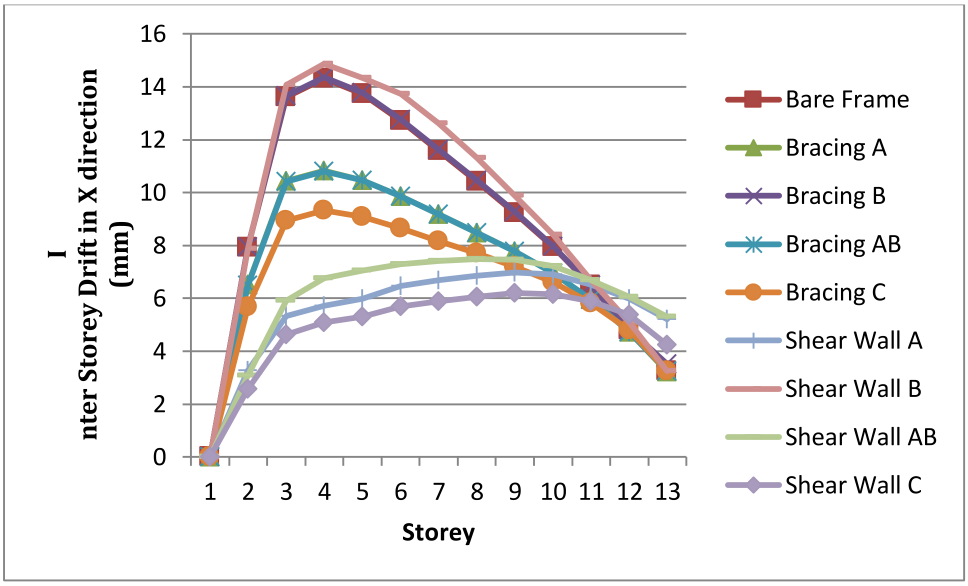


Fig 05. Variation of Inter-Storey Drift for ground motion in X direction

4.5 Comparison of Inter-Storey Drift for ground motion in Z- direction

Inter- storey drifts in bare frame was found to exceed this limit of 14mm. By using bracings it was found that there was no reduction in drift in Z direction but frame with shear wall showed remarkable reduction in the drift. Inter storey drift decreases remarkably in case of shear walls. For ground motion in Z-direction inter-storey drift is minimum in case Shear Wall C. Shear Wall B shows the least inter-store drift in Z- direction than Shear Wall A, because Shear Wall A is along Z direction only whereas Shear Wall A is along X direction only. Table 17 shows the inter-storey drift for ground motion in Z-direction for all the cases. Fig 10. Shows the variation of inter-storey drift.

Table 8. Inter-Storey Drift for ground motion in Z- direction

Storey	Bare Frame	Bracing A	Bracing B	Bracing AB	Bracing C	Shear Wall A	Shear Wall B	Shear Wall AB	Shear Wall C
1	0	0	0	0	0	0	0	0	0
2	12.527	12.483	12.49	12.306	12.484	11.848	4.011	2.695	2.759
3	16.019	15.963	16.021	15.841	15.963	15.675	4.762	4.227	4.213
4	15.531	15.476	16.03	16.393	15.476	15.935	3.82	4.555	4.543
5	14.536	14.485	15.052	15.45	14.485	15.119	3.624	4.784	4.844
6	13.354	13.307	13.392	13.283	13.306	13.939	4.457	5.107	5.308
7	12.114	12.071	12.089	11.962	12.07	12.692	5.341	5.48	5.757
8	10.868	10.828	10.855	10.719	10.828	11.341	5.25	5.814	6.141
9	9.59	9.555	9.573	9.447	9.553	9.933	5.739	6.063	6.462
10	8.2	8.169	8.182	8.068	8.168	8.401	5.752	6.124	6.589
11	6.609	6.584	6.592	6.497	6.583	6.728	5.96	5.913	6.467
12	4.767	4.749	4.755	4.685	4.747	4.959	5.738	5.544	6.132
13	2.756	2.745	2.751	2.713	2.743	3.054	5.139	4.845	5.39

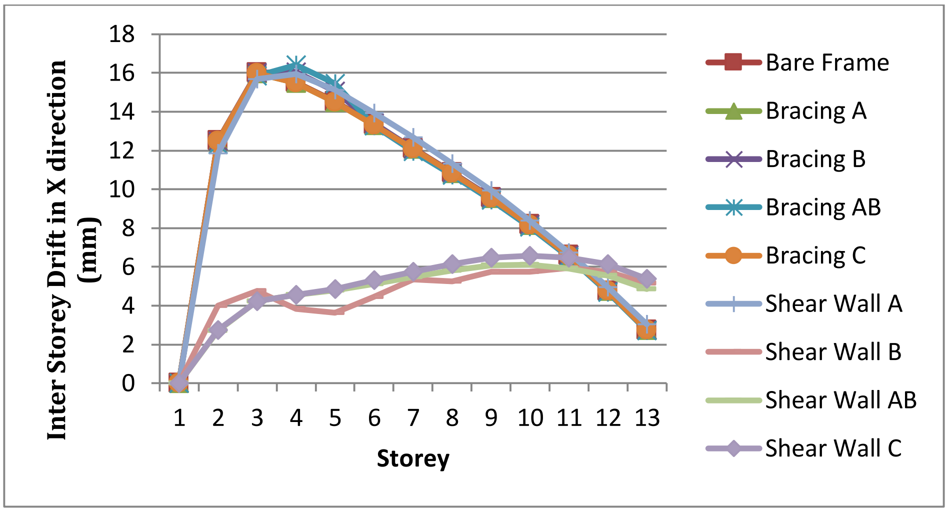


Fig 06. Variation of Inter-Storey Drift for ground motion in Z direction

4.6 Comparison of Top-Storey Deflection for ground motion in X- direction

There is reduction in top-storey deflection in the frame due to bracing and shear wall. Reduction is more in case of Bracing C and Shear Wall C. For ground motion in X- direction Shear Wall B is ineffective since in Shear Wall B case shear wall is present in Z-direction not in X-direction.

Table 18 below shows the top-storey deflection for each case, Fig 11. shows the variation in top-storey deflection in X direction and Fig.12 shows the Etab results for top-storey deflection.

Table 9. Top-Storey Drift for ground motion in X- direction

Cases	Top- Storey Deflection (mm)
Bare Frame	105.876
Bracing A	80.129
Bracing B	84.483
Bracing AB	75.551
Bracing C	54.88
Shear Wall A	108.349
Shear Wall B	56.836
Shear Wall AB	42.696
Shear Wall C	105.876

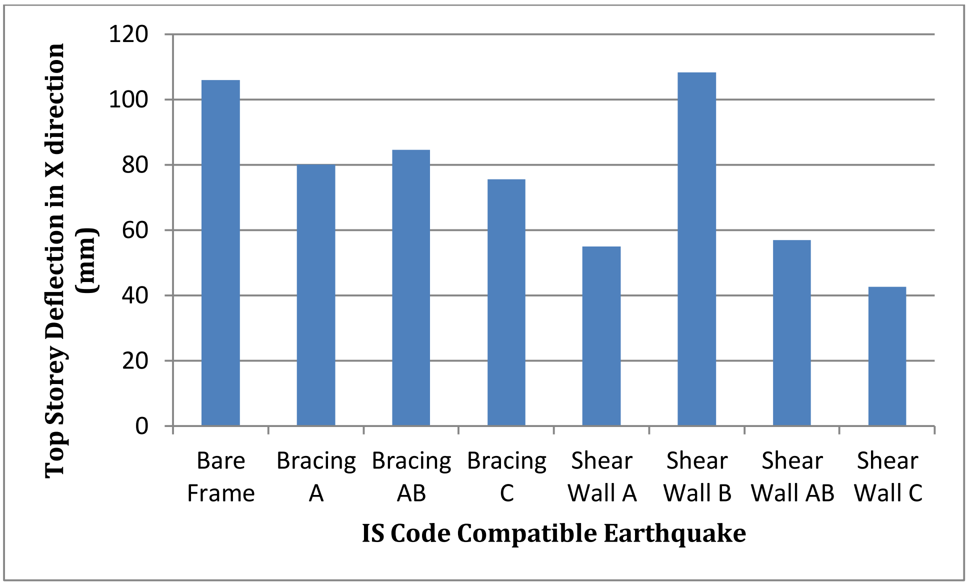
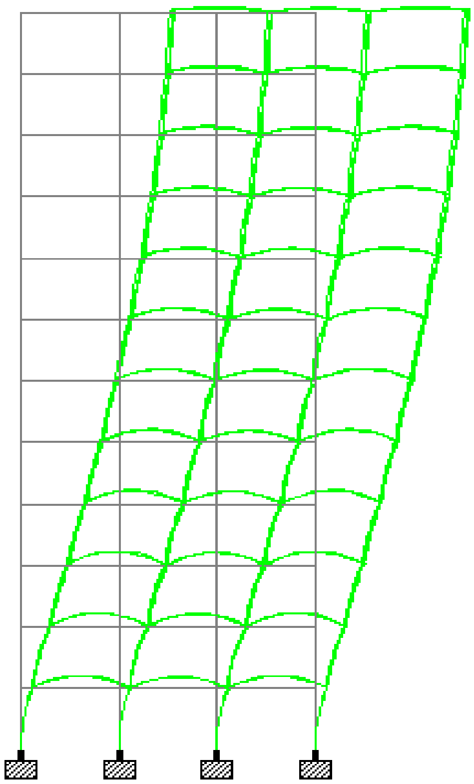


Fig 07. Variation of Top-Storey Deflection for ground motion in X direction



Bare Frame

4.7 Comparison of Top-Storey Deflection for ground motion in Z- direction

Bracings were found to be ineffective in reducing top-storey deflection in Z direction in the frame. But there is remarkable reduction in top-storey deflection in Z direction due to shear wall. Reduction is more in case of Shear Wall C. For ground motion in Z- direction Shear Wall A is ineffective since in Shear Wall A case shear wall is present in X-direction not in Z-direction.

Table 19 below shows the top-storey deflection for each case, Fig 13. shows the variation in top-storey deflection in Z direction and Fig 14. shows the Etab results for top-storey deflection.

Table 10. Top-Storey Drift for ground motion in Z- direction

Cases	**Top- Storey Deflection (mm)**
Bare Frame	116.355
Bracing A	116.385
Bracing B	132.365
Bracing AB	131.377
Bracing C	150.214
Shear Wall A	108.366
Shear Wall B	59.63
Shear Wall AB	49.365
Shear Wall C	58.939

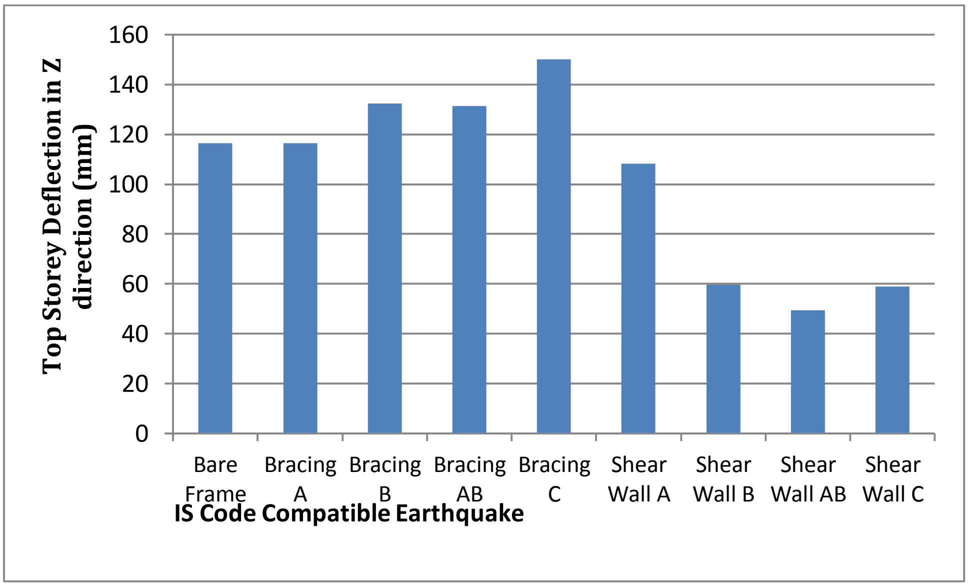


Fig 08. Variation of Top-Storey Deflection for ground motion in Z direction

V. CONCLUSION

This project work was a small effort towards perceiving the how introducing bracing or a shear wall in a building can make in difference in protecting the building in earthquakes. Almost all the buildings in India are RC frame, and earthquake tremors are felt every now a then in some or the other part of the country. Hence through this project it was tried to appreciate the effectiveness and role of this small extra structural elements that can save both life and property, at least for most of the earthquakes.

The following conclusions were drawn at the end of the study:

1. There is a gradual reduction in time periods of the bracing and shear wall systems from the time period of bare frame, indicating increase in stiffness.
2. Time Period in case of Shear Wall C is the highest, hence is the most stiff and better option for strengthening the structure.
3. Base Shear produced in the Bare Frame is maximum for Shear wall at C.
4. In case of bracing system, Bracing System C (with braces at the corners) are the most effective one than other bracing systems, effectively reducing top-storey drift and inter storey drifts in both X- and Z- directions.
5. There is hardly any reduction in drift along Z- direction due to Bracing B, for all the ground motions.
6. Shear Wall A is effective in reducing drifts along X- direction only, and Shear Wall B is effective in reducing drifts along Z- direction only, for all the ground motions.
7. Above all Shear Wall C is the best in all the stiffening cases considered.

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