

Seismic Analysis of Reinforced Concrete Frames

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ABSTRACT: Reinforced Concrete frames are the most common construction practices in India, with increasing numbers of high-rise structures adding up to the landscape. There are many important Indian cities that fall in highly active seismic zones. Such high-rise structures, constructed especially in highly prone seismic zones, should be analyzed and designed for ductility and should be designed with extra lateral stiffening system to improve their seismic performance and reduce damages. Two of the most commonly used lateral stiffening systems that can be used in buildings to keep the deflections under limits are bracing system and shear walls. The use of steel bracing system is a viable option for retrofitting a reinforced concrete frame for improved seismic performances. Steel braces provide required strength and stiffness, takes up less space, easy to handle during construction, can also be used as architectural element and is economic. Steel braces are effective as they take up axial stresses and due to their stiffness, reduce deflection along the direction of their orientation. Shear wall is a vertical member that can resist lateral forces directed along its orientation. Shear walls are structural system consisting of braced panels, also known as Shear Panels. Concrete Shear walls are widespread in many earthquake-prone countries like Canada, Turkey, Romania, Colombia, Russia. It has been in practice since 1960's, used in buildings ranging from medium- to high-rise structures. Shear walls should always be placed symmetrically in the structure and on each floor, including the basement. Reinforced concrete Shear walls transfer seismic forces to foundation and provide strength and stiffness.

KEYWORDS: Earthquake, Reinforced Concrete Frames, Seismic Zones, Shear wall

I. INTRODUCTION

Earthquake has always been a threat to human civilization from the day of its existence, devastating human lives, property and man-made structures. The very recent earthquake that we faced in our neighboring country Nepal has again shown nature's fury, causing such a massive destruction to the country and its people. It is such an unpredictable calamity that it is very necessary for survival to ensure the strength of the structures against seismic forces. Therefore, there is continuous research work going on around the globe, revolving around development of new and better techniques that can be incorporated in structures for better seismic performance. Obviously, buildings designed with special techniques to resist damages during seismic activity have much higher cost of construction than normal buildings, but for safety against failures under seismic forces it is a prerequisite. Earthquake causes random ground motions, in all possible directions emanating from the epicenter. Vertical ground motions are rare, but an earthquake is always accompanied with horizontal ground shaking. The ground vibration causes the structures resting on the ground to vibrate, developing inertial forces in the structure. As the earthquake changes directions, it can cause reversal of stresses in the structural components, that is, tension may change to compression and compression may change to tension. Earthquake can cause generation of high stresses, which can lead to yielding of structures and large deformations, rendering the structure non-functional and unserviceable. There can be large storey drift in the building, making the building unsafe for the occupants to continue living there.

II. RELATED WORK

Chandurkar, Pajgade (2013) evaluated the response of a 10 storey building with seismic shear wall using ETAB v 9.5. Main focus was to compare the change in response by changing the location of shear wall in the multi-storey building. Four models were studied- one being a bare frame structural system and rest three were of dual type structural system. The results were excellent for shear wall in short span at corners. Larger

dimension of shear wall was found to be ineffective in 10 or below 10 stories. Shear wall is an effective and economical option for high-rise structures. It was observed that changing positions of shear wall was found to attract forces, hence proper positioning of shear wall is vital. Major amount of horizontal forces were taken by shear wall when the dimension is large. It was also observed that shear walls at substantial locations reduced displacements due to earthquake.

Viswanath K.G (2010) investigated the seismic performance of reinforced concrete buildings using concentric steel bracing. Analysis of a four, eight, twelve and sixteen storied building in seismic zone IV was done using Etabs software, as per IS 1893: 2002 (Part-I). The bracing was provided for peripheral columns, and the effectiveness of steel bracing distribution along the height of the building, on the seismic performance of the building was studied. It was found that lateral displacements of the buildings reduced after using X-type bracings. Steel bracings were found to reduce flexure and shear demand on the beams and columns and transfer lateral load by axial load mechanism. Building frames with X- type bracing were found to have minimum bending as compared to other types of bracing. Steel bracing system was found to be a better alternative for seismic retrofitting as they do not increase the total weight of the building significantly.

Chavan, Jadhav (2014) studied seismic analysis of reinforced concrete with different bracing arrangements by equivalent static method using Etabs. software. The arrangements considered were diagonal, V-type, inverted V-type and X-type. It was observed that lateral displacement reduced by 50% to 60% and maximum displacement reduced by using X- type bracing. Base shear of the building was also found to increase from the bare frame, by use of X-type bracing, indicating increase in stiffness.

Esmaili et al. (2008) studied the structural aspect of a 56 stories high tower, located in a high seismic zone in Tehran. Seismic evaluation of the building was done by non-linear dynamic analysis. The existing building had main walls and its side walls as shear walls, connected to the main wall by coupling of beams. The conclusion was to consider the time-dependency of concrete. Steel bracing system should be provided for energy absorption for ductility, but axial load can have adverse effect on their performance. It is both conceptually and economically unacceptable to use shear wall as both gravity and bracing system. Confinement of concrete in shear walls is good option for providing ductility and stability.

Akbari et al. (2015) assessed seismic vulnerability of steel X-braced and chevron-braced Reinforced Concrete by developing analytical fragility curve. Investigation of various parameters like height of the frame, the p-delta effect and the fraction of base shear for the bracing system was done. For a specific designed base shear, steel-braced RC dual systems have low damage probability and larger capacity than unbraced system. Combination of stronger bracing and weaker frame reduces the damage probability on the entire system. Irrespective of height of the frame, Chevron braces are more effective than X-type bracing. In case of X-type bracing system, it is better to distribute base shear evenly between the braces and the RC frame, whereas in case of Chevron braced system it is appropriate to allocate higher value of share of base shear to the braces. Including p-delta effect increases damage probability by 20% for shorter dual system and by 100% for taller dual systems. The p-delta effect is more dominant for smaller PGA values.

III. METHODOLOGY

The entire work is divided into three parts:

- Analysis of bare frame in all the above-mentioned ground motion
- Analysis of the braced frames.
- Analysis of the frame with shear wall

For analysis a 12 stories high building is modeled in Etabs as a space frame. The building is does not represent any real existing building. The building is unsymmetrical with the span more along Y direction than along X direction. The building rises up to 42m along Y direction and spans 15m along X direction and 20 m along Y 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. 1 and Fig.2 respectively. In the entire course work X and Y are taken as the horizontal axes and Z 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 Y direction	4
Bay Length along X direction	5m
Bay Length along Y 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/m ³
Live Load	3.5 kN/m ³
Zone	IV
Soil Conditions	Hard Soil
Damping Ratio	5%

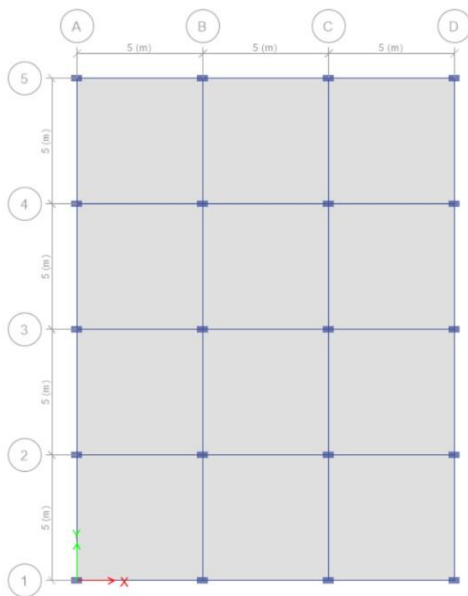


Fig. 1 Plan of the building

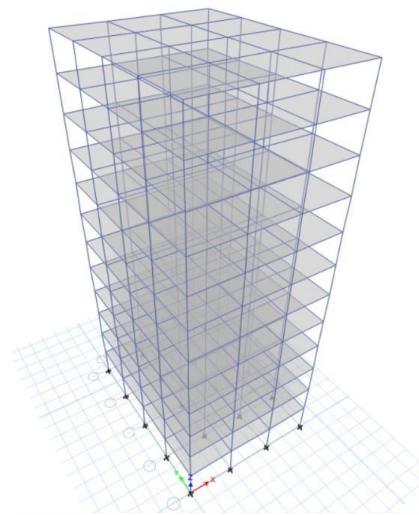


Fig. 2 Model of the building

IV. EXPERIMENTAL RESULTS

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 A base shear, inter-storey drifts and top-storey deflections for ground motions along X and Y 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.

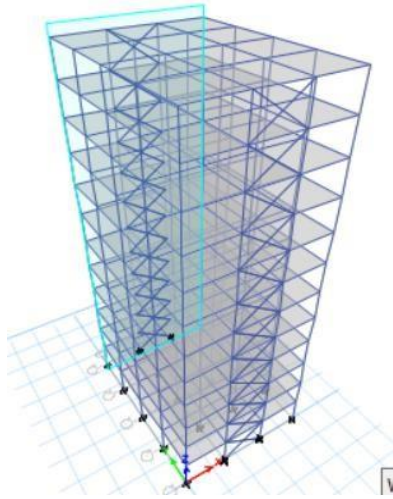


Fig 3 - 3D Model of the building with braces at location 1

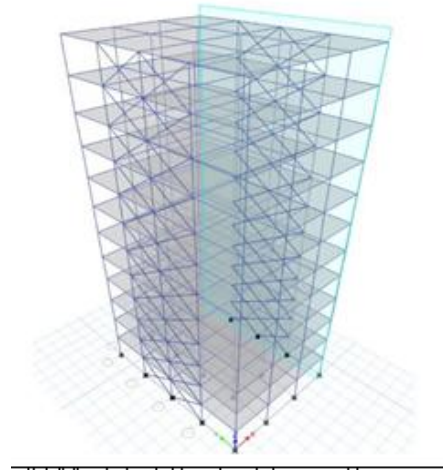


Fig 4 - 3D Model of the building with braces at location 2

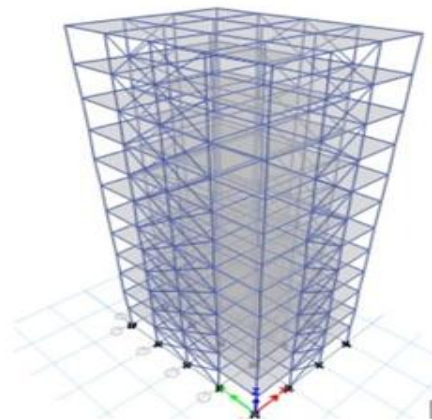


Fig 5- 3D Model of the building with braces at location 3

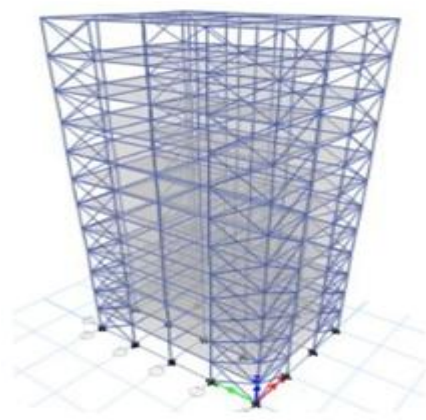


Fig 6-3D Model of the building with braces at location 4

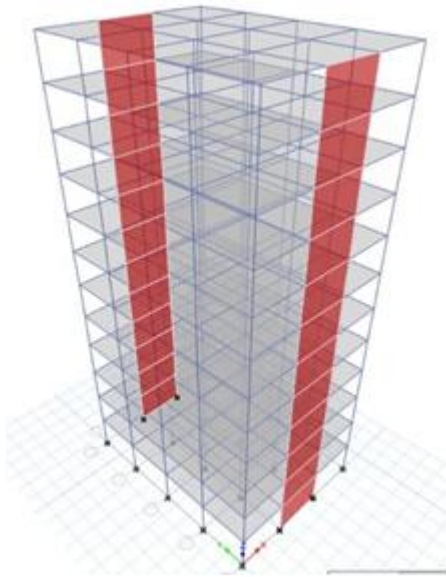


Fig 7-3D Model of the building with shear wall at location 1

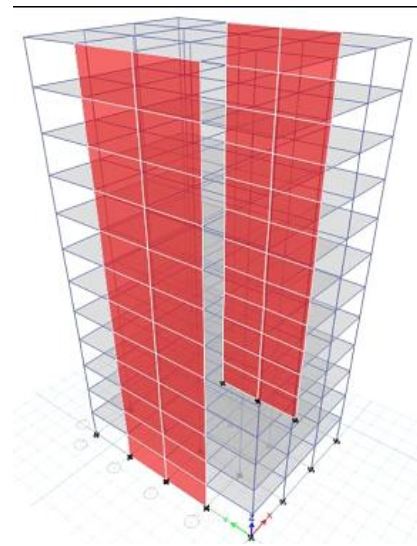


Fig 8- 3D Model of the building with shear wall at location 2

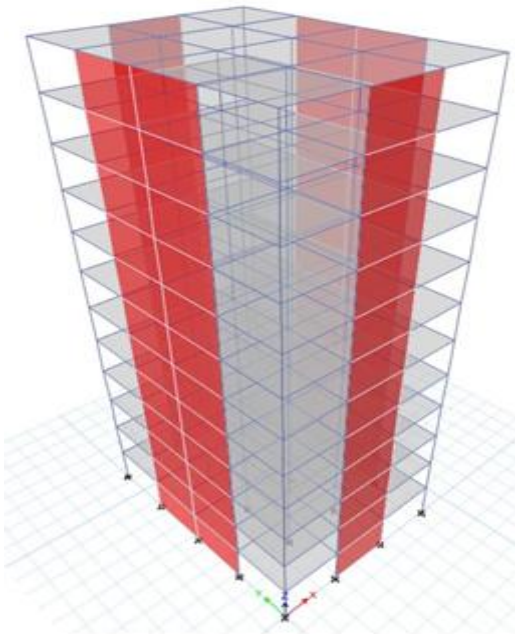


Fig 9-3D Model of the building with shear wall at location 3

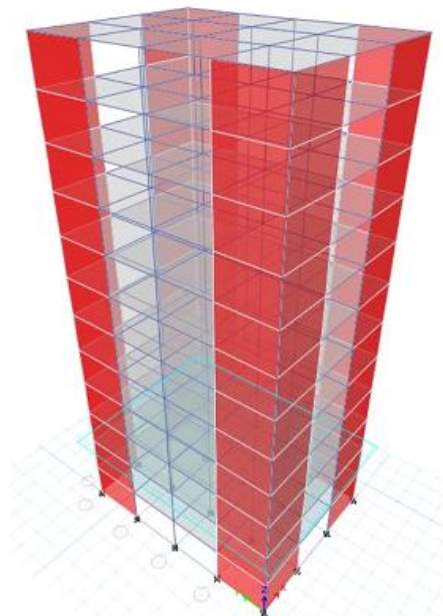


Fig 10-3D Model of the building with shear wall at location 4



V.COMPARISON OF TIMEPERIOD

a) Variation of time period

Table 2: Variation of Time period

Sl no	Cases	Time Period (s)
1	Bare Frame	3.51224
2	Bracing A	3.51208
3	Bracing B	3.53179
4	Bracing AB	3.53164
5	Bracing C	3.5124
6	Shear Wall A	3.59052
7	Shear Wall B	3.36548
8	Shear Wall AB	2.05164
9	Shear Wall C	1.70323

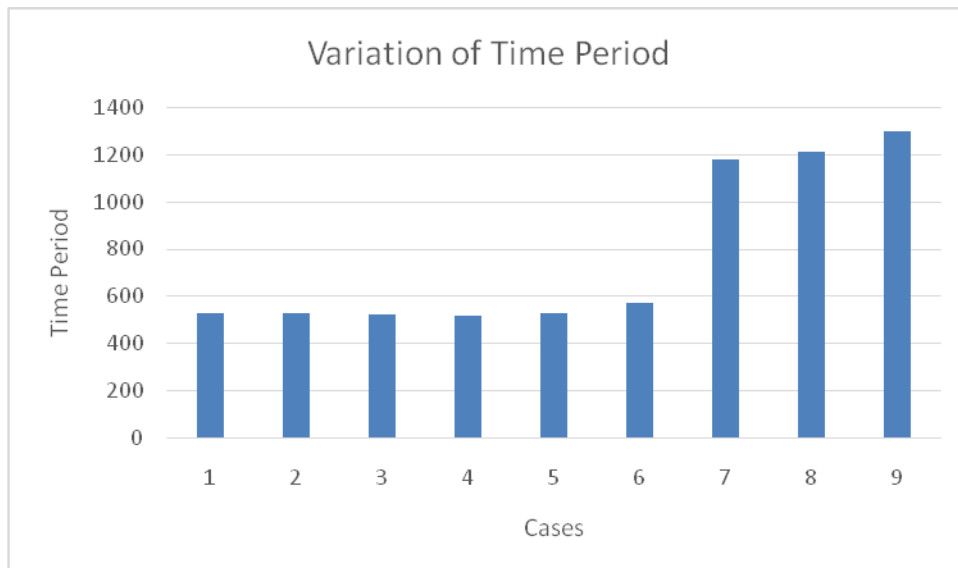


Fig 11 – Variation of time period

a) Variation of base shear in X direction

Table 3 : Variation of base shear in X direction

Sl no	Cases	Base Shear(kN)
1	Bare Frame	568.86
2	Bracing A	688.48
3	Bracing B	568.32
4	Bracing AB	686.95
5	Bracing C	750.62
6	Shear Wall A	916.7
7	Shear Wall B	658.36
8	Shear Wall AB	990.91
9	Shear Wall C	1227.99

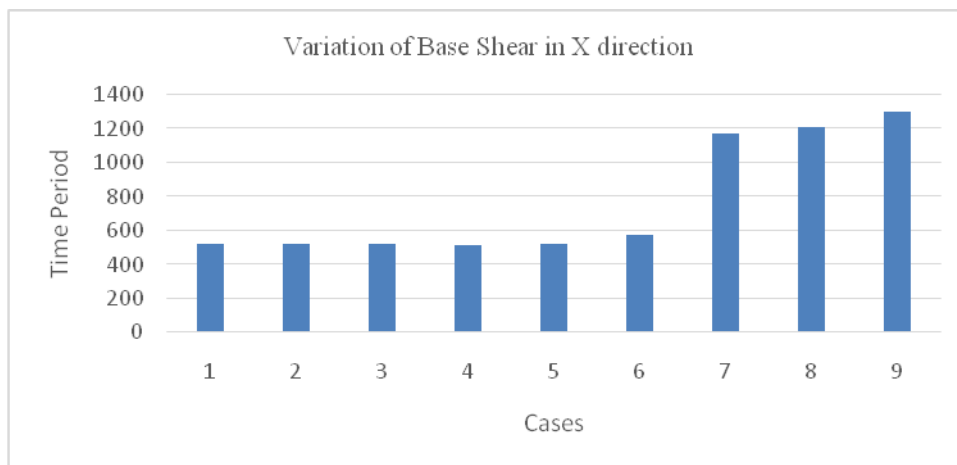


Fig 12 - Variation of Base Shear in X direction

b) Variation of base shear in Y direction

Table 4 : Variation of base shear in Ydirection

Sl no	Cases	Base Shear(kN)
1	Bare Frame	525.76
2	Bracing A	525.79
3	Bracing B	522.16
4	Bracing AB	518.04
5	Bracing C	525.81
6	Shear Wall A	571.47
7	Shear Wall B	1176.35
8	Shear Wall AB	1207.73
9	Shear Wall C	1298.11

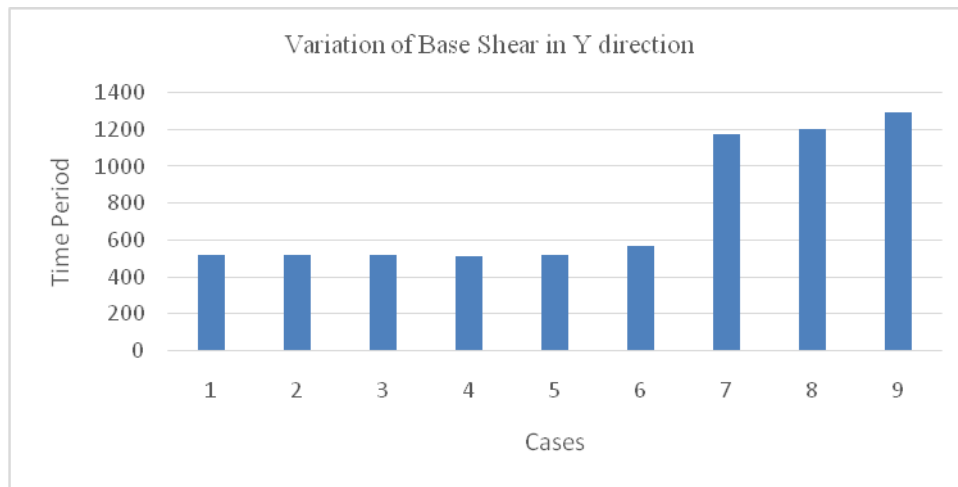


FIG 13 - VARIATION OF BASE SHEAR IN X DIRECTION

VI.CONCLUSION

This project work shows that 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:

- 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.
- Time Period in case of Shear Wall C is the highest, hence is the most stiff and better option for strengthening the structure.
- 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 Y- directions.
- There is hardly any reduction in drift along Y- direction due to Bracing B, for the ground motions.
- Shear Wall A is effective in reducing drifts along X- direction only, and Shear Wall B is effective in reducing drifts along Y- direction only, for all the ground motions.
- Above all Shear Wall C is the best in all the stiffening cases considered

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