Comparative Study and Analysis of Unbraced RCC Framed Structure with Steel Braced RCC Framed Structure using Response Spectrum Method

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Abstract- **Lateral forces induced on the structure due to seismic waves have given rise to the study of lateral load resisting elements such as braces, shear wall, dampers etc. These lateral load resisting elements should be analysed before arriving on a best orientation and configuration. This work is an analysis of braces and there orientation, configuration and arriving on a best bracing system. In this project there is a comparison of unbraced RCC framed structure and steel Braced RCC framed structure the steel braces are of different configurations such as X, V, inverted V and their different arrangements have been studied, analysed using ETABS 2015 and results are compared. For the analysis a Special Moment Resisting Frame of G+15 Storey is modelled in ETABS 2015 which is 33m×15m. The objective is to have a comparative perspective of unbraced and steel braced RCC frame, all the frames are subjected to same DL, IL and Earthquake loads all the structure are in the same earthquake zone i.e.; Zone V. It is found that when X-braced RCC frame structure performed best when compared with the parameters of Maximum Storey Displacement, Maximum Storey Drift, Base Shear, Overturning moments and Time period of unbraced RCC frame structure. With the use of X-braced steel bracings the structure can be designed using lighter section and thus economic efficiency can be achieved. High construction quality should be maintained while embedding steel bracing at beam-column joints. IS 13920 (1993): Ductile detailing of reinforced concrete structures subjected to seismic forces – Code of practice should be preferred and the codal provisions should be achieved as far as possible.**

Key words- Maximum storey displacement, Maximum storey drift, Base shear, Resisting moments, Time period, ETABS, RCC.

1. INTRODUCTION

Earthquake can be understood as the shaking of earth's crust which can be due to relative movement in tectonic plates, volcano eruptions and even in case of explosions. There can be huge loss of life as experienced in past earthquakes in India and the world. Apart from loss of life there is economic loss also. Industrialization has given rise to many things one of which is high rise buildings. High rise building requires in depth analysis of response of the building for a given set of load conditions. In general structure is designed for gravity loads, imposed loads, wind loads, snow loads and earthquake loads. Earthquake loads have a different tendency as compared to other loads, these loads induces lateral forces on to the structure. Lateral force induces forces parallel to the plane of the structure this has given rise to study of lateral force resisting elements such as shear wall, dampers, bracings etc. Steel which have good compressive and tensile load carrying property are used as braces. Depending upon the configuration steel braces can be classified as concentric and eccentric. Concentric braces such as X, V, inverted V are used.

In the previous works many such bracing configurations have been studied. This work aims at studying the response of G+15 storied special moment resisting RCC framed structure subjected to earthquake excitation in seismic Zone V(as per IS 1893: (Part 1) 2002). X, V and inverted V braces are used in different arrangements (shown in modelling). All the models are in same seismic zone with same structural properties.

2. OBJECTIVES OF PRESENT STUDY

The objective of this work is to know the response of a G+15 storey unbraced RCC framed structure in comparison to concentrically steel braced G+15 storey RCC framed structure with different arrangements of steel bracing. To have an insight in the performance of these steel braced RCC framed structure linear dynamic analysis is performed i.e.; Response Spectrum Analysis. Following are the aspects which are attempted to study:

I. Comparison of storey displacement for G+15 storied unbraced RCC framed structure and concentrically steel braced G+15 RCC framed structure.
II. Comparison of storey drift for G+15 storied unbraced RCC framed structure and concentrically steel braced G+15 RCC framed structure.
III. Comparison of base shear for G+15 storied unbraced RCC framed structure and concentrically steel braced G+15 RCC framed structure.
IV. Comparison of base reaction for G+15 storied unbraced RCC framed structure and concentrically steel braced G+15 RCC framed structure.
V. Comparison of time period for G+15 storied unbraced RCC framed structure and concentrically steel braced G+15 RCC framed structure.

3. MODELLING

The structure which is considered in this project work have been analysed in ETABS 2015. A G+15 storied structure is considered for the analysis using Response Spectrum Method. The structure is 33×15 m in plan. Columns are placed in 3m interval in both X and Y direction. The structure lies in earthquake zone V and has a importance

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factor 1. Seismic zone factor is 0.36 for zone V as per IS 1893 (Part-1): 2002. The factors which affect the calculation of seismic forces induced on the structure are:

Structure	SMRF
Number of storey	G+15
Storey height	3m
Seismic zone	V
Seismic zone factor (Z)	0.36
Soil type	medium
Damping ratio	5%
Importance factor	1

Table 3.1- Structural Parameters

Materials	
Concrete grade	M30
Steel	Fe 415
Masonry	As per ETABS 2015

Table 3.2- Material Property

Frame Property Dimension	
Outer column C1	400*400 (mm)
Inner column C2	450*450 (mm)
Outer beam B1	450*300 (mm)
Inner bream B2	500*300 (mm)
Slab thickness	125mm Membrane type
Bracings	ISA 100*100*8 (mm)

Table 3.3- Frame property and Slab property

Loads	
Dead load (DL)	As per the unit weight of material and their volume
Dead load on slab (DL)	2 KN/mm^2 (floor finish + partition wall)
Imposed load (IL)	5 KN/mm^2 As per IS 875 (Part 2):1987
Masonry load outer wall	6 KN/m
Masonry load inner wall	13.8 KN/m
Earthquake load	As per IS 1893 part I 2002

Table 3.4- Dead Load and Live Load considered

Support/Diaphragm	
Support	Fixed
Membrane rigidity	Rigid

Table 3.5- Support and Diaphragm Property

Load combination Load combinations which are used in this work are based on codal provisions which are given in IS 857 part5. Following are load combinations are used to analyse the structure. When earthquake loads are applied to a structure then the loads are resolved in mutually perpendicular directions (as IS 857 part5).

1. 0.9*(DL+Masonry)-1.5*EY
2. 0.9*(DL+Masonry)+1.5*EY
3. 0.9*(DL+Masonry)-1.5*EX
4. 0.9*(DL+Masonry)+1.5*EX
5. 1.2*(DL+Masonry+IL+EX)
6. 1.2*(DL+Masonry+IL-EX)

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7. 1.2*(DL+Masonry+IL+EY)
8. 1.2*(DL+Masonry+IL-EY)
9. 1.5*(DL+Masonry+EX)
10. 1.5*(DL+Masonry+EY)
11. 1.5*(DL+Masonry+IL)
12. 1.5*(DL+Masonry-EX)
13. 1.5*(DL+Masonry-EY

Models and their bracings

1. Model 1 -Bare frame

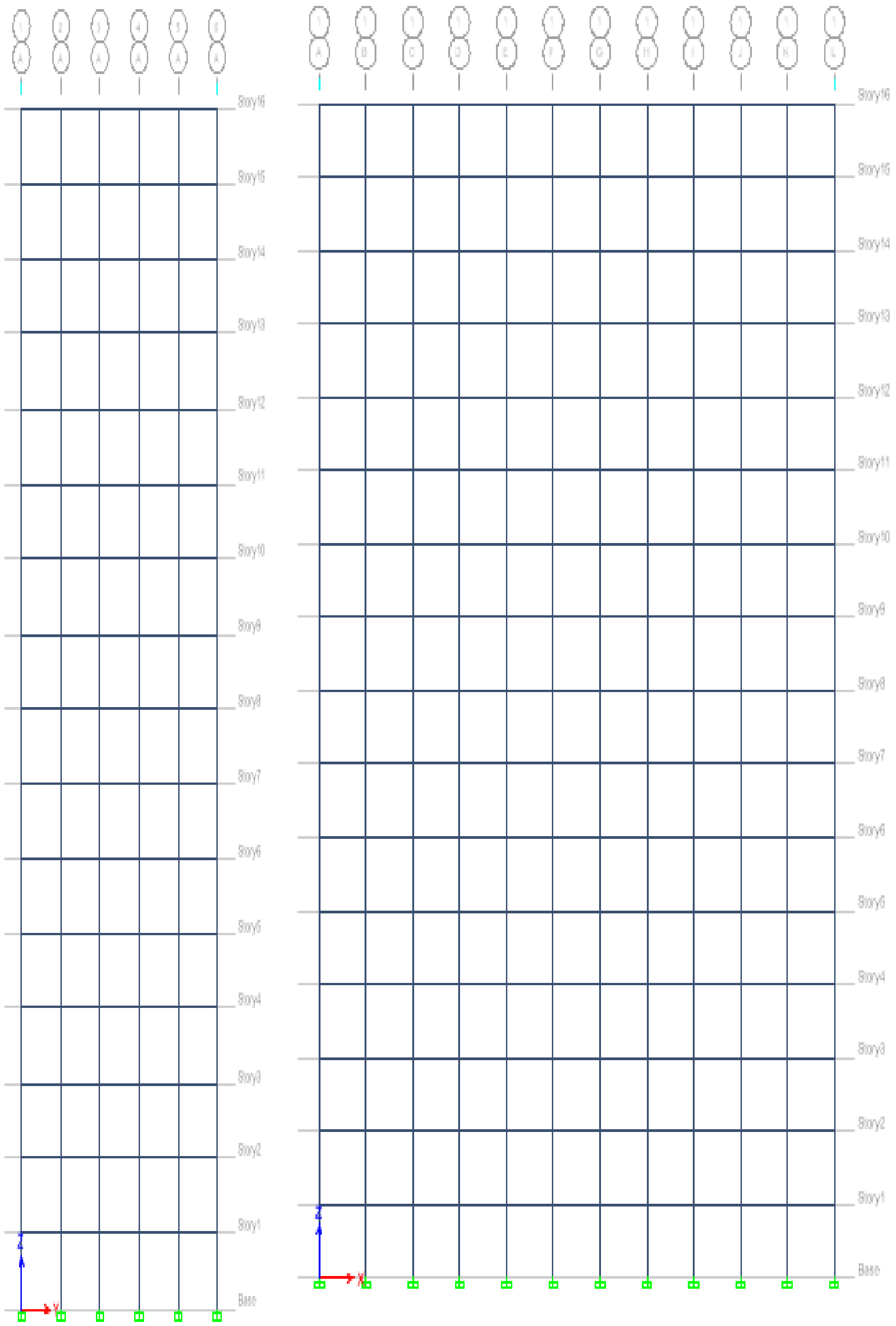

Fig 1- Side view and Front view of Model 1

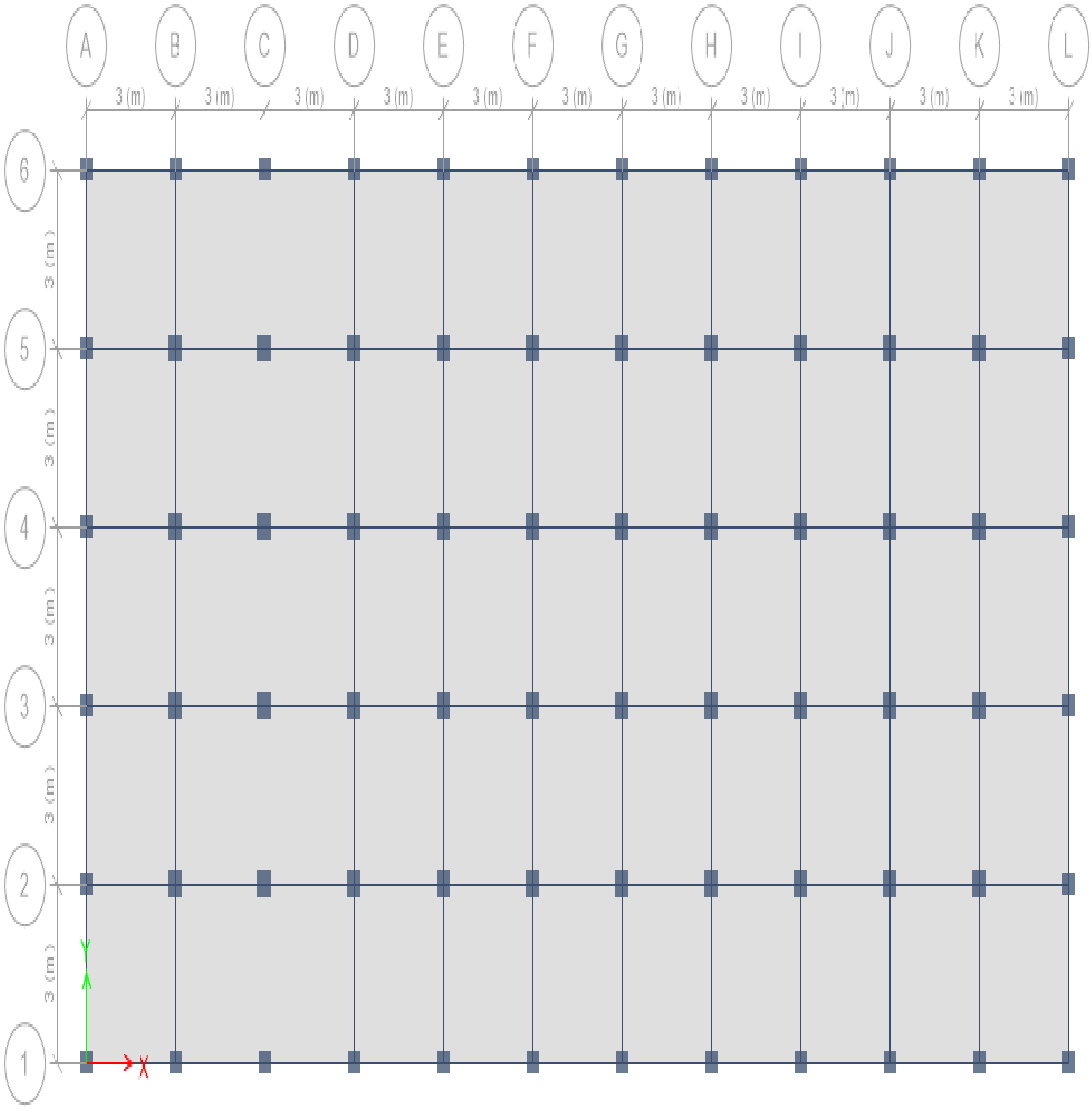

Fig 2- Plan View

2. Model 2 - X bracing in pairs

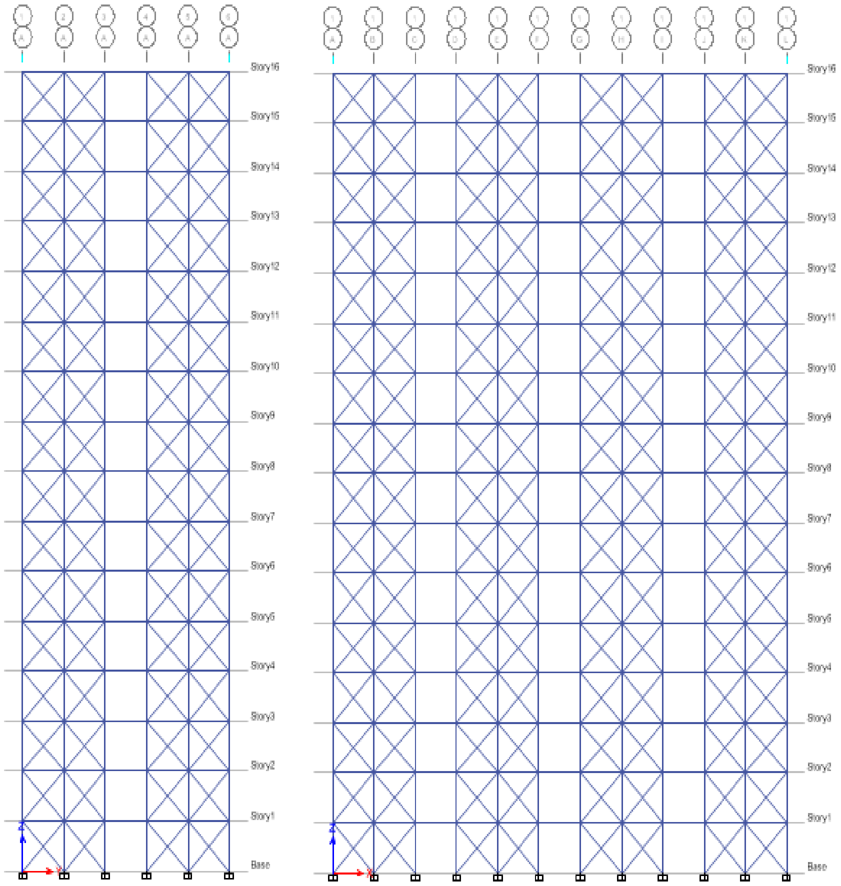

Fig 3- Side view and Front view of Model 2

3. Model 3- X bracing alternate arrangement

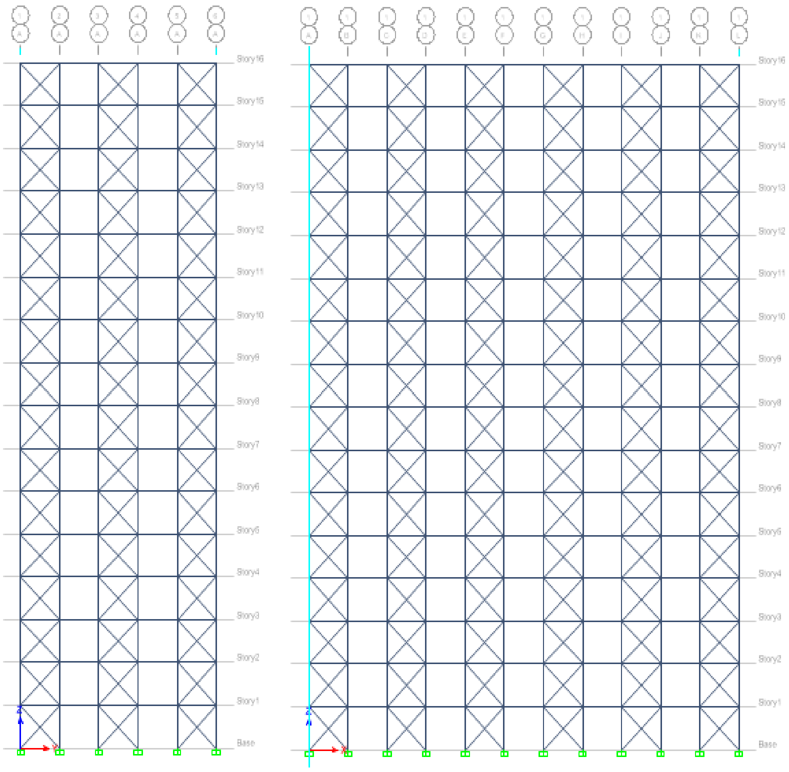

Fig 4- Side view and Front view of Model 3

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4. Model 4- V bracing in pair

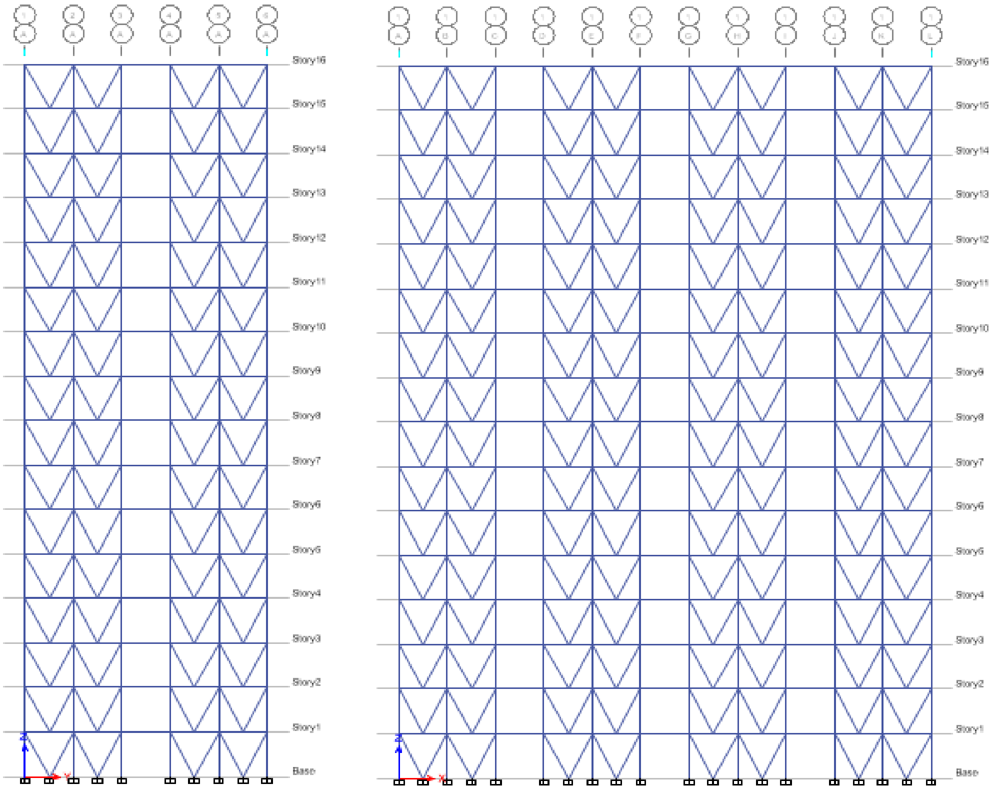

Fig 5- Side view and Front view of Model 4

5. Model 5- V bracing alternate arrangement

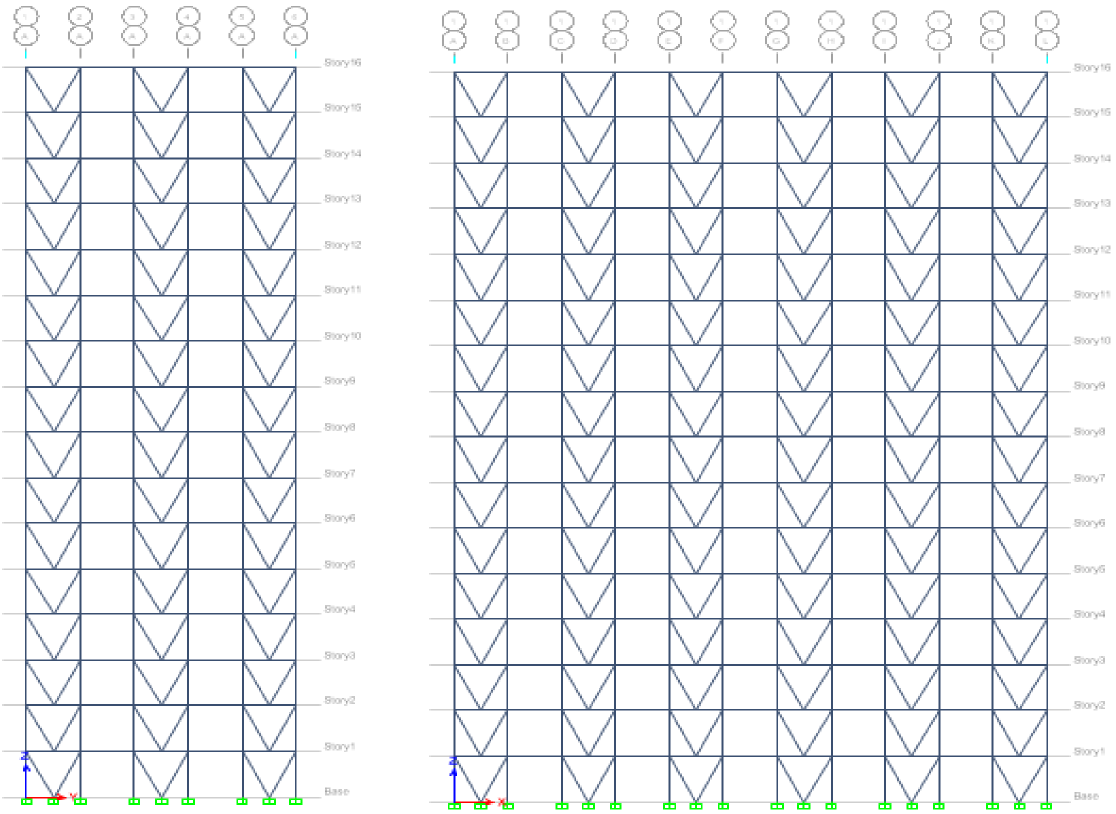

Fig 6- Side view and Front view of Model 5

6. Model 6- Inverted V bracing in pair

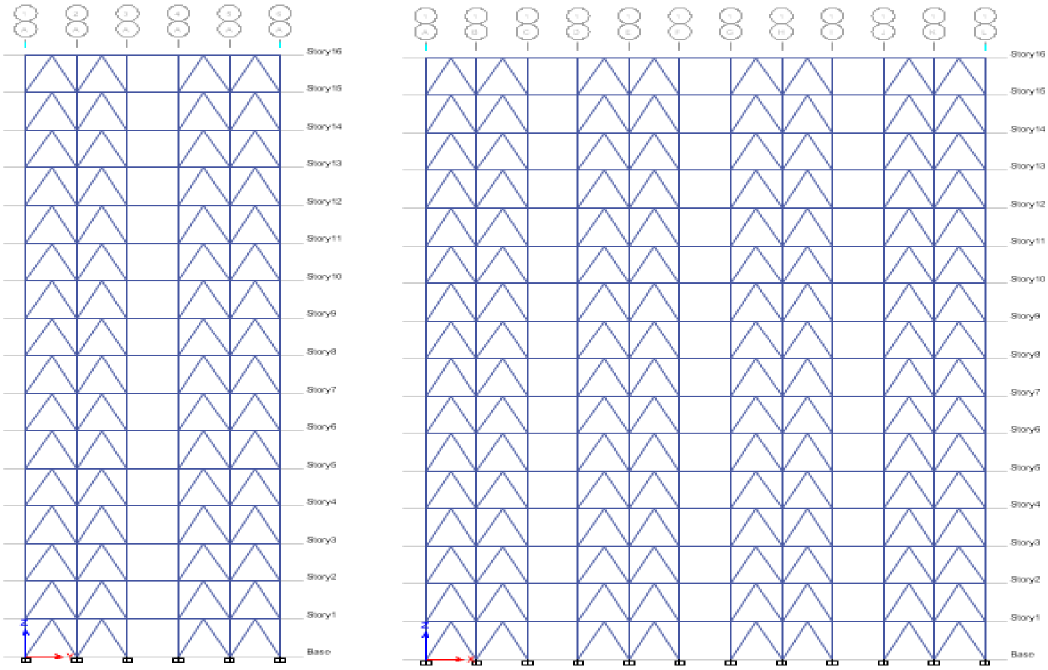

Fig 7- Side view and Front view of Model 6

7. Model 7- Inverted V bracing alternate arrangement

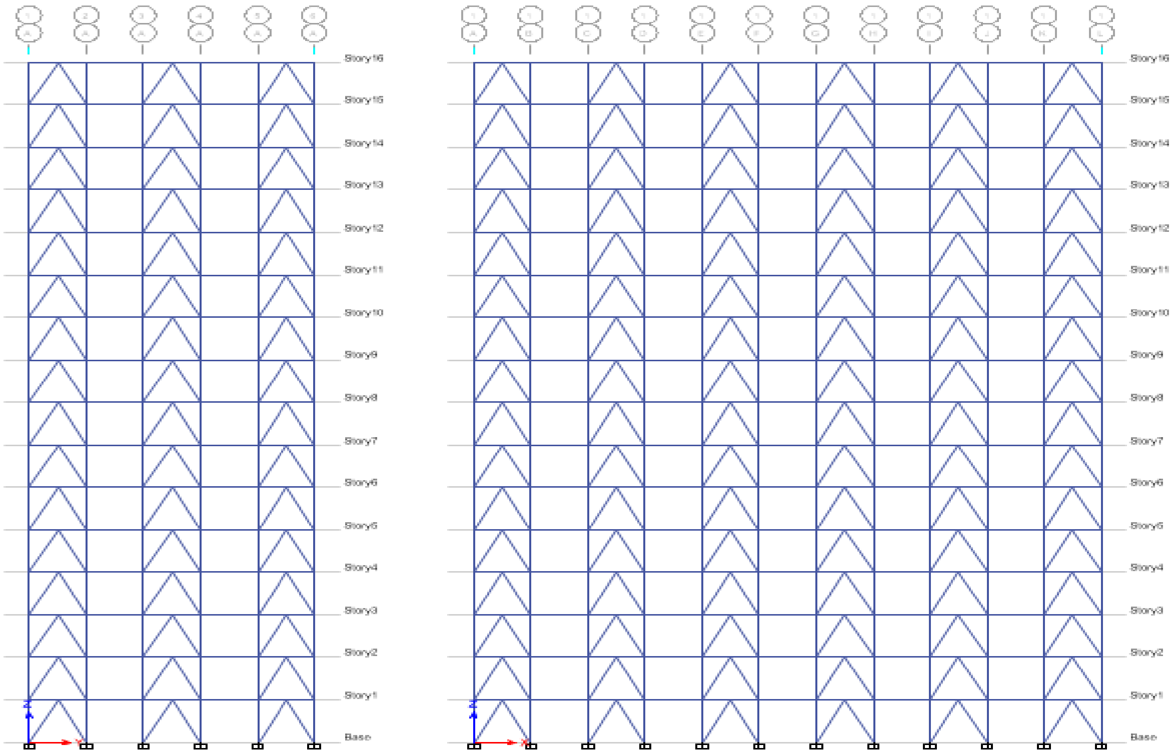

Fig 8- Side view and Front view of Model 7

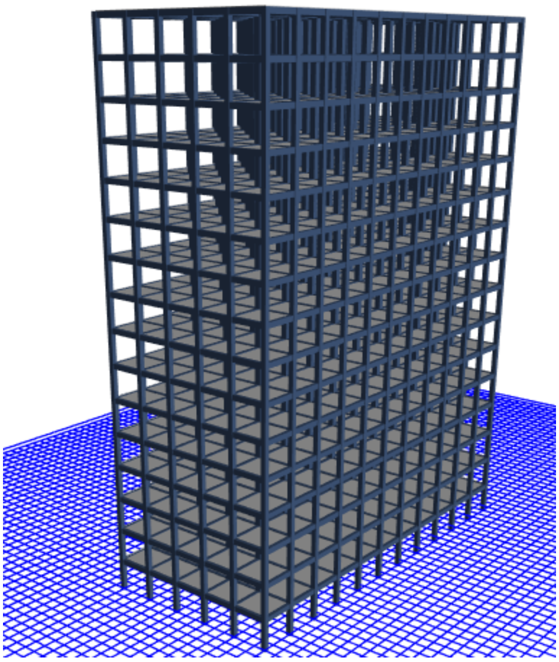

Fig 9- 3D model of Unbraced RCC frame

4. RESULTS AND DISCUSSION

Bracings are used to reduce the seismic forces which are developed under the earthquake excitation. As the objectives of the work were to have comparative analyses of unbraced RCC framed structure and steel braced RCC structure. The seismic responses of the models are shows in graphical as well as tabular fashion:

Maximum storey displacement

Displacement is the parameter of maximum importance as it governs the failure pattern of the structure. From the present study, the displacement of the model with and without braces is tabulated and the results are plotted.

Maximum storey Displacement(mm)			
S. NO.	Name	X-Direction	Y-Direction
1	Bare RCC frame	34.544	38.182
2	X bracing	18.858	23.225
3	X bracing alternate	31.013	42.278
4	V bracing	31.224	42.338
5	V bracing alternate	31.268	36.377
6	Inverted V bracing	29.864	35.637
7	Inverted V bracing alternate	31.086	36.251

Table 4.1- Maximum Storey Displacement

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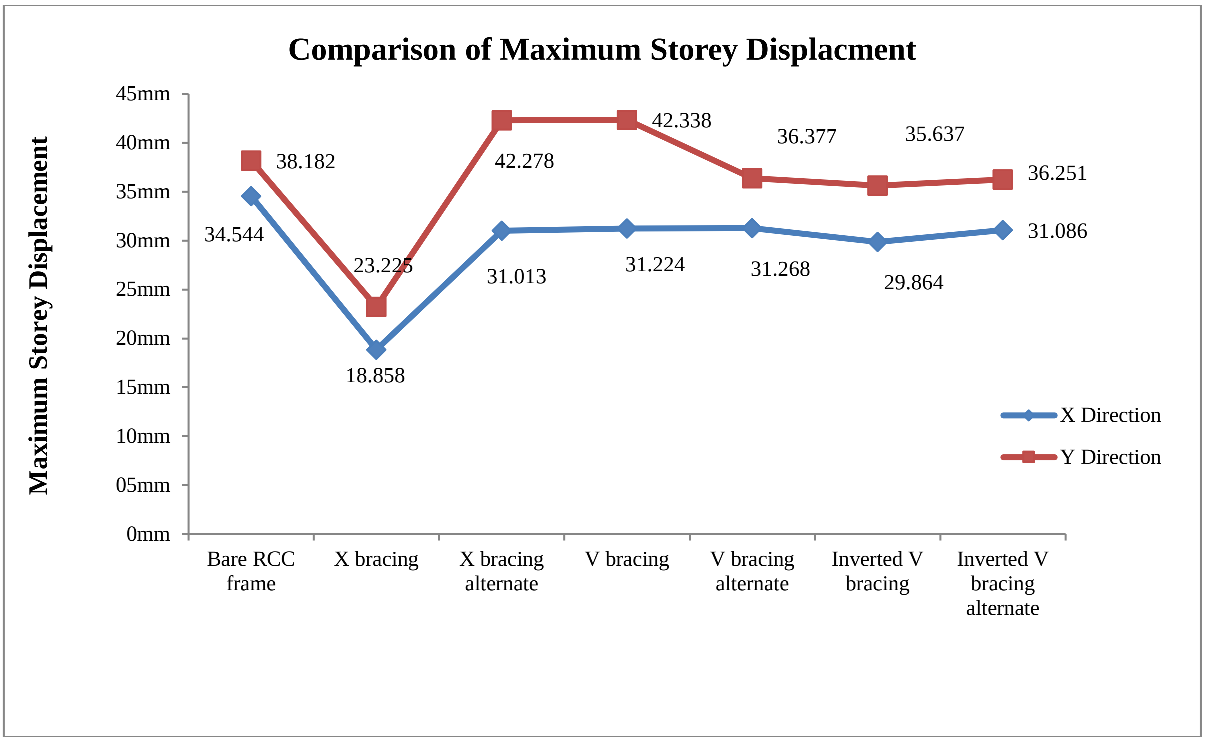

Graph 4.1- Comparison of Maximum Storey Displacement

Storey drift

Storey drift is the drift of one level of a multi storey building relative to the level below.

Maximum Storey Drift			
S. NO.	Name	X-Direction	Y-Direction
1	Bare RCC frame	0.001065	0.001075
2	X bracing	0.000517	0.000603
3	X bracing alternate	**0.00087**	**0.001126**
4	V bracing	0.000904	0.001147
5	V bracing alternate	0.000922	0.000993
6	Inverted V bracing	0.000866	0.00096
7	Inverted V bracing alternate	0.000912	0.000986

Table 4.2- Maximum Storey Drift

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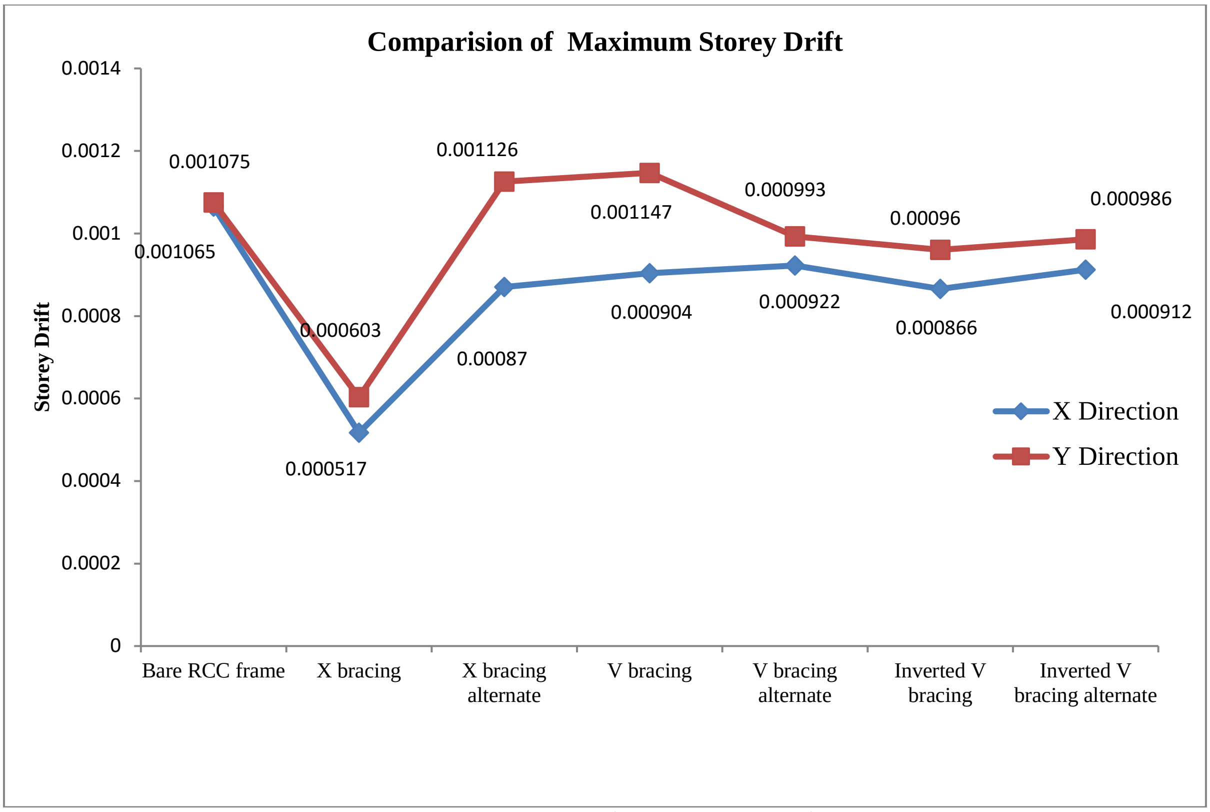


Graph 5.2- Comparison of Maximum Storey Drift

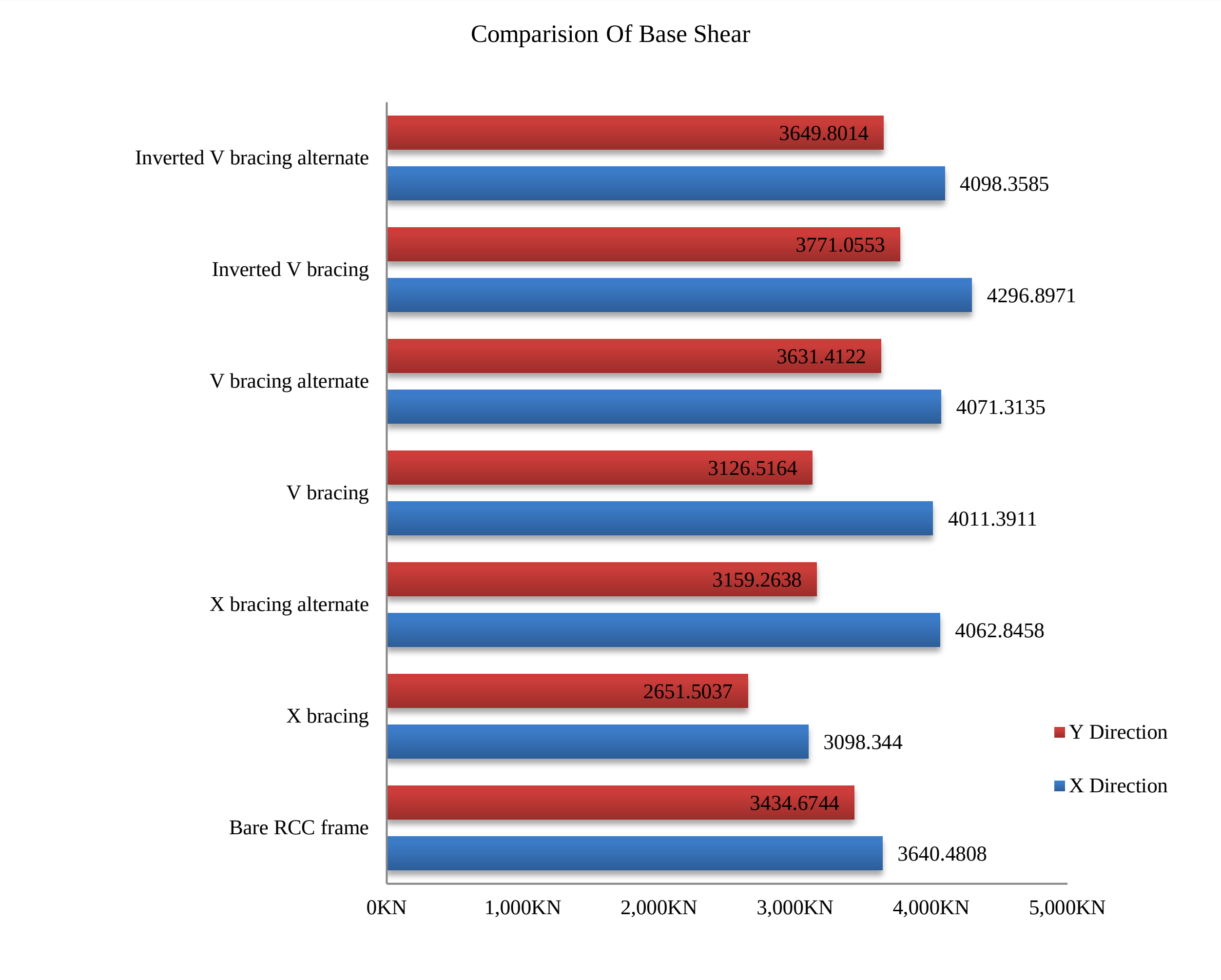
Base shear

Base shear is an estimate of the maximum expected lateral force that will occur due to seismic ground motion at the base of a structure. Calculation of base shear depends on:

- Soil condition at site.
- The level of ductility and over strength associated with various structural configurations and total weight of the structure
- The fundamental (natural) period of vibration of the structure when subjected to dynamic loading

Comparison of Base Shear (in KN)			
S. NO.	Name	X Direction	Y Direction
1	Bare RCC frame	3640.4808	3434.6744
2	X bracing	3098.344	2651.5037
3	X bracing alternate	4062.8458	3159.2638
4	V bracing	4011.3911	3126.5164
5	V bracing alternate	4071.3135	3631.4122
6	Inverted V bracing	4296.8971	3771.0553
7	Inverted V bracing alternate	4098.3585	3649.8014

Table 4.3- Comparison of Base Shear

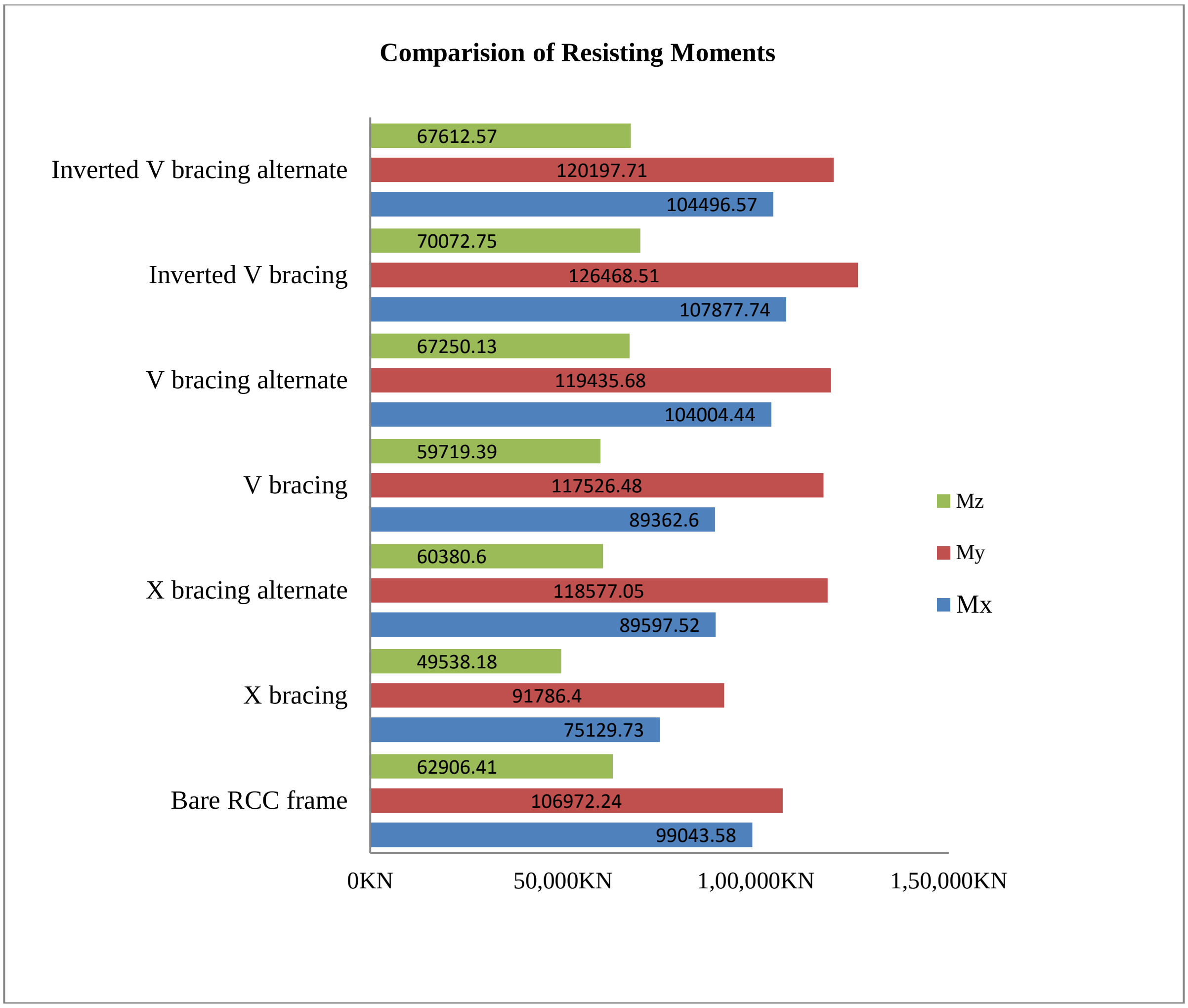


Graph 4.3- Comparison of Base Shear

Resisting Moments

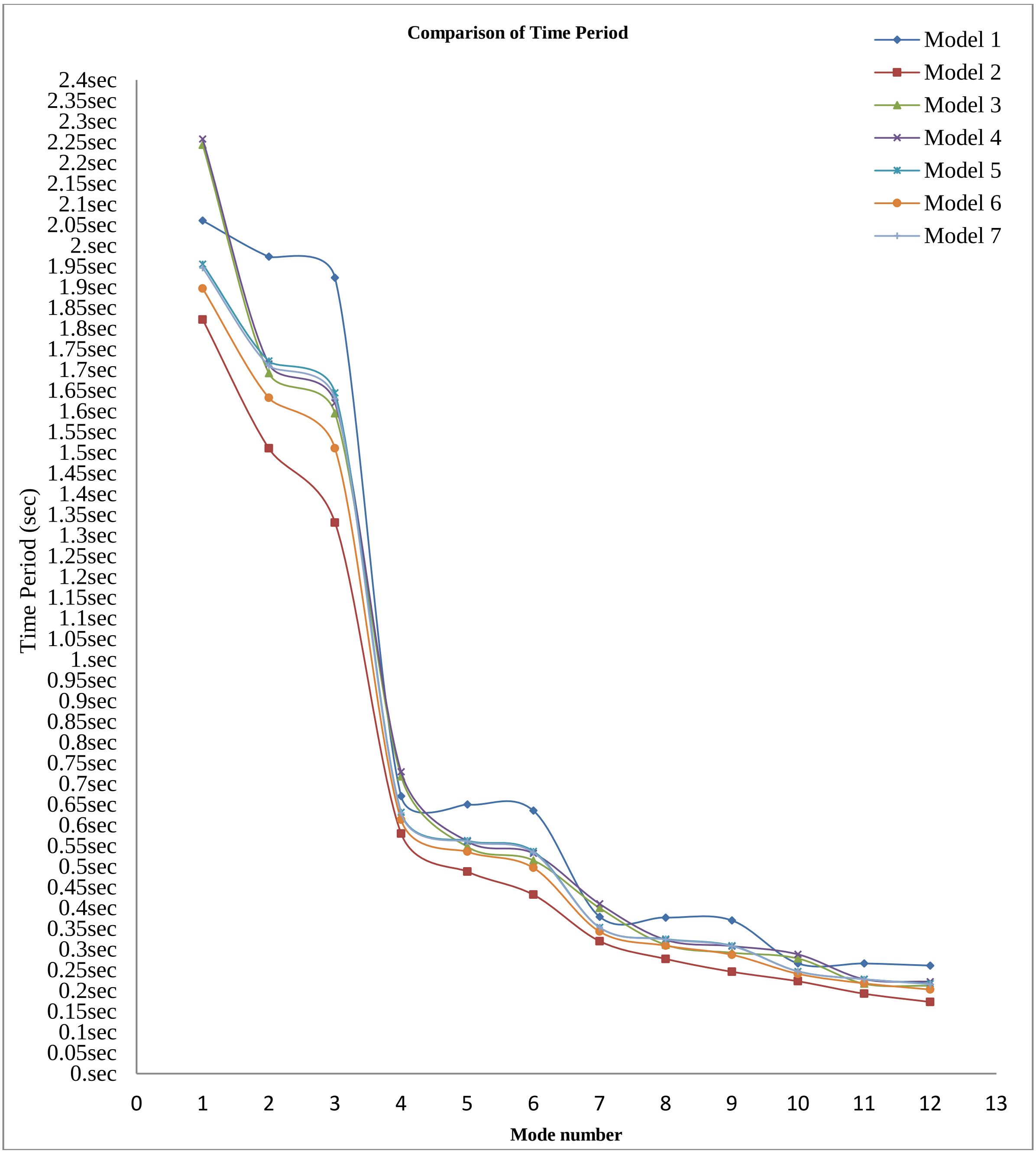
Comparison of Resisting Moments (in KN-m)				
S. NO.	Name	Mx	My	Mz
1	Bare RCC frame	99043.58	106972.24	62906.41
2	X bracing	75129.73	91786.4	49538.18
3	X bracing alternate	89597.52	118577.05	60380.6
4	V bracing	89362.6	117526.48	59719.39
5	V bracing alternate	104004.44	119435.68	67250.13
6	Inverted V bracing	107877.74	126468.51	70072.75
7	Inverted V bracing alternate	104496.57	120197.71	67612.57

Graph 4.4- Comparison of Resisting Moments



Graph 4.4- Comparison of Resisting Momen

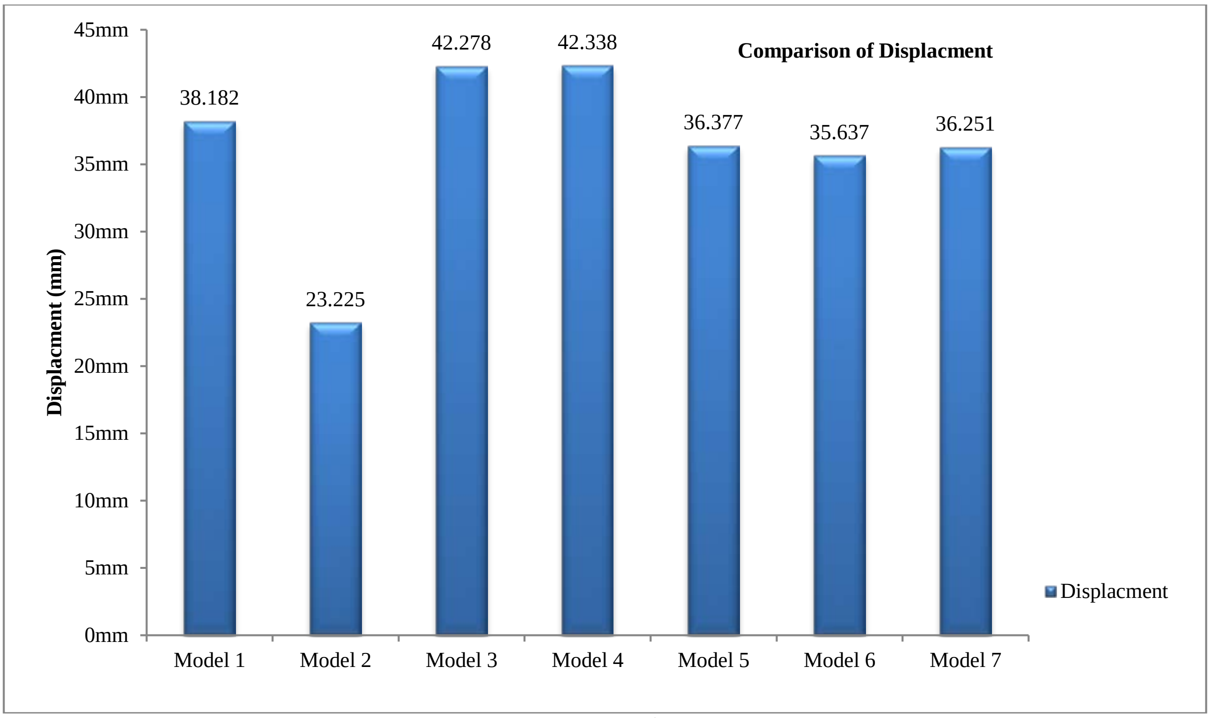
Time Period



Graph 4.5- Comparison of Time Period

DISPLACEMENT

Displacement is the parameter of maximum importance as it governs the failure pattern of the structure. From this present study, the displacement of the model with and without bracings is observed. By providing the bracings to the structure we observe that the displacement of the structure is reduced for X-bracing used in pairs shown in model 2.



Graph 4.6- Comparison of Displacement

5. CONCLUSIONS

Steel braced RCC frame was analysed with different arrangements of steel braces and with various types of concentric braces such as X, V, inverted V. After the analysis the results were represented in tabular as well as graphical manner. On the basis of the graphs following are the conclusion inferred:

Maximum Storey Displacement:

Comparative to unbraced RCC frame there is 64.40% reduction in maximum storey displacement in X-direction and 83 18% reduction in Y-direction when X-braced frame (Model 2) arrangement is used.

Maximum Storey Drift:

Comparative to unbraced RCC frame there is 78.27% reduction in maximum storey drift in X-direction and 105.99% reduction in Y-direction when X-braced frame (Model 2) arrangement is used.

Base Shear:

Comparative to unbraced RCC frame there is 17.5% reduction in base shear in X-direction and 29.54% reduction in Y-direction when X-braced frame (Model 2) arrangement is used.

Resisting Moments:

Comparative to unbraced RCC frame there is 31.83% reduction in overturning moments in X-direction, 16.54% reduction in Y-direction and 26.99% reduction in Z-direction when X-braced frame (Model 2) arrangement is used.

Time Period:

When braces are used the time period decreases this makes the structure stiffer. More stiff structure will have increased frequency and there is more chance of failure. Resonance condition can be seen when the frequency induced by the seismic waves will be equal to the natural frequency of the structure but for this condition to happen the seismic waves should not end before the structure reaching is resonating frequency.

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