EFFECT OF STEEL BRACING ON VERTICALLY IRREGULAR R.C.C BUILDING FRAMES UNDER SEISMIC LOADS

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Abstract

Earthquakes are one of the most life threatening, environmental hazardous and destructive natural phenomenons that causes shaking of ground. This result in damage to the structures, hence we need to design the buildings to withstand these earthquakes which may occur at least once in the life time of the structure. Structures possess less stiffness and strength in case of irregular configured frames; to enhance this, lateral load resisting systems are introduced into the frames. In this study, G+5 storey building model has been analyzed considering different types of vertical geometric irregularities and steel bracings using pushover analysis with the help of ETABS 9.7 software. Addition of X type brace, V type Brace and Inverted V/K type brace shows that use of X-type of bracing is found more suitable to enhance the performance of the irregular buildings.

Key Words: *pushover analysis, vertical irregularity, steel bracings, performance point.*

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1. INTRODUCTION

Earthquakes are the most destructive and life damaging phenomenon of all the times. Earthquakes are caused due to the large release of strain energy by the movement of faults, which causes shaking of ground as the seismic waves travel in all the directions inside the earth layer. These seismic waves will carry different levels of energy, have different amplitudes and arrive at various instants of time to the surface. Earthquake can be classified based on its size and occurrence into minor, moderate and strong depending on the severity of ground shaking during the earthquake event. Magnitude (M) is the parameter which is used to measure the size of the earthquake which is recorded on Seismograms. For the same magnitude, shaking of ground will have different intensity at different locations. This is measured in MMI scale (Modified Mercalli Intensity).

When an earthquake does occur, different buildings located on the same site will show variation in the level of performance experienced by them shown in Fig-1. This variation in levels depend on many factors such as random differences in the material strength, the amount of mass and stiffness of structural and non-structural members, levels of workmanship, condition of each structure, intensity and distribution of live load at the time of earthquake and response of the soil beneath the buildings. Hence there is an urgent need to assessment in urban areas of India for the seismic vulnerability of buildings which is an essential component of a comprehensive earthquake disaster risk management policy.

An ideal multi-story building which is designed to resist lateral loads due to earthquake would be symmetric in distribution of mass and stiffness in plan at every story and as well as along the height of the building. Such building would respond only laterally and is considered as torsionally balanced building. Because of restrictions as architectural requirement and functional needs, it is very difficult to achieve such a condition in the building.

Now-a-days the buildings with irregular configurations in both plan and elevation are seen. These buildings with asymmetry will suffer severely during earthquake.

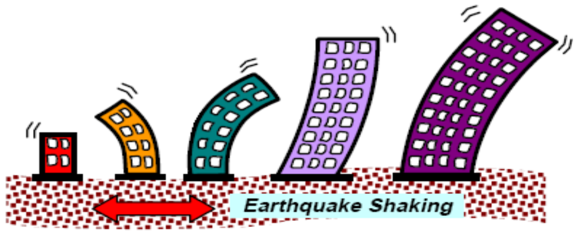

Fig-1: Seismic response of different buildings

It can be seen during previous earthquakes; such buildings undergo coupled torsion and lateral motions. A building can be designed to be earthquake proof for a rare but strong earthquake, which will be more stable but at the same time it will be more expensive. The most logical approach to the seismic design problem is to accept the uncertainty of the seismic phenomenon.

The analysis procedure teaches us how to identify the earthquake forces and its demand. Depending on the importance and cost, the method of analyzing the structure varies from linear to non-linear. Both the linear and nonlinear analysis procedures can be performed statically as well as dynamically. The static non-linear procedure indicates which part of the building fails first.

The elements begin to yield and deform in elastically as the load and displacement increases. The resulting curve shows the capacity of the building and demand from a specific earthquake (or) intensity of ground shaking. This graph will generate a point on the curve where capacity and demand are equal and is called as 'Performance point'. It is an estimate of actual displacement of building for the specified ground motion. This performance point helps an engineer to characterize the associated damage state for the structure and compare it with the desired performance objective.

At last, the procedure gives the engineer a better understanding of the seismic performance characteristics of the building and results in more effective designs in new buildings and where as cost effective retrofits strategy in an existing building. The guidelines which recommends on these topics are ATC-40[16] and FEMA-356[17].

2. STEEL BRACINGS SYSTEM

Braced-frames virtually eliminate the columns and girder bending factors and thus improve the efficiency of the pure rigid frame actions. By the addition of truss members such as diagonals (between the floor systems) this can be achieved effectively. These diagonals carry the lateral loads and transfers the axial loads to the columns, which is an effective structural system.

2.1Types of Bracing Systems

There are mainly two types of bracing systems.

i. Concentric bracing system.
ii. Eccentric bracing system

i. Concentric bracing increases the lateral stiffness of the frame which in turn increases the natural frequency and also decreases the lateral storey drift. Further, the bracing increases the axial compression in the columns to which they are connected by decreasing the bending moments and shear forces in the column.
ii. Eccentric bracing improves the energy dissipation capacity and reduces the lateral stiffness of the system. At the point of connection of eccentric bracings on the beams, the vertical component of the bracing force due to earthquake causes concentrated load.

3. MODELING AND ANALYSIS

In the present study reinforced concrete frame building of G+ 5 storeys is considered. The plan layout and elevations of bare frames are shown in the figures below. The different configurations of buildings are modeled by considering only mass of the infill. The storey height is kept uniform of 3m for all building models. The building models are studied for vertical geometric irregularity in seismic zone V of India. Later on Steel bracings are provided on the outer periphery of the models on all the four sides and analyzed. Types of bracings considered for the study are X-type, V-type and K-type bracing.

Table-1: Assumed data for the study

Sl No.	Contents	Description
1	Grade of Concrete	M30
2	Young's modulus of Concrete, E	27386.127 N/mm^2
3	Density of Concrete	25 kN/m^3
4	Poisson's ratio of Concrete	0.2
5	Grade of Steel	Fe415
6	Young's modulus of Steel	20000 N/mm^2
7	Density of Steel	76.81 kN/m^3
8	Poisson's ratio of Steel	0.3
9	Slab thickness	0.15m
10	Size of Column	0.3m X 0.5 m (upto roof from 5th floor)
		0.3m X 0.8 m (upto 5th from base)
11	Size of Beam	0.3m X 0.45 m (upto roof from 5th floor)
		0.3m X 0.6 m (upto 5th floor from base)
12	Bracing section	ISMB350
13	Roof and Floor finish	1 kN/mm^2
14	Live load on Roof	2 kN/mm^2
15	Live load on Floor	3 kN/mm^2
16	Wall load	12 kN/mm^2

Model M-1- Building is modeled as bare frame, however the mass of the walls are included. The plan of the building is symmetrical in shape and consisting of 5X5 bays (Fig-4).

Model M-2- Building is modeled as bare frame. The Vertical configuration of the structure and lateral force resisting system in top storey consist an offset of 60% in X direction only on one side (Fig-5).

Model M-3- Building is modeled as bare frame. The Vertical configuration of a structure and lateral force resisting system in top story consist an offset of 40% in X direction on each side (Fig-6).

Model M-4- Building is modeled as bare frame. The Vertical configuration of a structure and lateral force resisting system in top story consist an offset of 20% in X direction on each side (Fig-7).

Model M-5- Building is modeled as bare frame. The Vertical configuration of a structure and lateral force resisting system in top story consist an offset of 16.66% in X direction on each side (Fig-8).

Model M-6- Building is modeled as bare frame. The Vertical configuration of a structure and lateral force resisting system in top story consist an offset of 1.5 times lesser than the width of the base of the building in X direction only on one side (Fig-9).

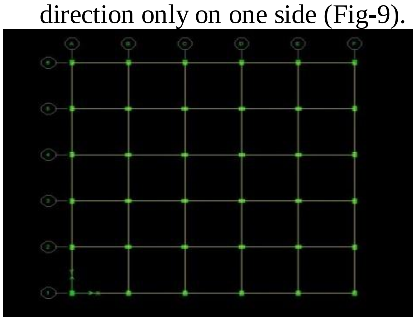

Fig-2: Common Plan for all the Models

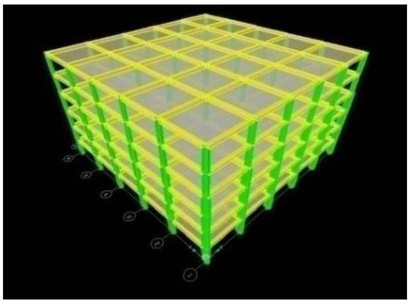

Fig-3: 3D view of Model M-1

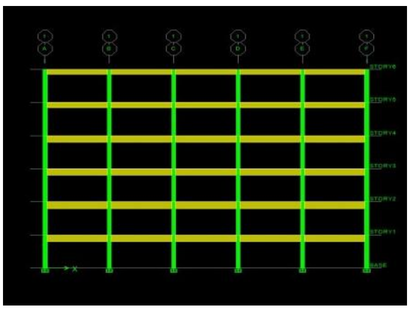

Fig-4: Elevation of Model M-1

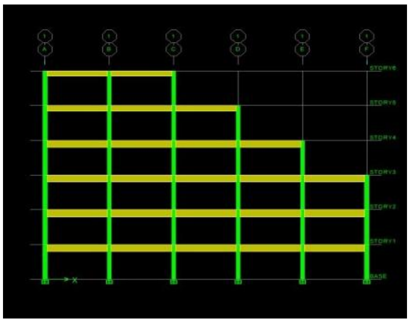

Fig-5: Elevation of Model M-2

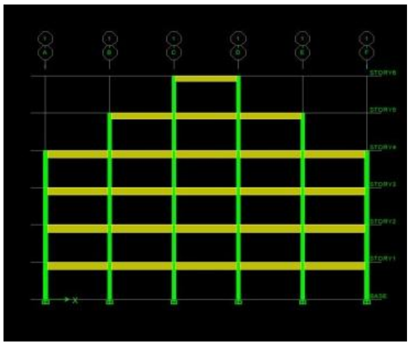

Fig-6: Elevation of Model M-3

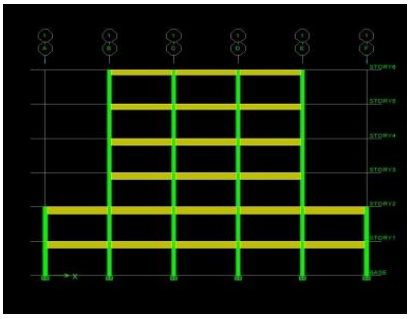

Fig-7: Elevation of Model M-4

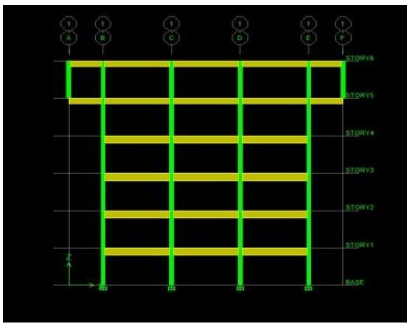

Fig-8: Elevation of Model M-5

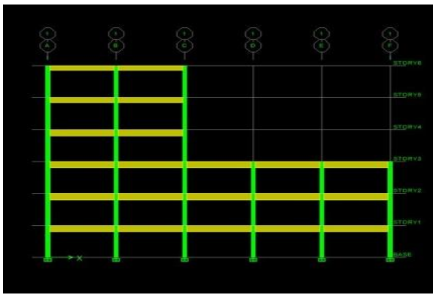

Fig-9: Elevation of Model M-6

The analysis is carried out for the bare frames as well as for the braced frames by considering X type bracing, V type bracing and Inverted V/K bracing for the same model configurations described above.

4. RESULTS AND DISCUSSION

G+5 storey building is analyzed for bare frame models and steel braced frame models for obtaining the following results. Later on the results of bare frame models are compared with braced frame models in terms of lateral displacement, storey drift, base shear and performance point.

4.1 Linear analysis

4.1.1 Lateral Displacement

It is clear that the addition of bracings to the bare frames and irregular configured buildings will reduce the lateral displacement to a greater extent.

Table-2: Comparison results of Lateral displacement (mm) for bare frame and braced frame models

Model No.	Model M6	Model M6-X	Model M6-V	Model M6-K
Model M-1	27.40	5.40	6.30	6.10
Model M-2	24.20	5.00	5.80	5.60
Model M-3	22.10	4.70	5.40	5.20
Model M-4	26.40	5.70	6.60	6.40
Model M-5	33.00	6.80	7.80	7.40
Model M-6	27.40	6.00	6.90	6.60

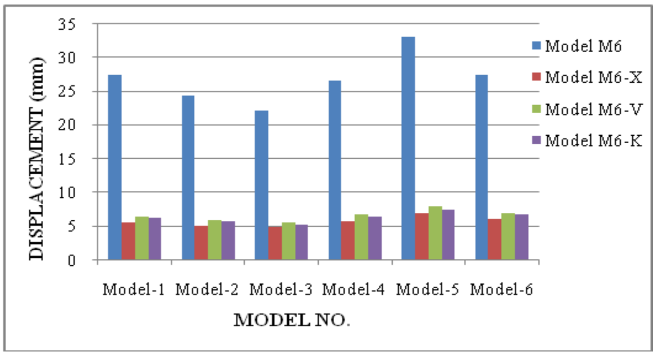

Chart-1: Comparison graph of Lateral Displacement for bare frame and braced frame models

The above graph shows that the addition of X type bracing will reduce maximum lateral displacement in the bare frame models. Maximum displacement is seen in Model-5. The reduction varies from 80.3% to 78.1% by the use of X type bracing, 77% to 74.81% by the use of V type bracing and 77.73% to 75.91% by using K type bracing. We can see there is a reduction of 80.3% in the Model-1 by using X type steel bracing.

4.1.2 Storey drift

Storey drift of the models are also reduced by the addition of steel bracings. For comparison maximum storey drift is **considered.**

Table-3: Comparison results of Storey drift for bare frame and braced frame models

Model No.	Model M6	Model M6-X	Model M6-V	Model M6-K
Model M-1	0.001937	0.000277	0.000323	0.00031
Model M-2	0.001836	0.000300	0.000348	0.000334
Model M-3	0.001472	0.000242	0.000282	0.000272
Model M-4	0.002074	0.000358	0.000413	0.000396
Model M-5	0.003178	0.000395	0.000456	0.000427
Model M-6	0.002532	0.000463	0.000535	0.000507

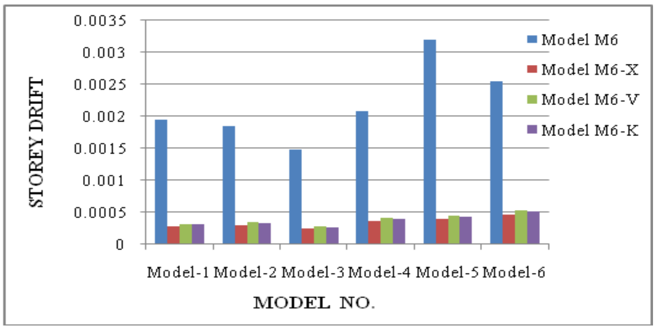

Chart-2: Comparison graph of Storey drift for bare frame and braced frame models

The above graph shows that the addition of X type bracing will reduce maximum Storey drift in the bare frame models. Maximum storey drift is seen in Model-5. The reduction varies from 87.57% to 81.71% by the use of X type bracing, 85.65% to 78.87% by the use of V type bracing and 86.56% to 79.97% by using K type bracing. We can see there is a reduction of 87.57% in the Model-5 by using X type steel bracing.

4.1.3 Base Shear

There is a slight increase in the base shear of the buildings considered by the addition of bracings.

Table-4: Comparison results of Base shear (kN) for bare frame and braced frame models

Model No.	Model M6	Model M6-X	Model M6-V	Model M6-K
Model M-1	4339.42	4397.78	4378.51	4378.51
Model M-2	3662.03	3714.03	3696.86	3696.86
Model M-3	3732.30	3784.25	3767.08	3767.08
Model M-4	3291.30	3341.14	3324.67	3324.67
Model M-5	2963.36	3011.48	2995.82	2995.82
Model M-6	3217.12	3266.26	3250.13	3250.13

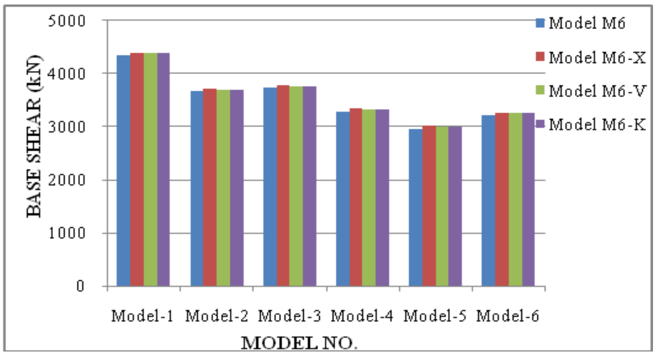

Chart-3: Comparison graph of Base shear for bare frame and braced frame models

4.2 Performance Point

Performance point is an estimate of the actual displacement and base shear of the building for the specified ground motion. Addition of bracings to the bare frame shows a huge increase in the performance point.

Table-5: Comparison results of Performance point (kN) for bare frame and braced frame models

Model No.	Model M6	Model M6-X	Model M6-V	Model M6-K
Model M-1	10585.86	35516.17	33580.93	34382.76
Model M-2	9550.87	29485.13	29238.73	29222.47
Model M-3	9919.22	31252.45	31030.3	31098.73
Model M-4	8197.05	23665.88	23354.24	23555.87
Model M-5	8280.85	22504.27	20596.37	21526.46
Model M-6	8217.73	22283.3	22205.44	22178.96

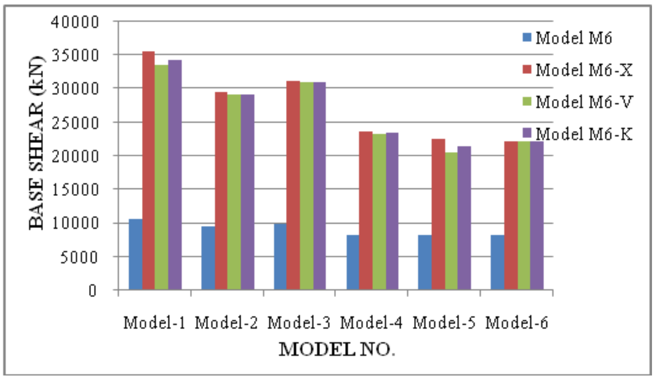

Chart-4: Comparison graph of Performance point (kN) for bare frame and braced frame models

The above graph shows that the addition of X type bracing will increase maximum performance point in the bare frame models. Minimum performance point is seen in Model-4. The increase varies from 235.50% to 171.16% by the use of X type bracing, 217.22% to 148.72% by the use of V type bracing and 224.79% to 159.95% by using K type bracing. We can see there is an increase of 235.50% in the Model-1 by using X type steel bracing.

5. CONCLUSIONS

The analysis of G+5 storey model for regular and irregular configuration with the addition of steel bracings concludes the following.

1. Introduction of irregularities affects the performance of the building.
2. Lateral displacement and Storey drift increases as the amount of irregularity present in the building increases.
3. Base shear of irregular configured buildings will be less compared with the regular building.
4. Performance point of regular frame is found more than the irregular frame.
5. Addition of bracings to the bare frames shows reduction in lateral displacement and storey drift.

6. Base shear of the bare frame is also increased in the presence of steel bracings.
7. There is large increase in the Performance point of bare frames when the bracings are added to it.
8. Use of X type of bracing is found more suitable among all the bracings considered in this study.

From the above conclusions it is clear that the use of irregular configuration will cause greater damage to the structure during earthquakes. Hence addition of steel bracings improves its lateral load carrying capacity

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