Comparative Study on Braced Unbraced Regular and Re-entrant Corners Irregular Steel Building

Ashwini Baviskar[1], V.G. Jadhav[2]

[1]M.Tech. Student, *Dept. of Civil Engineering, MGM's JNEC, Maharashtra, India*
[2]Assistant Professor, Dept. of Civil Engineering, MGM*'s JNEC, Maharashtra, India*

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Abstract – Structures which are located in seismic zone undergo damage due to story lateral displacement and story drift. Inclusion of steel bracing has proved to be very useful in reducing the story drift and displacement. In present study effectiveness of inclusion of steel bracing in regular and irregular structure having re-entrant corners at different locations is analyzed. The structure is 10 story steel building and it is analyzed dynamically using response spectrum method of analysis as per IS 1893-2016 in ETABS 17 software.

Key Words: plan irregularity, re-entrant corners, lateral displacement, storey drift, response spectrum analysis, dynamic analysis, seismic analysis, ETABS.

1. INTRODUCTION

Due to seismic activities economical and life loss takes place. Even after designing the building as per seismic codes adequate strength is not attained. Hence provision of special lateral force resisting system proves to be very necessary. Steel bracing is very effective in reducing the lateral displacement as well as storey drift.

Static and Dynamic these are the two methods of structural analysis. According to IS: 1893-2016 For buildings having height greater than 15m and located in seismic zone II or above must be analyzed using 3D dynamic method of analysis. In the present study Response Spectrum method is performed using ETABS 17.

1.1 Steel Bracing

Steel bracings are broadly classified as Eccentric and Concentric which are again classified as V, K, X etc. Out of these two concentric X type bracings are very efficient in reducing the story displacement and story drift and also increasing the base shear carrying capacity of the structure. Hence these are very effective lateral load resisting systems to be used in the structure located in seismic zone. Analysis of such buildings can be performed using ETABS, SAP, STAAD softwares with ease.

The bracings can be included in structure along its outer face, corners or also internally. In present study concentric X type bracing is used.

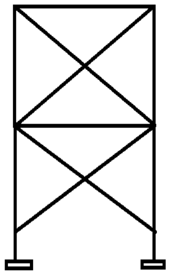

Fig -1: X Braced Frame

2. MODELLING

G+9 multi-storied steel building having 5 bays in both X and Y directions is considered. Corresponding L and Plus shaped irregular buildings with re-entrant corners are also considered. These buildings are analyzed with and without bracing. The bracings are located on face, corners or internal frames and response spectrum analysis is carried out.

Table -1: Necessary Data for Modeling

Type of building	Steel
No of story	G+9
Plan Dimension	20x20m
No. of grids	6 along X and Y direction
Width of each bay	4m
Height of each story	3m
Material Properties	Steel grade: Fe345 Concrete Grade: M25
Section Properties	Beam: ISWB 300 Column: ISHB 400-2 X Bracing: ISLB 175 Slab thickness: 150 mm

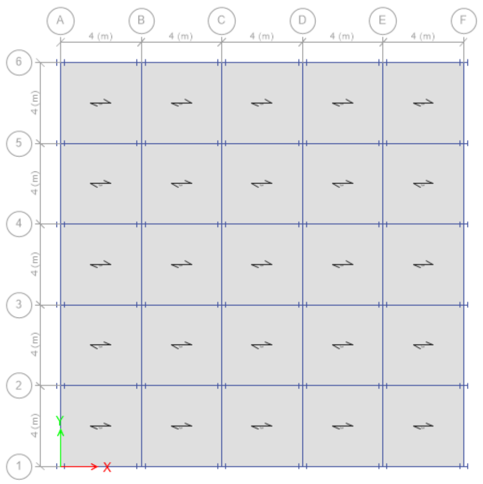

Fig -2: Regular plan building Model 1

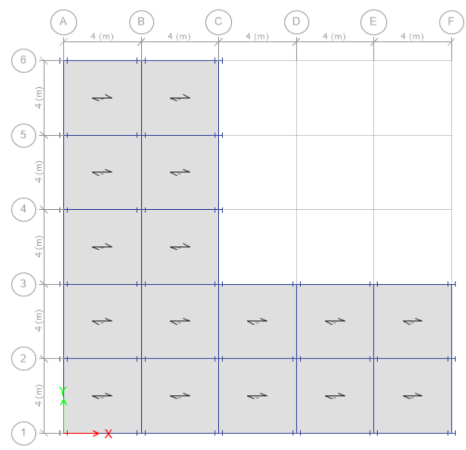

Fig -3: Irregular L-shape building with re-entrant corners Model 2

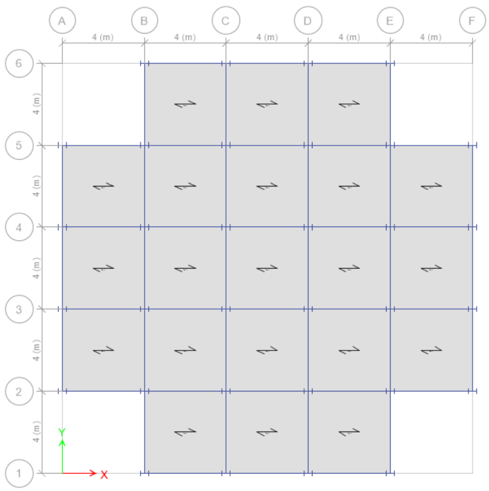

Fig -4: Irregular Plus-shape building with re-entrant corners Model 3

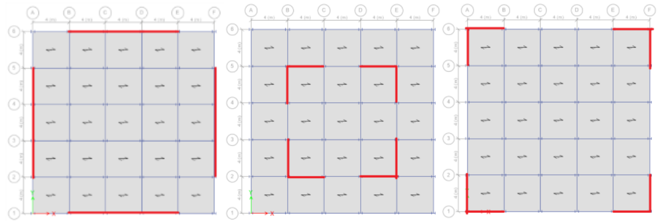

Fig -5: Regular plan building showing braces located on faces, internally, at corners Model 1A), 1B), 1C) respectively

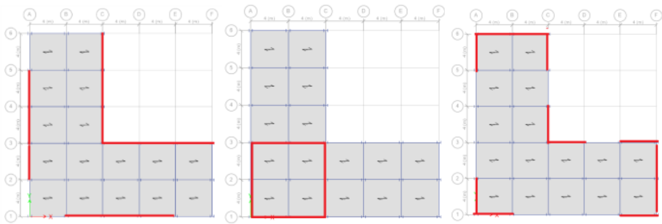

Fig -6: L shaped building showing braces located on faces, internally, at corners Model 2A), 2B), 2C) respectively

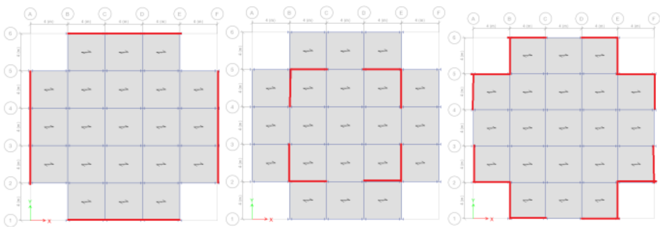

Fig -7: Plus shaped building showing braces located on faces, internally, at corners Model 3A), 3B), 3C) respectively

3. ANALYSIS

In IS 1893 Part 1 -2016 there are broadly two methods of analysis which are Static and Dynamic. Static method is known as equivalent static method also. Dynamic method is of two types one is time history method and other is Response spectrum method. The static method can only be used for structure of height up to 15m and located in zone II. In other cases dynamic methods must be adopted. Even in case of structural irregularity dynamic analysis must be done.

The structure 30m high is analyzed for Seismic Zone III and also having re-entrant corners the linear dynamic analysis is performed using response spectrum method. In response spectrum method the structure is considered as single degree of freedom system (SDOF) of varying natural period hence effects on structure are related to this simple SDOF system.

Hence response spectrum analysis is carried out in present study. Following is the necessary data for analysis.

Loads on structure	Dead load: 1 kN/m² Live load: 3 kN/m²
Seismic Zone	III
Zone factor (Z)	0.16
Importance factor (I)	1
Soil type	Type II
Response reduction factor (R)	4
Damping percentage	5%

4. RESULTS AND DISCUSSION

4.1 Lateral Displacements

Maximum lateral displacement of buildings in X-direction

Table -2: Maximum Lateral displacement of regular plan building Model 1, 1A), 1B), 1C)

Model	Model 1	1 A)	1 B)	1 C)
Maximum Displacement at top story (mm)	13.15	8.61	10.61	10.59

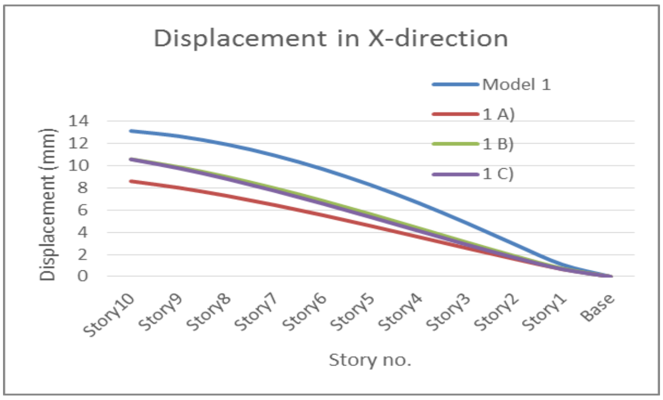

Chart -1: Story displacement of model 1, 1A, 1B, 1C.

After application of braces on faces of structure maximum reduction in displacement in X direction is 34.52%.

Table -3: Maximum Lateral displacement of L-shaped building Model 2, 2A), 2B), 2C)

Model	Model 2	2 A)	2 B)	2 C)
Maximum Displacement at top story (mm)	14.75	13.18	13.68	10.94

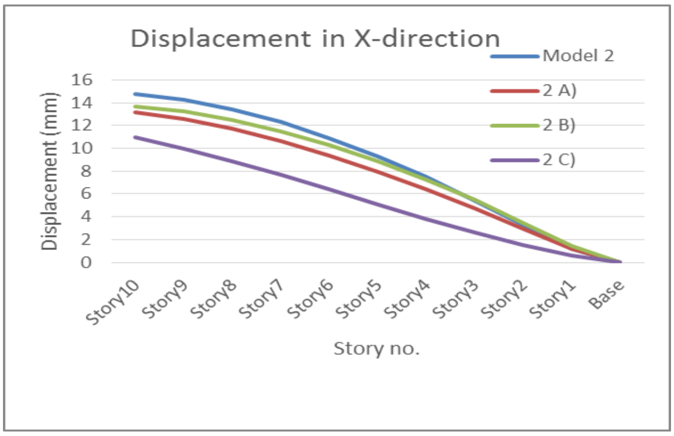

Chart -2: Story displacement of model 2, 2A, 2B, and 2C.

After application of bracing at re-entrant corners the displacement in X direction is reduced by 25.83%.

Table -4: Maximum Lateral displacement of plus-shaped building Model 3, 3A), 3B), 3C)

Model	Model 3	3 A)	3 B)	3 C)
Maximum Displacement at top story (mm)	13.72	8.73	10.21	8.25

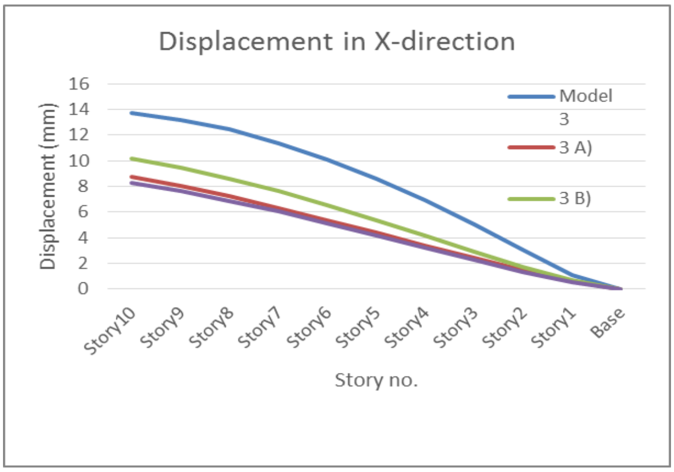

Chart -3: Story displacement of model 3, 3A, 3B, and 3C.

After including bracing at re-entrant corners the lateral displacement in X direction is reduced by 39.87%.

Maximum lateral displacement of buildings in Y-direction

Table -5: Maximum Lateral displacement of regular plan building Model 1, 1A), 1B), 1C)

Model	Model 1	1 A)	1 B)	1 C)
Maximum Displacement at top story (mm)	22.28	9.61	12.90	13.37

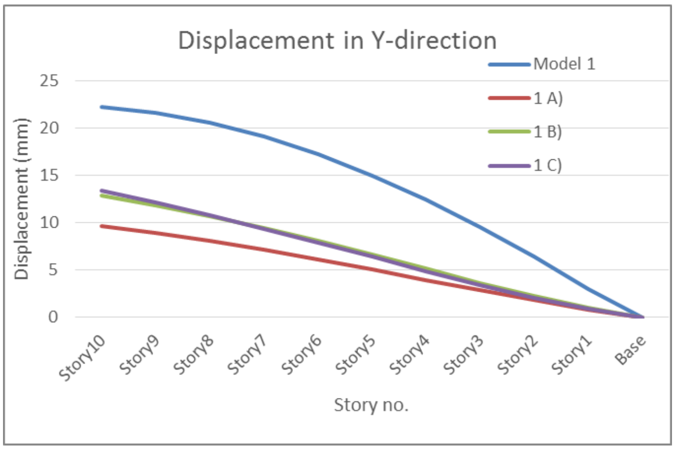

Chart -4: Story displacement of model 1, 1A, 1B, 1C.

After application of braces on faces of structure maximum reduction in displacement in Y direction is 56.87%.

Table -6: Maximum Lateral displacement of L-shaped building Model 2, 2A), 2B), 2C)

Model	Model 2	2 A)	2 B)	2 C)
Maximum Displacement at top story (mm)	22.91	15.13	18.46	11.93

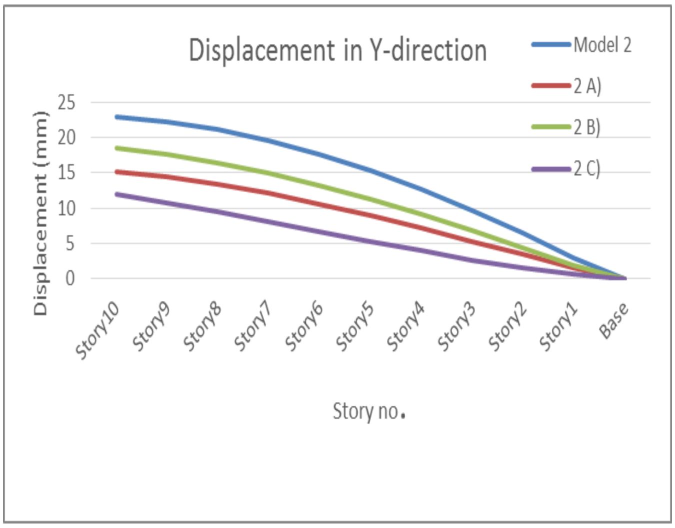

Chart -5: Story displacement of model 2, 2A, 2B, 2C

After application of bracing at re-entrant corners the displacement in Y direction is reduced by 47.93%.

Table -7: Maximum Lateral displacement of plus-shaped building Model 3, 3A), 3B), 3C)

Model	Model 3	3 A)	3 B)	3 C)
Maximum Displacement at top story (mm)	23.07	9.53	12.20	9.13

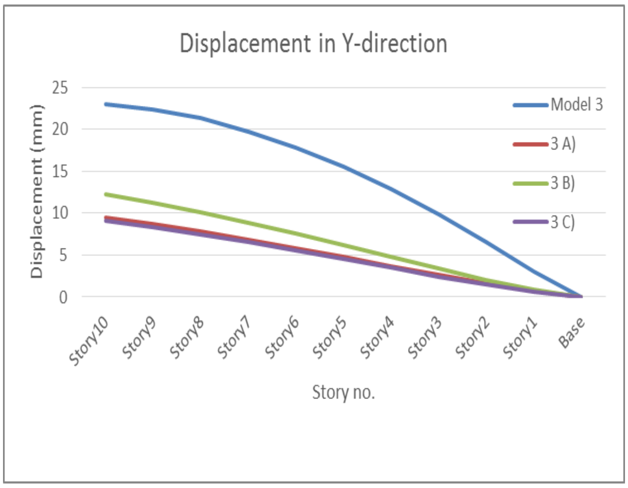

Chart -6: Story displacement of model 3, 3A, 3B, and 3C.

After including bracing at re-entrant corners the lateral displacement in Y direction is reduced by 60.42%.

4.2 Story Drift

Maximum story drift of buildings in X-direction

Table -8: Maximum story drifts of different buildings in X-direction

Model configuration	Maximum story drift		
	Regular plan building	L shaped building	PLUS shaped building
Unbraced Model	0.00068	0.00072	0.00067
Bracing on faces	0.00034	0.00065	0.00035
Internal bracing	0.00043	0.00070	0.00041
Corner bracing	0.00045	0.00045	0.00033

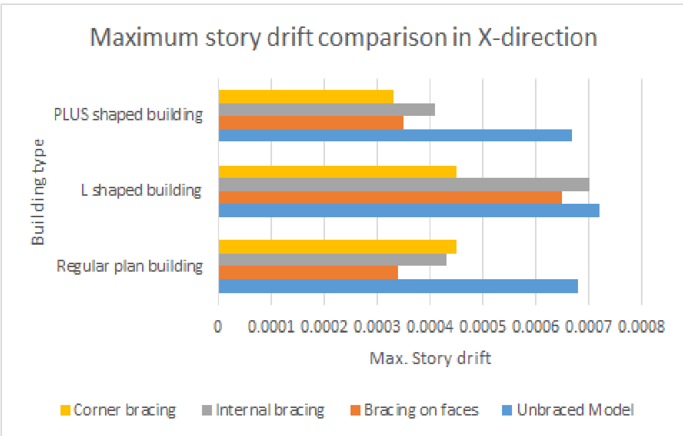

Chart -7: Story drift comparison in X-direction

In X-direction maximum 50%, 37.5% and 50.75% reduction in story drift is achieved in case of Regular, L shaped and PLUS shaped buildings respectively.

Maximum story drift of buildings in Y-direction

Table -9: Maximum story drifts of different buildings in Y-direction

Model configuration	Maximum story drift		
	Regular plan building	L shaped building	PLUS shaped building
Unbraced Model	0.00121	0.00117	0.00119
Bracing on faces	0.00037	0.00071	0.00038
Internal bracing	0.00051	0.00083	0.00041
Corner bracing	0.00057	0.00049	0.00036

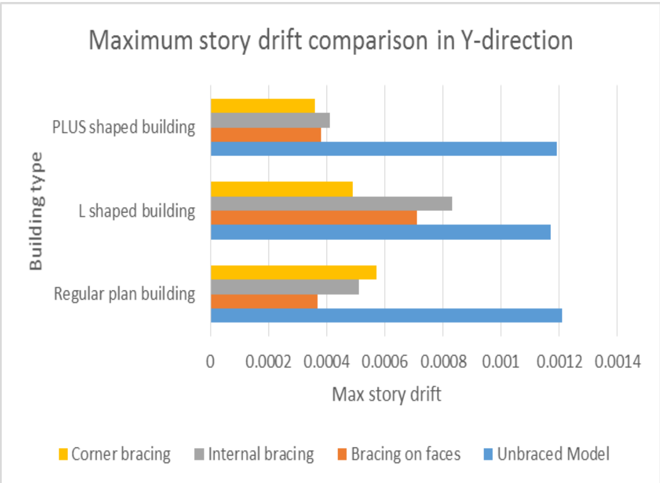

Chart – 8: Story drifts comparison in Y-direction

In Y-direction maximum 69.42%, 58.12% and 69.75% reduction in story drift is achieved in case of Regular, L shaped and PLUS shaped buildings respectively.

5. CONCLUSIONS

After analysis of 10 storied regular and irregular steel buildings with and without bracings the following conclusions are made.

1. In case of regular and irregular structures the steel braced frames found to have good performance over the conventional bare frames by reducing the story displacement and story drift.
2. In case of regular structure the application of bracing on faces reduced story displacement by 34.52% and 56.87% in X and Y direction respectively. Also story drift is reduced by 50% and 69.42% in X and Y direction respectively.
3. In case of L shaped structure with re-entrant corners the application of bracing on re-entrant building corners reduced story displacement by 25.83% and 47.93% in X and Y direction respectively. Also story drift is reduced by 37.5% and 58.12% in X and Y direction respectively.
4. In case of PLUS shaped structure with re-entrant corners the application of bracing on re-entrant building corners reduced story displacement by 39.87% and 60.42% in X and Y direction respectively. Also story drift is reduced by50.75 % and 69.75% in X and Y direction respectively.

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