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Effective Study of Bracing Systems for Irregular Tall Steel Structures

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Abstract: A high-rise or any multi-level structure is subjected to lateral or torsional deflections under the action of lateral loads, the resulting oscillatory movement can induce a wide range of responses in the building. As a result, lateral stiffness is a major consideration in the design of tall buildings. Bracing is a highly efficient and economical method of resisting lateral forces in a frame structure because the diagonals work in axial stress and therefore call for minimum member sizes in providing the stiffness and strength against horizontal shear. In this project, different types of bracing systems have been investigated for the use in tall building in order to provide lateral stiffness. The use of bracings has potential advantage over other scheme, the bracings are provided for peripheral columns. A multi-storey building with (G+19) floors situated at a seismic zone II is subjected to a wind speed of 33 m/s. The building models are analyzed by equivalent static analysis as per IS 1983: 2002 using STAAD ProV8i software and wind load analysis is analyzed as per IS:875(part 3)-1987.

Keywords: High rise structure, Bracing systems, Equivalent static analysis, Lateral force, Lateral stiffness, peripheral columns, Wind load analysis.

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I. INTRODUCTION

When a tall building is subjected to lateral or torsional deflections under the action of fluctuating wind loads, the resulting oscillatory movement can induce a wide range of responses in the building's occupants from mild discomfort to acute nausea. As far as the ultimate limit state is concerned, lateral deflections must be limited to prevent second order p-delta effect due to gravity loading being of such a magnitude which may be sufficient to precipitate collapse. To satisfy strength and serviceability limit stares, lateral stiffness is a major consideration in the design of tall buildings. The simple parameter that is used to estimate the lateral stiffness of a building is the drift index defined as the ratio of the maximum deflections at the top of the building to the total height.

Different structural forms of tall buildings can be used to improve the lateral stiffness and to reduce the drift index. In this, study is conducted for braced frame structures. Bracing is a highly efficient and economical method to laterally stiffen the frame structures against wind loads. Bracing is efficient because the diagonals work in axial stress and therefore call for minimum member sizes in providing the stiffness and strength against horizontal shear. Thus it is an important priority for a good structural design engineer to select the best and economical bracing system for the high rise steel structures.

II. STEEL BRACING SYSTEM

A bracing system is a structural system which is designed primarily to resist wind and seismic forces. Braced frames are designed to work in tension and compression similar to a truss. 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.

There are mainly two types of bracing systems.

i. Concentric bracing system.

ii. Eccentric bracing system.

1. Concentric bracing- These are the type of bracings whose centroidal axis coincides with each other. They mainly increase 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.

2. **Eccentric bracing**- These are the type of bracing whose centerline braces are offset from the intersection of the centerline of columns and beams. It mainly 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.

III. OBJECTIVE OF PRESENT STUDY

The objective of this study is to evaluate the response of 5 braced and un-braced structure arranged at the peripheral corners subjected to seismic loads and to identify the suitable bracing system for resisting the seismic load and wind load efficiently.

IV. MODELING AND ANALYSIS

In the present study a three dimensional T shaped framed structure with 75m*75m plan size and 20 numbers of stories is selected for the study. Storey height of 3m with 15 bays of 5m each along X and Z direction is provided for structure. The columns and beams are designed to withstand the live and dead loads adequately. The bracing sections are provided at the corners of the whole section. The lateral loads to be applied on the building are based on the Indian standards. The study is performed for seismic zone II as per IS-1893 (Part1):2002 and basic wind speed of 33 m/s as per IS-875:1987. The frames are assumed to be firmly fixed and the soil structure interaction is neglected. The load combinations and other design parameters associated with the steel structure are as per IS-800:1998.

Five major type of bracing system are analyzed with respect to un-braced reference model. They are as follows:

i. X bracing system (Model 1)
ii. Diagonal bracing system (Model 2)
iii. Inverted V bracing system (Model3)
iv. Chevron bracing system (Model 4)
v. Knee bracing system (Model 5)

The above mentioned models are analyzed for:

1. wind load analysis
2. equivalent static analysis method.

Data considered for analysis

Table 1. Modeling data for analysis

Type of structure	Steel moment resisting frame
Number of stories	G+19
Height of each storey	3.00 m
Type of building	Industrial
Seismic zone	II
Basic wind speed	33 m/s

An I section of ISMB 350 @ 52.4 Kg/m is used throughout the structure as a beam member. To withstand the load coming from beams, wall loads and slab load, a column of ISHB 400 @ 77.4 Kg/m is chosen. Double channels connected toe to toe are used as bracing elements. The channel section used for present study is ISMC 200 @ 22.1Kg/m.

Table 2. Loads considered for analysis

Density of brick wall	20 kN/m^3
Dead load on slab	4 kN/m^2
Live load on slabs	4 kN/m^2
Thickness of wall	0.2 m
Wall load on beams	10 kN/m

Table 3. Earthquake load parameters

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Zone factor, Z	0.1 for zone II
Importance factor, I	1.0
Type of soil	II (medium)
Response reduction factor, R for un-braced reference model	5
Response reduction factor , R for braced model	5
Time period, Ta	1.83 sec
Percentage of imposed load considered during seismic load calculations	50 %
Fundamental damping ratio	0.05

Table 4. Wind load parameters

Basic wind speed , V_b	33 m/s
Risk co-efficient factor, k1	1
Terrain ,height and structure size factor, k2	1
Topography factor, k3	1
Class of structure	C

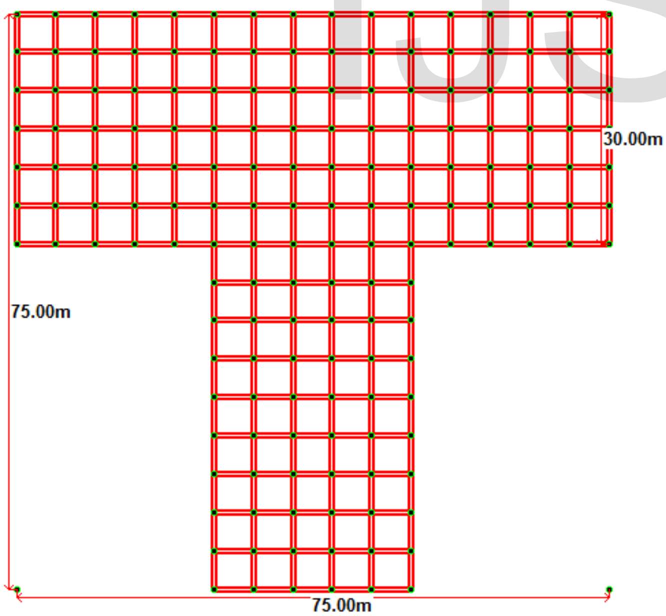

Fig 1. PLAN- Un-braced reference model

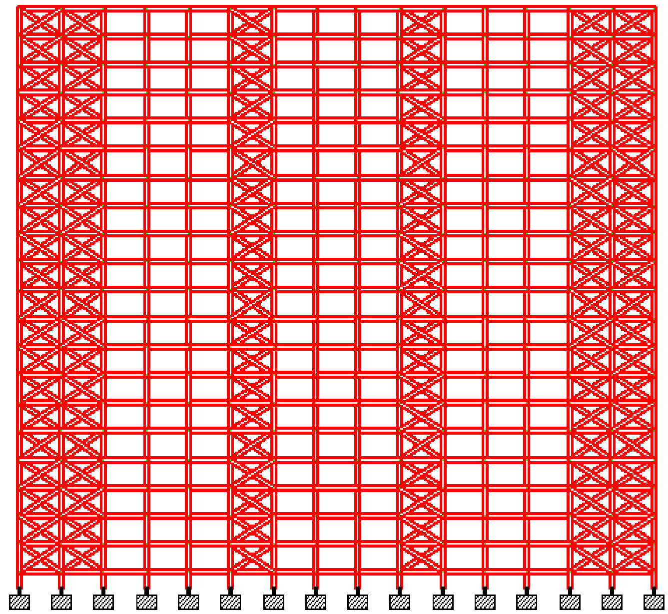

Fig 2. Elevation of X bracing system (Model 1)

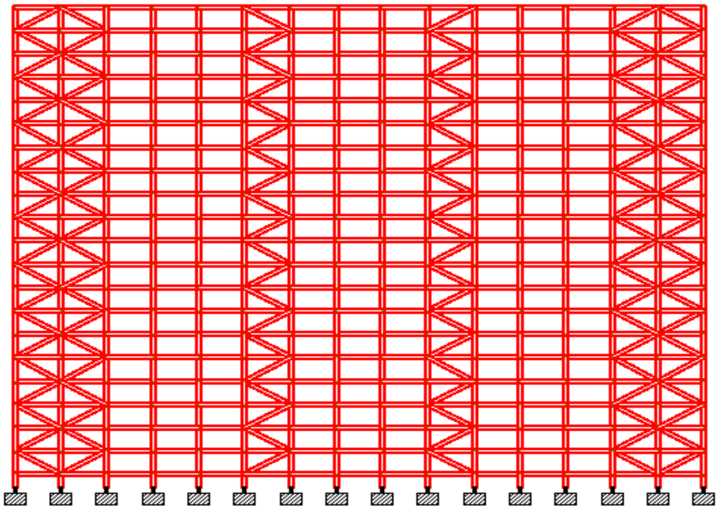

Fig 3. Elevation of Diagonal bracing system (Model 2)

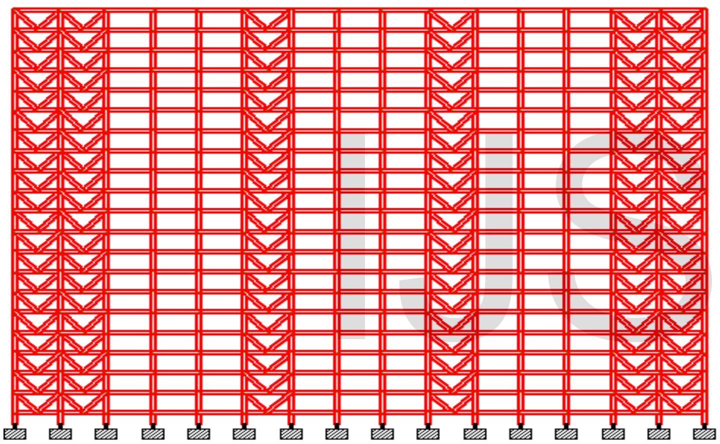

Fig 4. Elevation of Inverted V bracing system (Model 3)

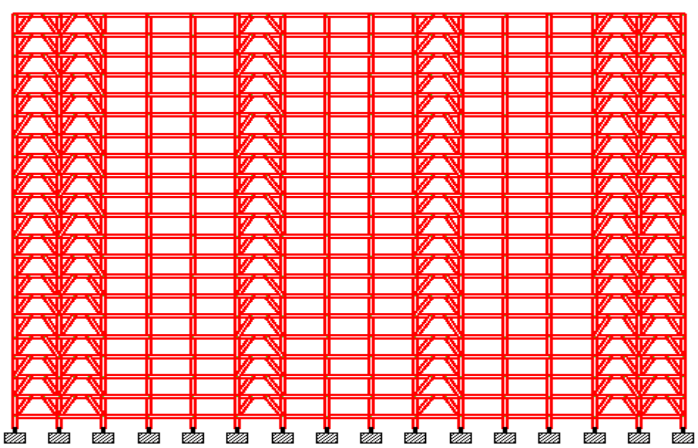

Fig 5. Elevation of eccentric bracing system (Model 4)

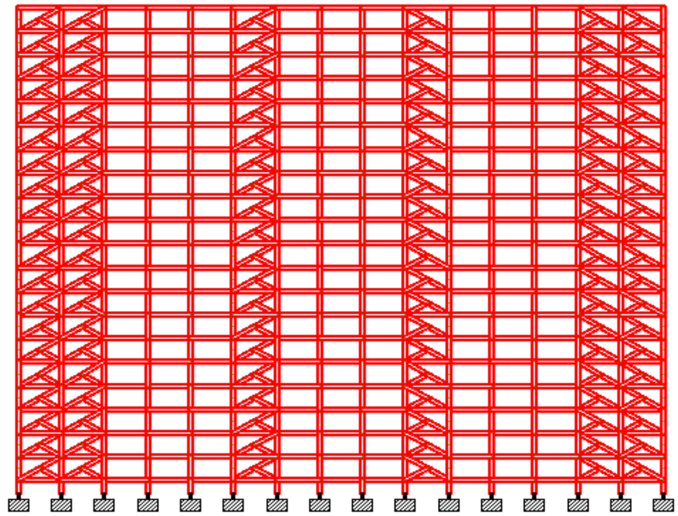

Fig 6. Elevation of knee bracing system(Model 5)

V. RESULTS

Table 5. Maximum nodal displacement at top storey in X direction at 33m/s in Zone II

Model	Node displacement (mm)
Reference model	158.741
Model 1	113.232
Model 2	107.981
Model 3	107.571
Model 4	108.172
Model 5	107.423

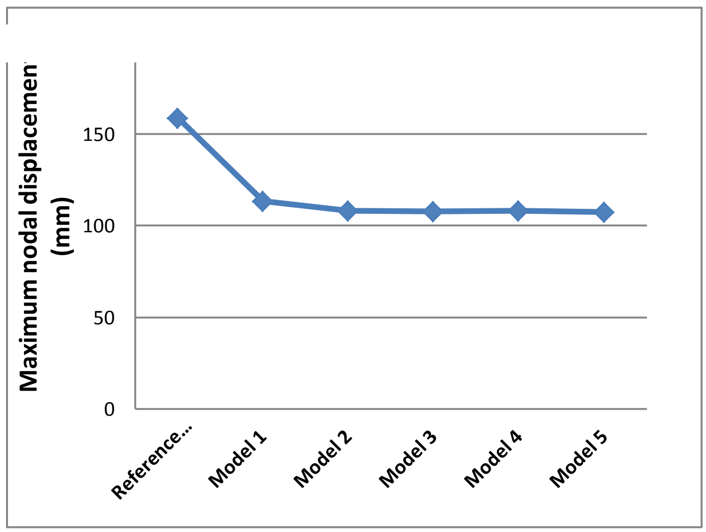

Fig 7. Maximum nodal displacement for different models in X direction for 33 m/s in Zone II.

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Table 6. Maximum nodal displacement at top storey in Z direction at 33m/s in Zone II

Model	Node displacement (mm)
Reference model	237.366
Model 1	134.333
Model 2	122.500
Model 3	122.088
Model 4	131.494
Model 5	123.859

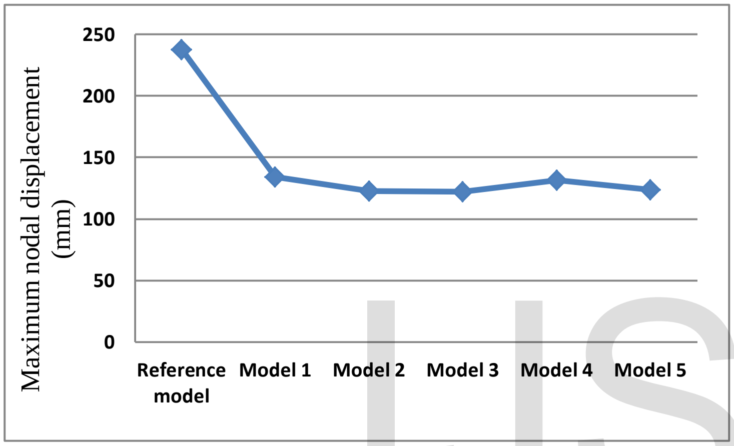

Fig 8. Maximum nodal displacement for different models in Z direction for 33 m/s in Zone II.

Table 7. Reduction in drift index percentage for various models in comparison with un-braced model along X direction in Zone II.

Model number	Displacement (mm)	Drift index	Percentage reduction
Reference model	147.863	0.002464	--
1	114.516	0.001908	22.565
2	109.165	0.001819	26.177
3	108.796	0.001813	26.420
4	109.358	0.001823	26.014
5	108.708	0.001812	26.461

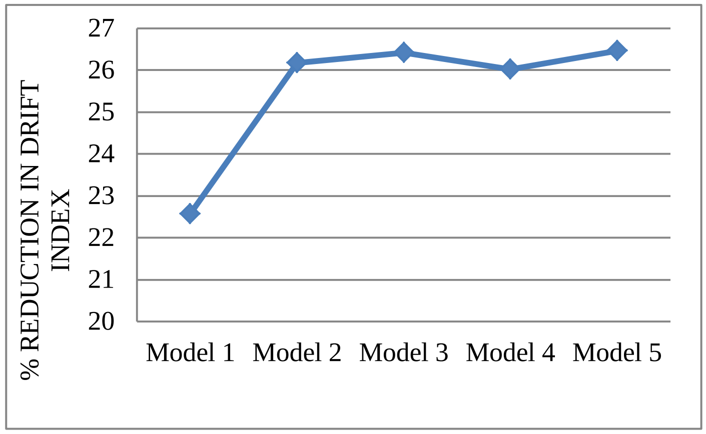

Fig 9. Reduction in drift index percentage versus various models considered along X direction

Table 8. Reduction in drift index percentage for various models in comparison with un-braced model along Z direction in Zone II

Model number	Displacement (mm)	Drift index	Percentage reduction
Reference model	223.831	0.003730	--
1	133.461	0.002224	40.375
2	123.207	0.002053	44.959
3	123.370	0.002056	44.879
4	132.685	0.002211	40.723
5	128.198	0.002137	42.708

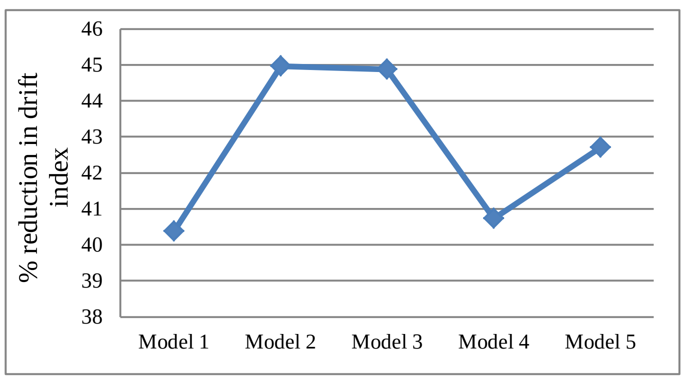

Fig 10. Reduction in drift index percentage versus various models considered along X direction

Table 9. Maximum axial force induced in the column for different bracing systems

Model number	Axial force (kN)
Reference model	1353.546
Model 1	2771.261
Model 2	2207.979
Model 3	2319.378
Model 4	2173.125
Model 5	2433.280

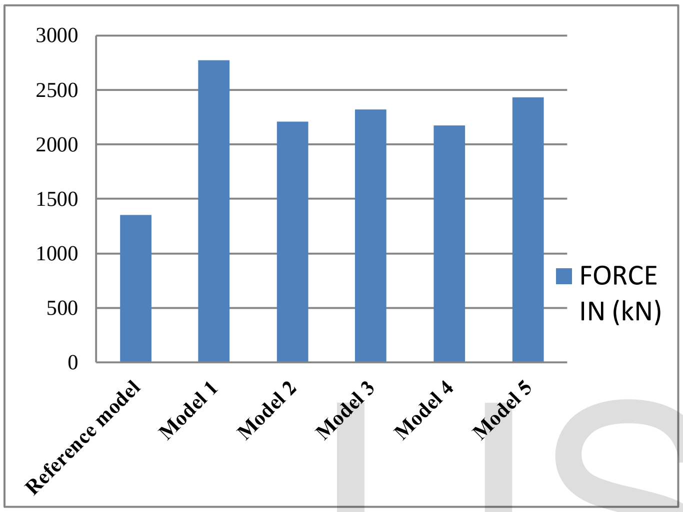

Fig 11. variation of axial force on column for different bracing system.

Table 10. Maximum bending moment induced in the different bracing systems

Model number	Bending moment (kN-m)
Reference model	97.213
Model 1	113.074
Model 2	85.581
Model 3	85.323
Model 4	127.644
Model 5	113.902

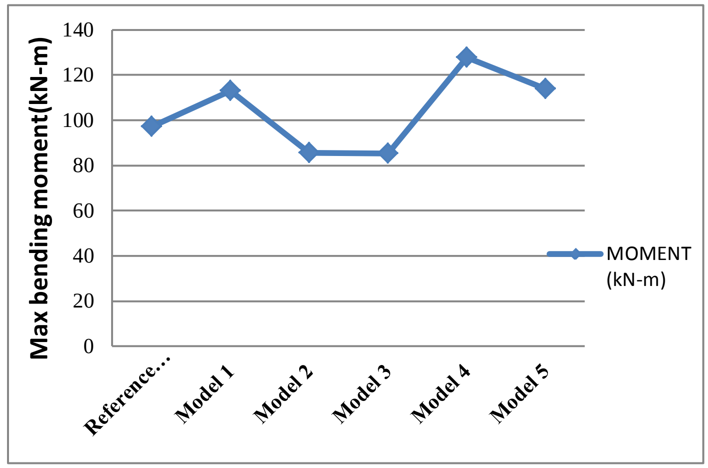

Fig 11. Maximum bending moment in column versus different bracing systems

Table 11. Quantity of structural steel for different bracing system.

Model number	Weight of steel (kN)
Reference model	23880.711
Model 1	26127.532
Model 2	25004.122
Model 3	25385.460
Model 4	25203.167
Model 5	25565.827

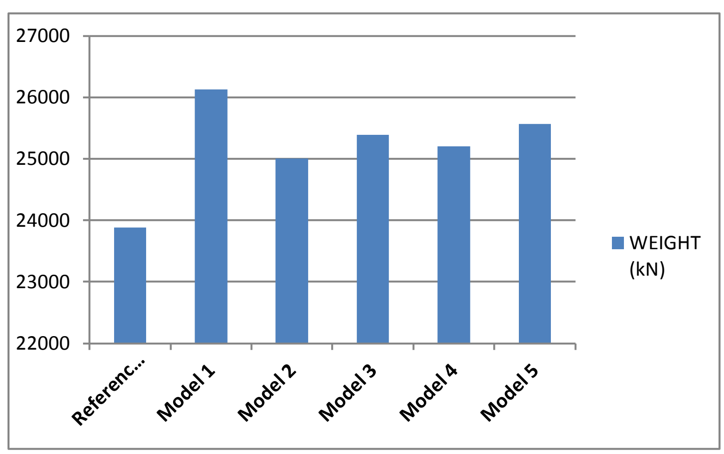

Fig 12. Variation in quantity of steel for different bracing arrangement.

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VI. CONCLUSION

Following conclusion were drawn after analyzing the different bracing systems with un-braced reference model:

1. Model 3 and Model 5 have least nodal displacements with respect to storey height when compared to un-braced reference model.
2. Model 3 has maximum reduction in drift index percentage in comparison with the un-braced reference model both in X and Z direction.
3. The axial loads on the columns increase in their value by 41.67% and 44.37% by using model 3 and Model 5 respectively.
4. The column moments have reduced by 12.21% and 12.23% by using bracings in Model 2 and Model 3 respectively.
5. The overall weight of the structure is increased by 8.60% and 6.59 % by using Model 1 and Model 5 respectively.

Thus we conclude that model 3 and model 5 consisting of diagonal bracing and knee bracing respectively are the effective bracing systems among 5 types of bracing arrangements considered for the present study.

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