Study on Effective Bracing Systems for High Rise Steel Structures

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ABSTRACT:

The resistance to the lateral loads from wind or from an earthquake is the reason for the evolution of various structural systems. Bracing system is one such structural system which forms an integral part of the frame. Such a structure has to be analysed before arriving at the best type or effective arrangement of bracing. This project is about the efficiency of using different types of bracings and with different steel profiles for bracing members for multi-storey steel frames. ETABS software is used to obtain the design of frames and bracing systems with the least weight and appropriate steel section selection for beams, columns and bracing members from the standard set of steel sections. A three dimensional structure is taken with 4 horizontal bays of width 4 meters, and 20 stories is taken with storey height of 3m. The beams and columns are designed to withstand dead and live load only. Wind load and Earthquake loads are taken by bracings. The bracings are provided only on the peripheral columns. Maximum of 4 bracings are used in a storey for economic purposes. In this study, an attempt has been made to study the effects of various types of bracing systems, its position in the building and cost of the bracing system with respect to minimum drift index and inter storey drift.

Keyword: *Bracing System; Tall Buildings; structural weight; lateral displacement.*

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 research the study is conducted for braced frame structures. Bracing is a highly efficient and economical method to laterally stiffen the frame structures against wind loads. A braced bent consists of usual columns and girders whose primary purpose is to support the gravity loading, and diagonal bracing members that are connected so that total set of members forms a vertical cantilever truss to resist the horizontal forces. 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.

1.1 Types of Bracings:

There are two types of bracing systems
1) Concentric Bracing System and 2) Eccentric Bracing System.

The steel braces are usually placed in vertically aligned spans. This system allows to obtaining a great increase of stiffness with a minimal added weight.

1) Concentric bracings increase the lateral stiffness of the frame thus increases the natural frequency and also usually decreases the lateral storey drift. However, increase in the stiffness may attract a larger inertia force due to earthquake. Further, while the bracings decrease the bending moments and shear forces in columns and they increase the axial compression in the columns to which they are connected.

2) Eccentric Bracings reduce the lateral stiffness of the system and improve the energy dissipation capacity. The lateral stiffness of the system depends upon the flexural stiffness property of the beams and columns, thus reducing the lateral stiffness of the frame. The vertical component of the bracing forces due to earthquake causes lateral concentrated load on the beams at the point of connection of the eccentric bracings.

1.2 Behaviour

Because lateral loading on a building is reversible, braces will be subjected in turn to both tension and compression, consequently, they are usually designed for the more stringent case of compression. For this reason, bracing systems with shorter braces, for example K bracing, may be preferred to the full diagonal types. As an exception to designing braces for compression, the braces in the double diagonal is designed to carry in tension the full shear in panel. A significant advantage of the fully triangulated bracing types is that the girders moments and shears are independent of the lateral loading on the structure. Consequently, the floor framing, which in this case, is designed for gravity loading only, can be repetitive throughout the height of the structure with obvious economy in the design and construction. The role of web members in resisting shear can be demonstrated by following the path of the horizontal shear down the braced bent as shown in Fig.1.

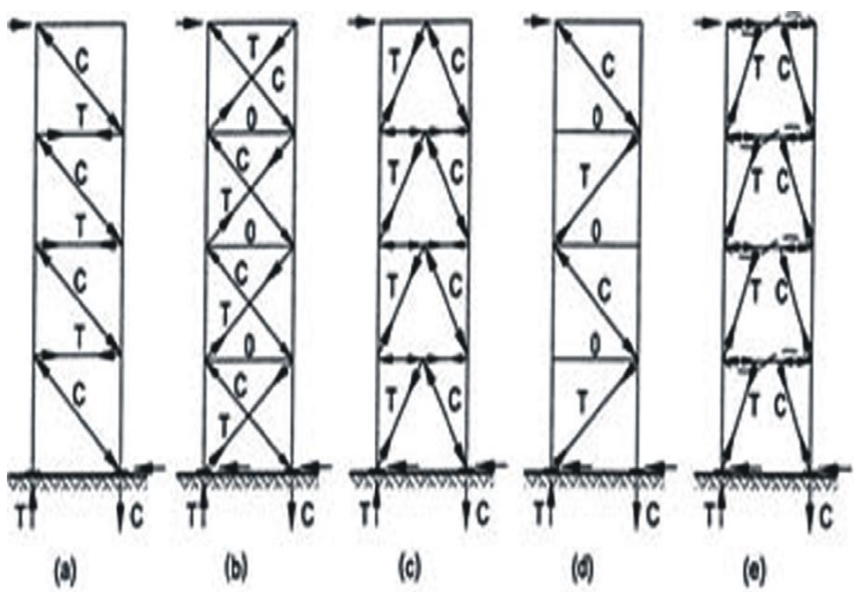

Fig 1: Behavior of Braces

2. MODELLING

The RC building used in this study is twenty storied (G+19) building having same floor plan with 4 bays of 4m each along longitudinal direction and along transverse direction as shown in figure.2. The storey height is 3m for all the stories. The live load taken has 3 KN/m^2 for all floors while the floor while the floor finish load is taken as 1 kN/m^2 on all other floors. Thickness of brick wall over all floor beams is taken as 0.230 m. Thickness of slab is taken as 0.125 m. The unit weight of reinforced concrete is $25kN/m^3$ and brick masonry is taken as $20kN/m^3$. The compressive strength of concrete is 30 N/mm^2 and yield strength of steel reinforcements is 415 N/mm2.The modulus of elasticity of concrete and steel are 25000 N/mm^2 and 2×10^5 N/mm^2 respectively. All the above mentioned building frames are analysed as per requirement of IS 800 and IS 1893. All the structures have been considered to be located in seismic region V with an importance factor 1 and sub-soil type 2 (medium). Seismic analysis is carried out on building models using the software ETABS. The load cases considered in the seismic analysis are as per IS 1893 – 2002.

Following models are considered for the analysis and design as per Limit State Design.
1. Without Brace model
2. X brace model
3. Single diagonal braces arranged to form a diamond shape in 3rd and 4th bay.
4. V brace model.
5. Inverted V brace model.

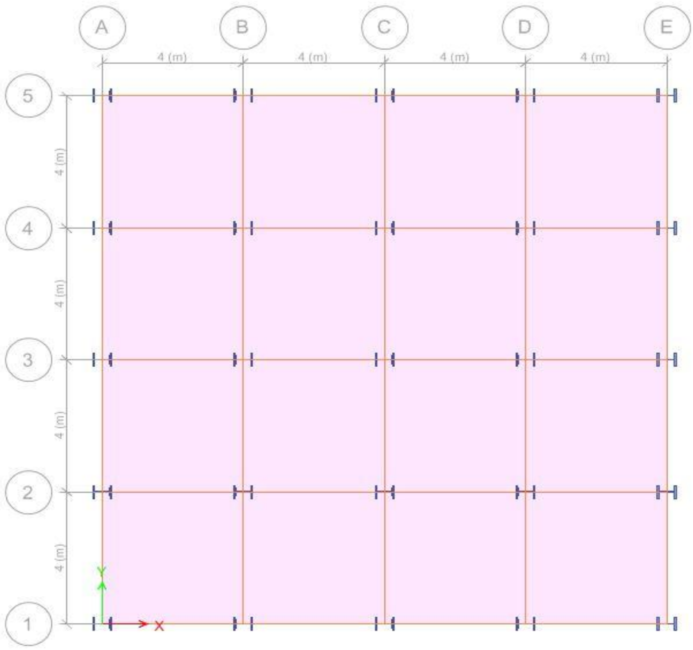

Fig 2: Plan of the building

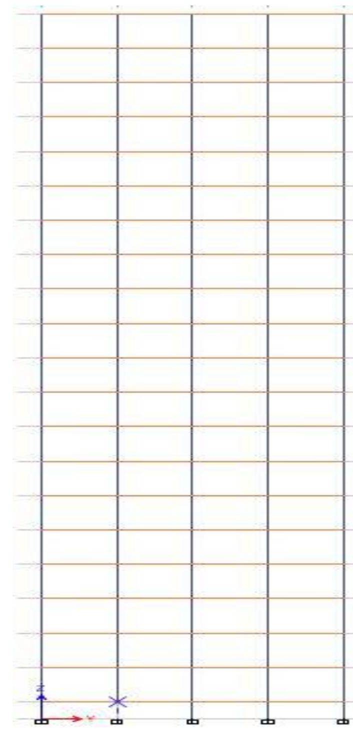

Fig 3: Building without Braces

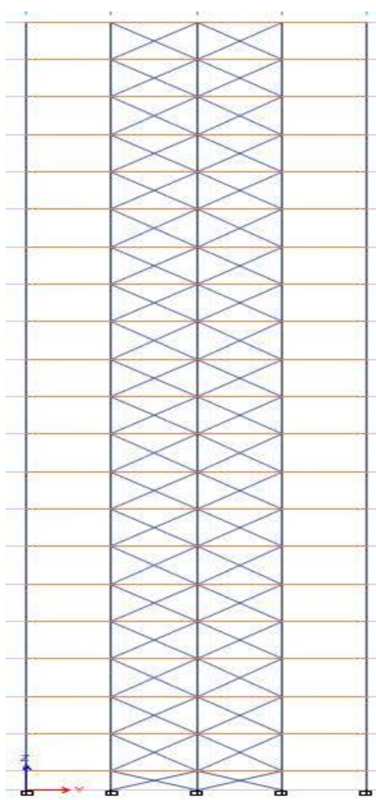

Fig 4: X- brace

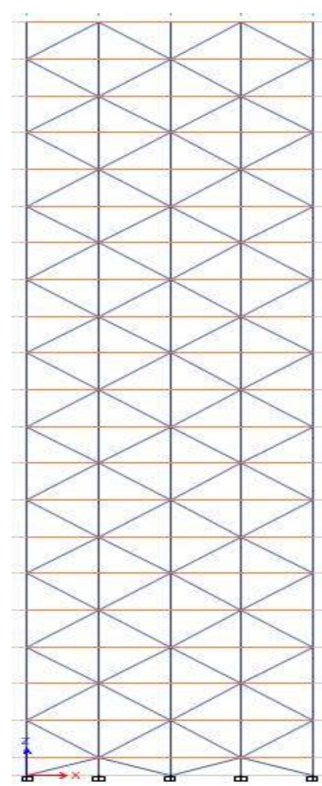

Fig 5: Single diagonal braces arranged as diamond shape in 3rd and 4th bay

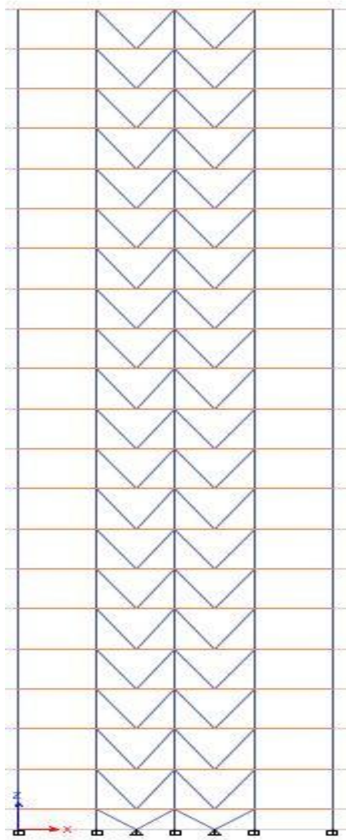

Fig 6: V- Braces

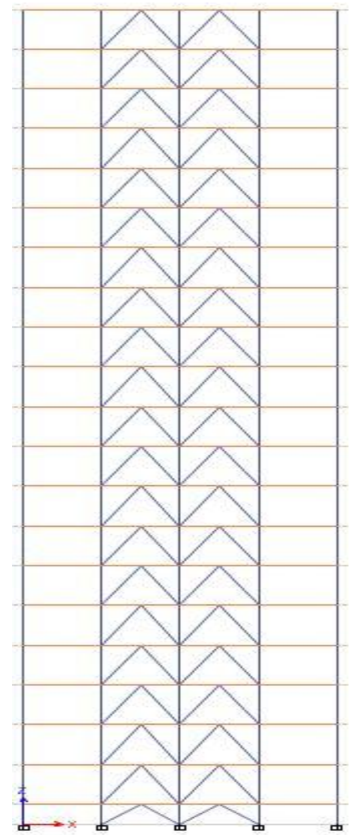

Fig 7: Inverted V Braces

2.1 Load calculations:

Loads and Load combinations are given as per Indian standards. (IS 875:1984, IS 1893:2002 and IS 800:2007)

1. Gravity Loading:- Floor load and member weight are calculated as per general considerations as per IS 875 part1.Live load is taken for residential building without separate storage as 4kN/m^2 and at top floor live load is taken 1.5kN/m^2 as per IS 875 part 2.

2. Seismic Loading: - Seismic load is given as per IS 1893- 2002. Following assumptions are used for the calculation.

Zone factor – 0.36
Soil type – 2 (medium Soil)
Importance Factor – 1.5
Damping co-efficient – 2%
Response reduction – 4 (for concentric brace)
5 (for eccentric brace)

3. Wind loading: - Static wind load is given as per IS 875-3. Following assumptions are used for calculation.

Wind speed – 39m/s
Terrain category – 3
Class – C

4. Wall Loading:- Density of brick loading is taken as 20kN/mm^3.

Wall thickness – 0.230
Height of the wall – 3m.
Total wall load on the beam – 13.8kN/mm^2.

3. RESULTS

All loads and load combinations are considered for the comparison but results are presented for maximum load case.

3.1 LATERAL DISPLACEMENTS

TABLE 1: Maximum lateral displacements

Types of models	Displacements	% Reduction in Displacement
unbraced model	44.69	
X- Brace	26.4	28.82
Single diagonal	15.2	68.43
V- Brace	28.9	32.64
Inverted V	27.1	34.75

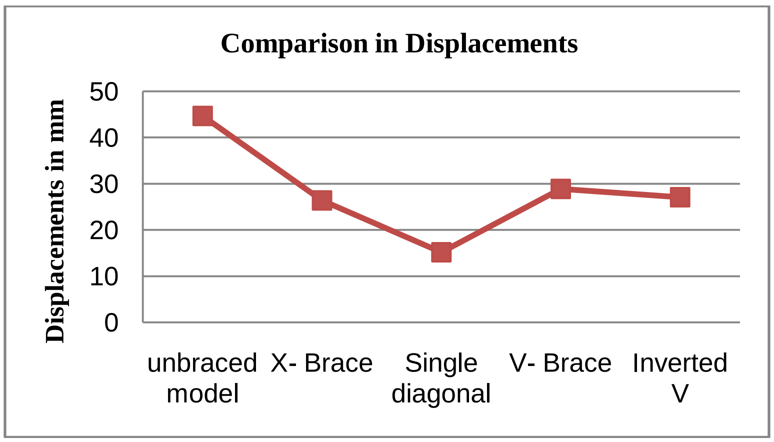

Fig 8: Comparison of Lateral Displacements

3.2 BENDING MOMENTS

TABLE 2: Bending Moments

Models	**Bending moments in KN-m**
Without braces	883435.53
X-Braces	1114999
Single diagonal braces	907647.44
V-Braces	1110893.37
Inverted V Brces	1112013

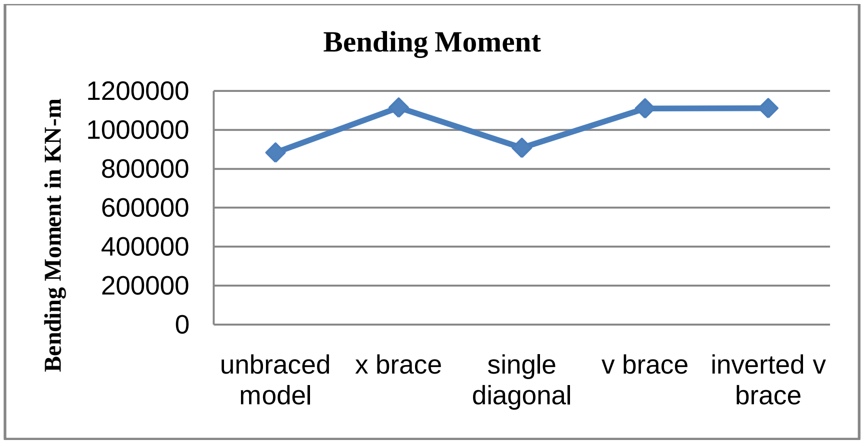

Fig 9: comparison in Bending moments

3.3 SHEAR FORCE

Table 3: Maximum Shear Force

Models	Shear Force in KN
Without braces	302.60
X-Braces	881.27
Single diagonal braces	1030.51
V-Braces	872.54
Inverted V Brces	872.547

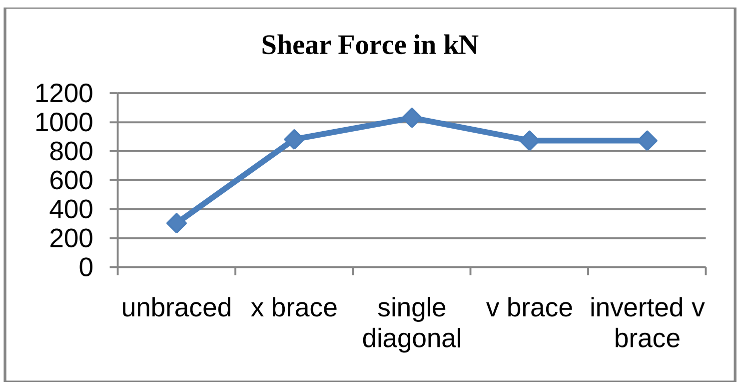

Fig 10: Comparison in Shear Force

4. CONCLUSION

The different parameters are compared for five models as shown above and it is found that as per displacement criteria bracings are good to reduce the displacement and the max reduction of **68.43%** is observed in Single diagonal braces arranged as diamond shape in 3rd and 4th bay model compared to model without brace. The bending moment and shear force in columns are also reduced in braced models from which it can found that these are less in single diagonal braced model compare to other models.
The following conclusions have been drawn based on the results obtained from present study:

1. The concept of using steel bracing is one of the advantageous concepts which can be used to strengthen or retrofit the existing structures.
2. The lateral storey displacements of the building are greatly reduced by the use of single diagonal bracings arranged as diamond shape in 3rd and 4th bay in comparison to concentric (X) bracing and eccentric (V) bracing system.

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