EFFECTS OF BRACING ON TUBULAR STRUCTURAL SYSTEM

[1]Anish Bhavsar, [2]Sandesh Sharma,
[1]Student, [2]Assistant Professor,
[1]L.J. Institute of Engineering and Technology, [2]Department of Civil Engineering IITE, Indus University, Ahmedabad, India

Abstract: Tall structures are always a challenge to the engineers from the structural point of view. Many structural systems have been developed to resists the gravity and lateral loads. These lateral forces are because of earthquake or wind forces which cause high base Shear and Bending moments in the structures. The current study focuses on framed tubular behaviour of structural system under gravity and lateral load. A parametric study is carried out on a building having 50, 70 & 90 stories with various types of bracing viz. single diagonal, double diagonal (X-bracing). The static and dynamic load are applied on the building and analysis is carried out on commercially available software 'E-TABS'. Various parameters like storey displacement, maximum displacement, time period, storey drift, base shear and moments are compared with the frame without bracings.

***Index Terms* – Tubular Structural System, Bracing, Dynamic Load**

I. INTRODUCTION

Basically, tall structural system is classified into two groups: interior structural system and exterior structural system lateral load resisting system. A system is classified as an interior structure when the major part of the lateral load resisting system is situated within the interior of the building. Likewise, if the major part of the lateral load-resisting system is situated at the building perimeter, it is called as exterior structural system. The detail classification of interior and exterior structural system is shown in Fig.1.1 and Fig.1.2 below.

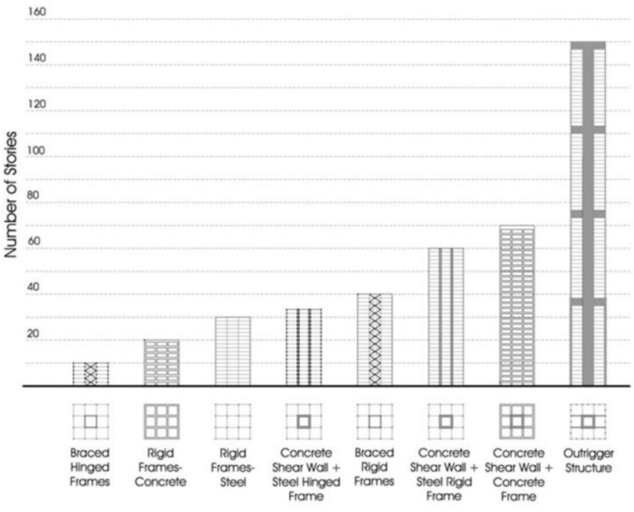


Fig. 1: Interior Structural System [1]

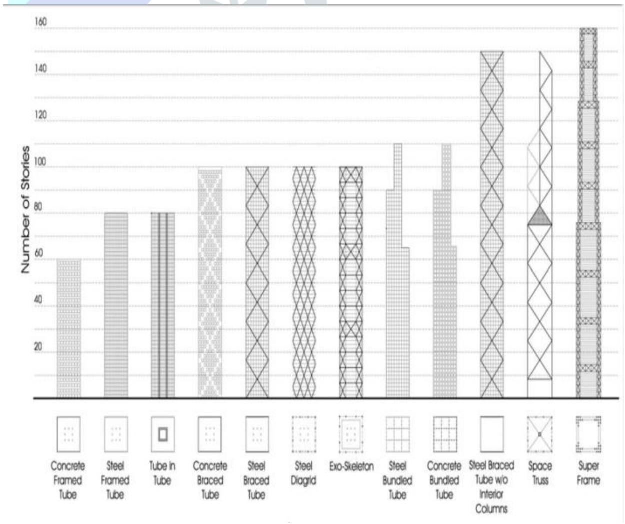
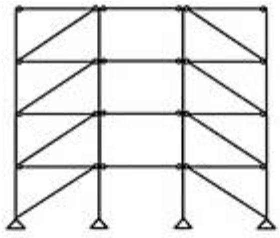


Fig. 2: Exterior Structural System [1]

Tubular structures have been evolved from the traditional rigidly jointed structural frame aiming to maximize flexural rigidity of cross-section. The original development was the framed tube, which under the action of wind loading, could suffer a considerable degree of shear lag in the normal-to-wind panels. The later more efficient bundled-tube and braced-tube systems were designed to produce a more uniform axial stress distribution in the columns of the normal panels.

Adding diagonal bracing improves the efficiency of the framed tube, thereby increasing its potential for use to even greater heights as well as allowing greater spacing between the columns. This arrangement was first used in a steel structure in 1969, in Chicago's John Hancock Building, and in a reinforced concrete structure in 1985, in New York's 780 Third Avenue Building.

In the steel tube the bracing traverses the faces of the rigid frames, whereas in the concrete structure the bracing is formed by a diagonal pattern of concrete window-size panels, poured integrally with the frame. Because the diagonals of a braced tube are connected to the columns at each intersection, they virtually eliminate the effects of shear lag in both the flange and web frames. As a result, the structure behaves under lateral loading more like a braced frame, with greatly diminished bending in the members of the frames. Consequently, the spacing of the columns can be larger and the depth of the spandrels less, thereby allowing larger size windows than in the conventional tube structure. In the braced-tube structure the bracing contributes also to the improved performance of the tube in carrying gravity loading differences between gravity load stresses in the columns are evened out by the braces transferring axial loading from the more highly to the less highly stressed columns.



Single Bracing

Cross Bracing

Fig. 3 Types of Bracing System

II. BEHAVIOUR UNDER LOADING

A. UNDER GRAVITY LOADING

The loading from their tributary floor areas would lead to the corner columns being less heavily stressed, and therefore shortening less than the intermediate columns. The mechanism by which the bracing contributes to the redistribution of the column loads can be envisaged readily by considering first the behaviour of the structural components if the bracing members are not connected to the vertical columns, and then ring the interaction that would be mobilized if the two were subsequently connected together. Consider initially a representative region of the facade frame in which the diagonals are disconnected from the intermediate columns. Under the action of gravity loading, the connection points on the intermediate columns will displace downward by more than the corresponding points on the diagonals, whose displacements are now controlled by the vertical displacements of the less highly stressed comer columns. At this stage, the diagonal members must be in compression while the spandrel beams are in tension.

Consider the forces that must be mobilized to provide vertical compatibility at the intersections when the intermediate columns and diagonals are connected together. Vertical forces must be provided that pull up on the columns and down on the diagonals. The initial compressive force in each intermediate column is now partially relieved by the upward force required at each of its intersections with a diagonal. The corresponding downward forces on each diagonal are carried at its ends by the corner columns, whose compressive forces are increased at each intersection with a diagonal. The net result tends to be an equalization of the stresses in the intermediate and corner columns the increments of force picked up by the diagonal result in a large compressive force at its lower end, which reduces in increments to a much lower compressive value at its upper end. At each intermediate intersection point in a diagonal, the horizontal thrust component must be balanced by an axial reaction in the intersecting spandrel, which will act as a strut in the upper half of each bracing diamond" and as tie in the lower half. Consequently, these actions reduce the initial tension in the spandrels in the upper halves of the bracing "diamonds." and increase the tension in the lower halves. The forces in both the intermediate and comer columns will change significantly at each diagonal intersection point. Over the vertical lengths between intersection points, changes will occur only by the increment of gravity load added at each floor level. The resulting force action in the facade panel is summarized qualitatively. In narrow face single zigzag diagonally braced frames, the bracing is relatively ineffective in equalizing gravity load stresses in the columns since the diagonals are not provided with the very significant cross-tying or cross-strutting action of the spandrels which occurs in double-braced frames.

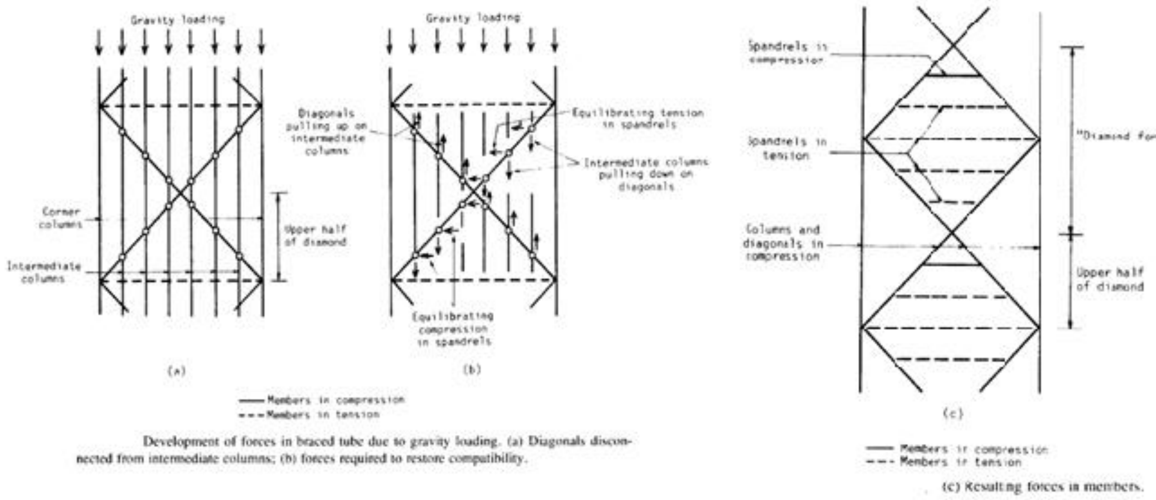


Fig. 4 Behaviour under Gravity Loading[1]

B. UNDER LATERAL LOADING

A similar procedure to that used for gravity loading may be used to determine the action of the braced tube in resisting wind loading. Under the action of wind loading, the side frames act as the webs and the normal frames as the flanges. Consider the structural actions in the frame that acts as the tension flange. If the diagonals are initially disconnected from the in intermediate columns, the columns and diagonals of the face will be in tension while the spandrels are in compression. The intermediate columns will now be less highly stressed than the corner columns and the connection points on the diagonals will be displaced upward by more than the corresponding points on the unconnected intermediate columns due to Shear lag effect.

If the diagonals and intermediate columns are connected together, interactive vertical forces will pull up on the intermediate columns and down on the diagonals in order to establish compatibility at the connections. These upward forces increase tension in the intermediate columns, while the downward increments acting on the diagonals are transferred at their ends to the corner columns, thereby reducing the higher tensile forces that initially existed. In this way, the stresses in the corner and intermediate columns again tend to be equal. When superimposed on the original large tensile force in the diagonal. The increments of axial force acting down the diagonal produce a gradually reducing tension along the member. Spandrels in the upper halves of the bracing diamonds will now act as struts, while those in the lower halves act as ties. The tensile forces in the intermediate columns increase down the structure by the increments applied at each intersection with a diagonal.

The forces in the columns, diagonals, and spandrels on the leeward face due to the lateral loading will be opposite in sense to those on the windward face. The narrow-face web frames are subjected to bending and shearing actions as a result of wind loading. Because of shear lag the axial forces in the columns nearest to the corners have values that are higher than they would be in pure tubular action.

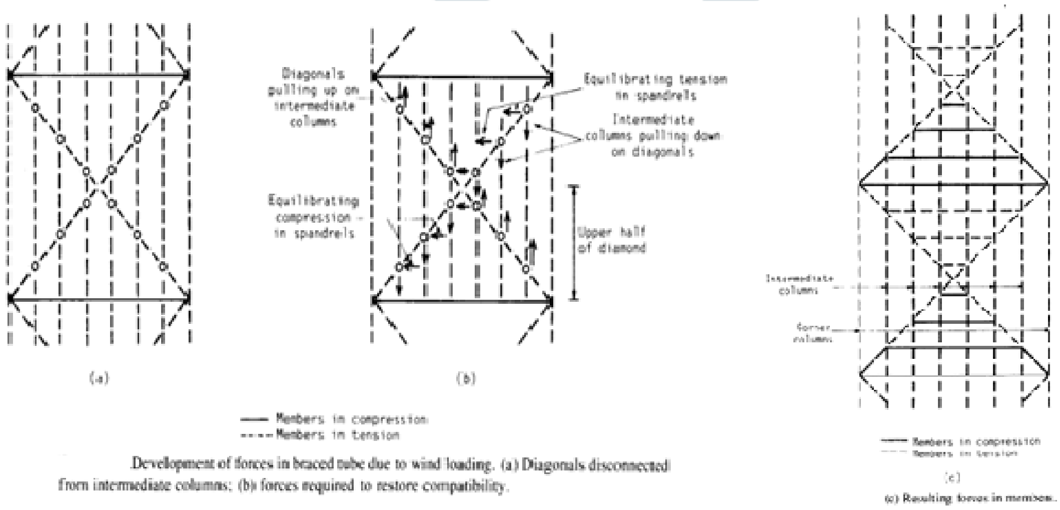


Fig. 5 Behaviour under Lateral Loading[1]

III. ANALYTICAL STUDY

An analytical study has been carried out on G+50, G+70 and G+90 stories without and with bracings. The descriptions of the models are mentioned in Table: 1.

Table: 1 Building description

Description	Frame	Single Braced	Double Braced
Material Property			
Concrete grade	M30		
Steel grade	FE650		
Number of Storey	G+50	G+50	G+50
Storey height (m)	3.5		
I-Beam size (mm)	750(flange) x 250 (web) x 30 (thickness)		
Bracing	ISMB 600		
Hollow Column 1 to 20 (mm)	2000(length) x 2000(width) x 150 (thickness)		
Hollow Column 21 to 41 (mm)	1300 x 1300 x 50		
Hollow Column 31 to 51 (mm)	700 x700 x 50		
Slab thickness (mm)	125		
Seismic parameters			
Location	Ahmedabad		
Soil type	Type II		
Wind parameters			
basic wind speed (m/s)	39	39	39
Terrain Category	3	3	3
Loading data			
Live load at typical floor	5 KN/m^2	5 KN/m^2	5 KN/m^2
Live load at roof	5 KN/m^2	5 KN/m^2	5 KN/m^2

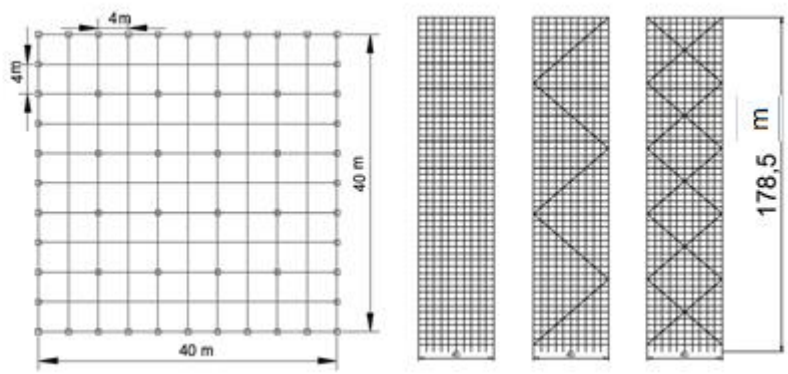


Fig. 6 Plan and Elevation of G+50 Building

Modelling, analysis and design of diagrid structure are carried out using ETABS software (ETABS 2017). For linear static and dynamic analysis the beams and columns are modelled by flexural elements and braces are modelled by truss elements.. All structural members are designed using IS 800:2007. Secondary effect like temperature variation is not considered in the design, assuming small variation in inside and outside temperature. Dynamic wind load is calculated as per IS-875-part-3:2015. Earthquake load is calculated using IS 1893:2016.

IV. RESULTS AND DISCUSSION

Analysis results obtained by considering design sections are compared. Table-2 shows first mode time period of G+50, G+70, G+90 frame (FR), Single Braces (SB), Double Braced (XB) structures. Top storey displacement is also showed in Table-2. Figure 7, 8 and 9 shows comparison of storey drift and storey displacement for different structure of G+50, G+70 and G+90 structures respectively.

Table 2- Time period, top storey displacement and Storey drift of G+50, 70, 90 structures

Structure	**First mode time period**	**Top Storey Displacement in X & Y-direction due to Dynamic wind load**	**Inter-Storey Drift in X-direction due to Dynamic Wind load**
	(sec)	**(mm)**	**(mm)**
G+50 FR	3.698	244.945	1.037
G+50 SB	3.452	213.133	0.988
G+50 XB	3.248	189.299	0.95
G+70 FR	5.169	513.858	1.714
G+70 SB	4.822	447.306	1.678
G+70 XB	4.548	399.908	1.642
G+90 FR	6.804	932.45	3.136
G+90 SB	6.349	815.791	3.089
G+90 XB	5.97	726.08	3.035

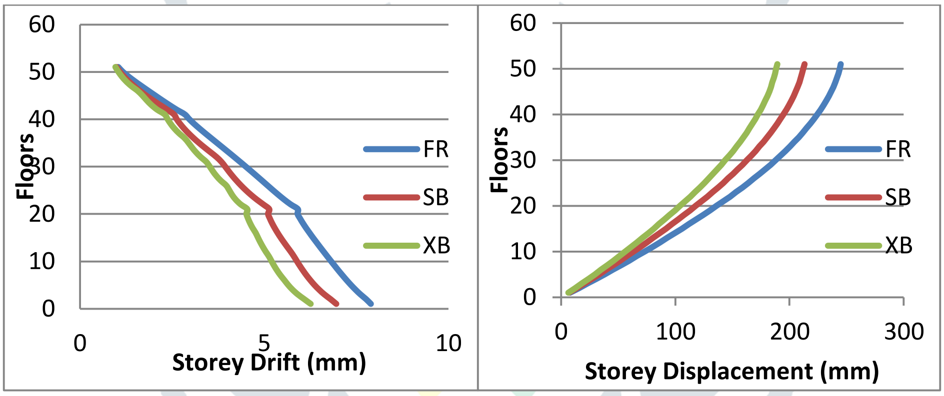


Fig. 7 Comparison for G+50 Due to Wind load

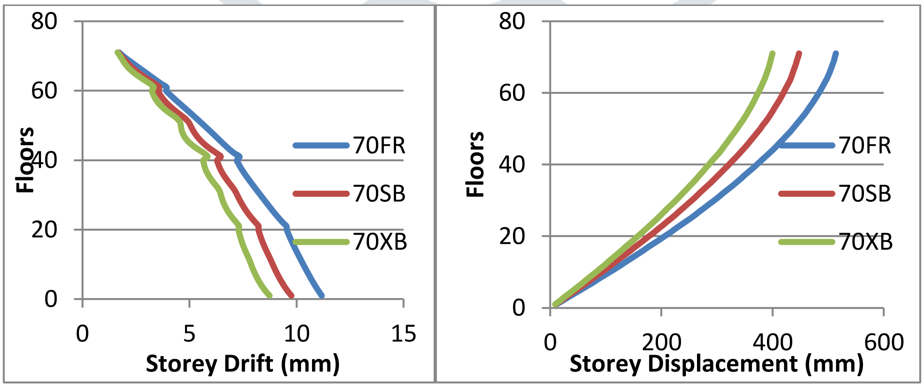


Fig. 8 Comparison for G+70 Due to Wind Load

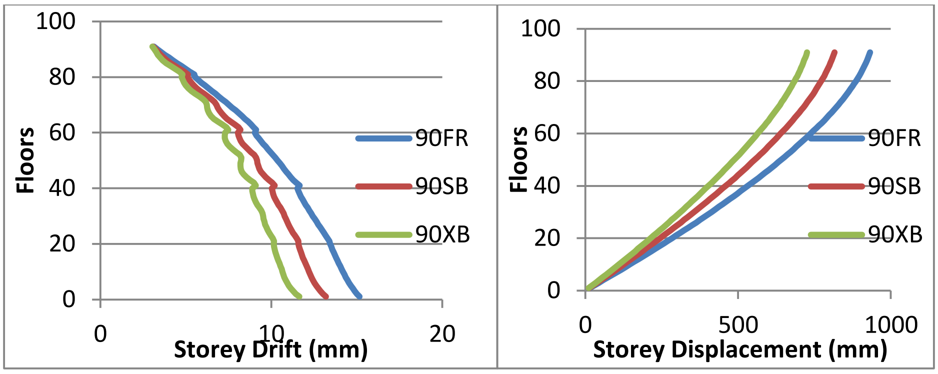


Fig. 9 Comparison for G+90 Due to Wind load

- The displacement, drift and top storey displacement is more in simple frame structure compared to other two.
- Time period is more in all Frame structure compared to other two viz. Single braced and double braced structures.
- Overall least displacement, drift, and top storey displacement is seen in double braced structure compared to single braced structure.

References

[1] Tall building structures Brayan Stanfford Smith and Alex Coull,

[2] http://www.skyscrapercenter.com/building/sunshine-60-tower/990

[3] https://en.wikiarquitectura.com/building/sears-tower-willis-tower/

[4] https://www.designingbuildings.co.uk/wiki/File:Xbrace.JPG