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Comparison Performance of Structural Tubular System and Bundled Tube System against Lateral Loads for Tall Buildings

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Abstract

With making of new materials and use those in construction projects, engineers and designers innovate various new structural forms which can be used in tall buildings execution. The structural form of building must be resist all combination of vertical and lateral loads. In general non-structural considerations have important effects in select of structural form and can be determinant. Furthermore, in slender and taller buildings structural parts have more importance and hence necessity to select of better structural form is more concern. In this paper dynamic response and performance of tall buildings with structural Tubular System (TS) and Bundled Tube System (BTS) against lateral loads have studied and compared. For this purpose, quadrangular plan by different heights have adapted. Spectral analysis has performed and the effect of parameters such as height of building, participation of higher modes, shear lag and the stiffness of perimeter beams have assessed. This research showed that performance of Bundled tube system structures from the view of above parameters variety is better than structural Tubular System and workable especially in shear lag reduction.

Keywords: Tubular System; Bundled Tube System; Dynamic Response; Shear Lag; Perimeter Beam; Spectral Analysis

1. Introduction

As yet multiple structural system for tall buildings have been used. Most of engineers believe that structural tubular and bundled tube systems are more appropriate than other systems for tall buildings. This systems are full-fledged of traditional rigid frame systems that columns locate at perimeter of building so flexural and torsional rigidity of system reach to maximum quantity and total moment of inertia of building is used to resist lateral loads [1]. Lateral displacements and stories buoyancy in rigid frames and symmetric framed tubes created by arch action, cantilever action, shear lag and distortion of connection zone. Therefore to reduce lateral displacement of floors, above parameters must be controlled accurately. One of the most important deficiencies of perimeter frame systems is shear lag

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phenomenon that affects strongly workability of system and hence this matter is more concerned in this system [2]. Various factors affect shear lag that can offer to ratio of web to flange width, opening size and loading statement. Shear lag affects not only longitudinal forces but also transverse and shear forces can be affected. Therefore shear lag effects must be considered in all stages of design process [3].

2. Research Procedure

For this study tubular and bundled tube system with quadrangular plan by side 40 m are selected. Axial distance between columns and height of floors are 3.3 m and 3.9 m respectively. Variable factors that are considered in buildings analysis as following:

a. Lateral resistance system type (TS and BTS)
b. Height of building as number of stories
c. The stiffness of perimeter beams

For each system 3 different height by 30 stories, 40 stories and 60 stories are selected. It is note that 50 story building is modeled for systems to validity control of plotted displacement curve for up level of buildings. For perimeter beams the section by 50 cm width and 100 cm height is adapted as base state and to put on their stiffness in analysis, two quantities of stiffness toward base state are selected by 0.5 and 2 times. In total 20 models for this study have analyzed and to search the effect of participation of higher modes in buildings responses each model analysis has performed for 3 to 30 modes three distance in 10 cases.

For simplicity show analysis models and results we have used summary words for each model. For example, base state in 30 story model of tubular system and bundled tube system is nominated as T-30 and B-30 respectively. Also to demonstrate the high and low stiffness of perimeter beams we have used H and L words like T-30-H that means 30 story tubular system with high stiff perimeter beams and etc. Table 1 show the summary of nominated models and details.

Table 1. Model names

	Tubular system				**Bundled tube system**			
	30 story	40 story	50 story	60 story	30 story	40 story	50 story	60 story
Base state	T-30	T- 40	T-50	T-60	B-30	B- 40	B-50	B-60
High stiff perimeter beams	T-30-H	T- 40-H	……….	T- 60-H	B-30-H	B- 40-H	……….	B- 60-H
Low stiff perimeter beams	T-30-L	T- 40-L	………..	T- 60-L	B-30-L	B- 40-L	………..	B - 60-L

To check rate of the shear lag 2 index were introduced as Q an R. The ratio of axial force in corner column to middle column of flange was called Q. According to results for bundled tube system buildings with quadrangular plan, axial force of corner and middle columns are equal approximately.

Hence for this system, R was defined the ratio of axial force in corner column to middle column of one cell of flange. It is note that R index for tubular system building will be the ratio of axial force in corner column to axial force of column corresponding middle column of exterior cell of bundled tube system building.

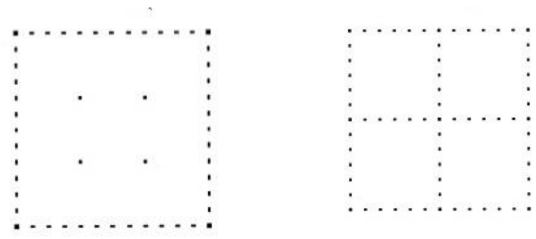
For models analysis in this research, dynamic spectral analysis with response spectrum basis on Iran code (2800) [6] using SAP2000 software has performed. Location of columns in plan for two systems has shown in figure 1.

3. Analysis results

3.1. . Height Effects

3.1.1. Height Effect on Lateral Displacement

Analysis results show that lateral displacement in bundled tube system models is less than from tubular system models for same height of building and also their increase percent of lateral displacement toward tubular system is low when height grow up. For instance, the lateral displacements at two same levels in different models have shown in table 2.



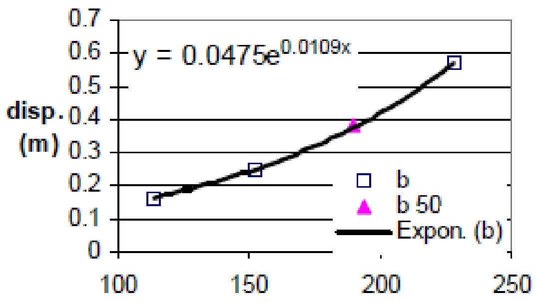
a)Tubular system b)Bundled tube system

Fig.1. Location of columns in plan

Table 2. Lateral displacement at two same levels for TS and BTS models

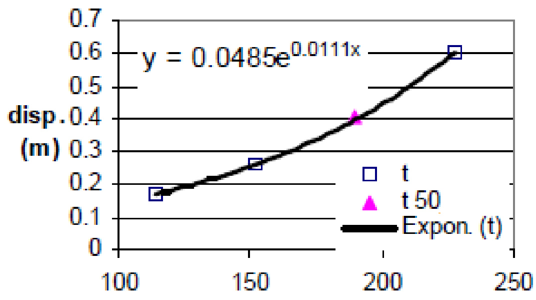
	Level 117 (m)		***Level 156 (m)***	
Building	***Lateral displacement (cm)***	***Increase percent toward to level***	***Lateral displacement (cm)***	***Increase percent toward to level***
T-30	***17.8***	-----------	-----------	-----------
T-40	***23.2***	***29%***	***27.4***	-----------
T-60	***34***	***91%***	***45.5***	***66%***
B-30	***17***	-----------	-----------	-----------

B-40	***20.5***	***20.5%***	***26***	-----------
B-60	***28.3***	***66.5%***	***40.3***	***55%***



Height (m)

a) Tubular system



Height (m)

b) Bundled tube system

Fig.2. Lateral displacement for up level of buildings

The curve of lateral displacement for up level of buildings for tubular system and bundled tube system models with height were plotted and to validity control of plotted curves the lateral displacement of up level for 50 story building was shown on plots and good compatibility was observed. Details have shown in figure 2.

3.1.2. Height Effect on Shear Lag

Figure 3 show the indexes Q and R for bundled tube system models that plotted in height of buildings. The index Q for total height is closely to unit approximately. The reason for this matter is being the middle web in this system and hence difference between axial force of corner and middle columns is minimum. Naturally we can see some positive and negative shear lag at lower and upper parts of building respectively. This means the effect of height on shear lag at low parts is more than up parts of building.

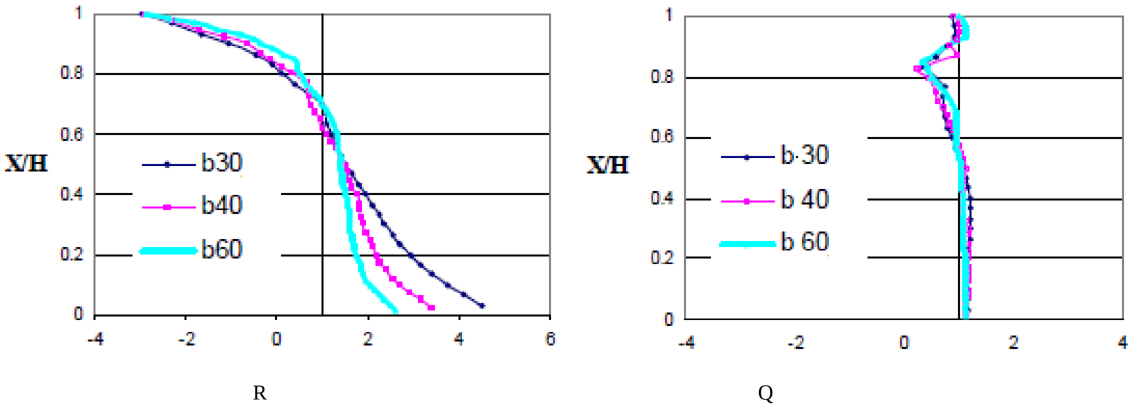


Fig.3. Height effect on shear lag (Bundled tube system)

The results for tubular system buildings are similar too which represented in figure 4. Comparison the plots on figures show that indexes Q and R in bundled tube system buildings have less quantities than tubular system buildings and hence force distribution in their flanges is more uniform and shear lag has controlled effectively. The other chief object is that the R quantities and varieties for bundled tube system buildings are lower than corresponding quantities in tubular system buildings so it can be said that shear lag has less sensibility to height variation in bundled tube system buildings.

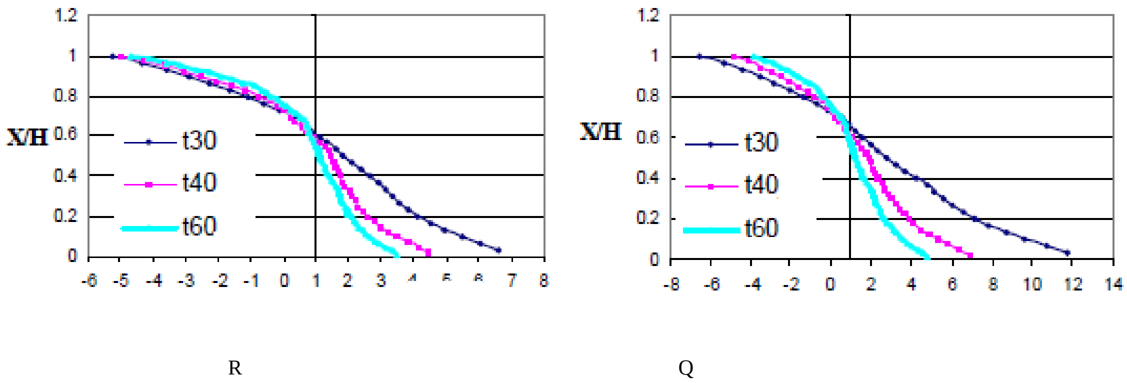


Fig.4. Height effect on shear lag (Tubular system)

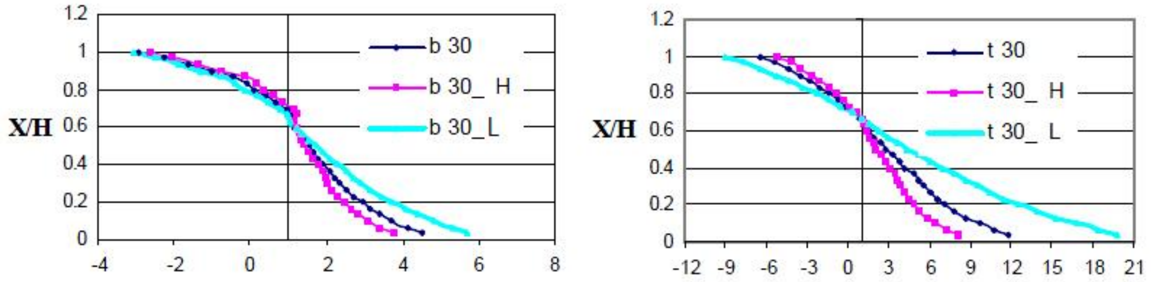
3.2. . Perimeter Beams Effects

3.2.1. Perimeter Beams Effect on Lateral Displacement

Analysis results showed that in all states, the increase of displacement from stiffness reduction in perimeter beams is more than the displacement reduction due to high stiff perimeter beams and ranges 1.5 to 2.5 times approximately. This matter is valid for both systems but the rate of reduction and addition in lateral displacement for bundled tube system buildings is less. In total it can be said that bundled tube system buildings have less sensibility toward variation of stiffness in perimeter beams.

3.2.2. Perimeter Beams Effect on Shear Lag

Results showed that for tubular system buildings, reduction in stiffness of perimeter beams cause to growth of shear lag (positive and negative). The effect of stiffness of perimeter beams is more observed at lower parts of building where positive shear lag exist and also the reduction of stiffness affects more the shear lag. For bundled tube system buildings, the results are similar to tubular system but quantities of shear lag parameters is less and variation of parameters is considerably less. For instance, details for 30 story building have shown in figure 5 for both systems.



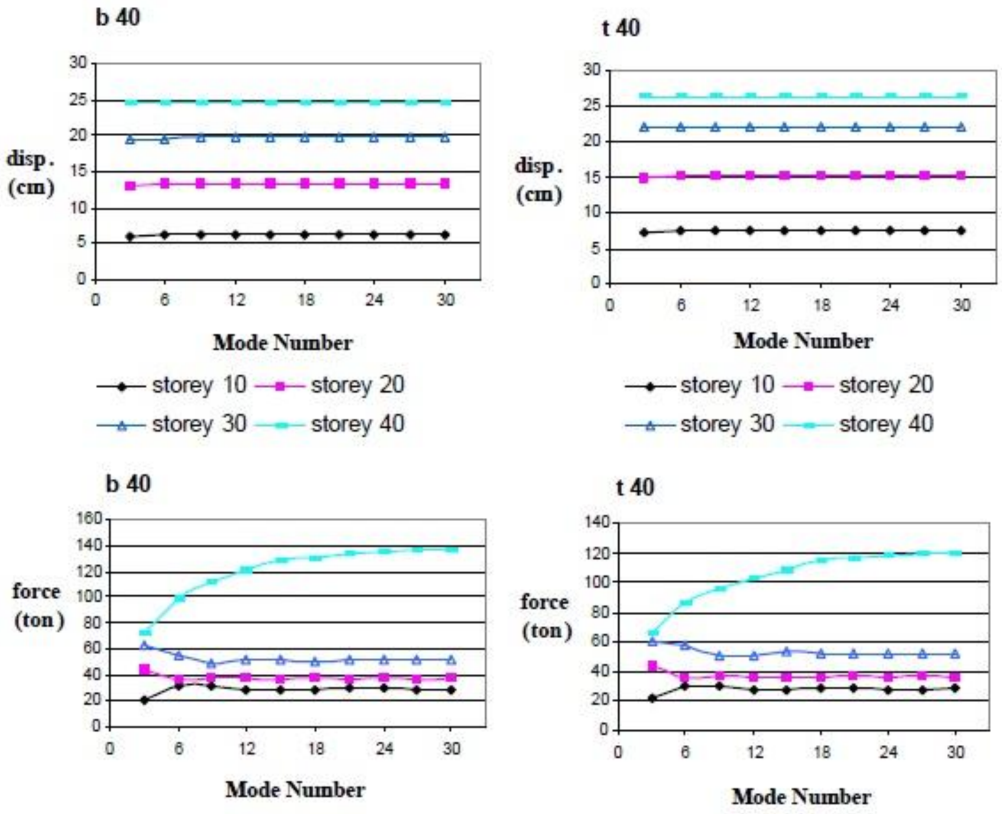
R

a) Bundled tube system

Q

b) Tubular system

Fig.5. perimeter beams effect on shear lag



a) Bundled tube system

b) Tubular system

Fig.6. Higher modes effect on lateral displacement and force

3.3. Effect of Participation of Higher Modes

The effect of modes in analysis was studied to answer two questions. First, the number of modes that lateral displacement or force of stories reaches to ultimate quantity and second, considering the higher modes in analysis affects more which levels of building. Results showed that in all models and levels the lateral displacement reaches to ultimate quantity considering first 6 modes and the higher modes effects are neglible. The lateral force of stories compare with displacement is more affected by number of modes and also higher levels of buildings are too. For instance and due to plots similarity, results for 40 story building have shown in figure 6.

4. Conclusion

The results of this research can be summarized as followings:

1. The rate of displacement growth for bundled tube system buildings is less than tubular system when height go up.
2. For both systems, positive and negative shear lag were created at lower and upper parts of buildings respectively.
3. Existence of middle webs for bundled tube systems cause to cells work together and difference between axial force in corner and middle columns at flanges and webs intersection point reaches to minimum.
4. Shear lag for bundled tube system buildings has less sensibility to height variation.
5. Reduction in stiffness of perimeter beams cause to growth of shear lag in both systems but the quantities for bundled tube system buildings are less.
6. Bundled tube system buildings have less sensibility to stiffness variation of perimeter beams.
7. Stiffness reduction of perimeter beams more affects the shear lag at lower parts of buildings.
8. To get the lateral force of stories, considering the higher modes is more important especially for upper levels of building.

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