



Comparison of Different Types of Tubular Systems

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ABSTRACT- Tall building developments have been rapidly increasing worldwide and also in India. Steel has a more advantages material in world today it gives innovative framing systems, easy to assembling, high strength to weight ratio availability of various strength and wider selection of sections and it is a environment friendly so steel is being used in worldwide tall building. In past designers are only considering a gravity loads for the design of building. But now improvisation in seismic and wind study, lateral forces is added in design of building. Tubular frames are one of the common structural systems in designing tall buildings. Framed Tube and Bundled Tube are famous structural system. Design of these systems requires precise analysis.

Tubular system is considering in two parts, exterior and interior which uses to resist lateral load and gravity load respectively. In this study one steel building of each framed tube system and bundled tube system of optimum section with 64 stories with symmetric plan area and identical loading condition using ETABS. Various parameters like fundamental time period, maximum top story lateral displacement, maximum base shear, steel weight, and maximum story drift are considered in this study.

Keywords- Framed Tube, Bundled Tube, ETABS, Time Period, Story displacement, Story drift, Base shear, Steel weight, Lateral load resisting systems, High-rise structure.

I. INTRODUCTION

Construction of high-rise buildings used to be driven by the demand for space in densely populated land areas. Advancements in structural engineering and technology have greatly pushed the height limit. Combined with the improvement in fabrication and construction methods, the construction of skyscrapers not only has become more relevant and feasible; it has pushed the height limit even further. Over the years, Nations and major companies have been constantly pursuing the title of the tallest building in the world.

Major advancements in structural engineering have been the development of different structural systems that allow for higher buildings. As the height of the building increase, the lateral resisting system becomes more important than the structural system that resists the gravitational loads.

A. Framed Tube System

Sufficient design of exterior frame for the purpose of resisting lateral loads allows the interior part of the building to only resist the gravity loads. Not only this concept is a clever solution for resisting lateral loads but also leaves the architect with the wonderful choices for the interior space of the buildings. Framed-tube and braced-tube structural systems are popular structural systems among the exterior lateral load resisting systems.

Beedle et al. defines this type of structural system as following: "In structural engineering, the tube is the system where in order to resist lateral loads (wind, seismic, etc.) a building is designed to act like a hollow cylinder, cantilevered perpendicular to the ground" [11]. This system was introduced by Fazlur Rahman Khan while at Skidmore, Owings and Merrill's (SOM) Chicago office. The first example of the tube's use is the 43-story Khan-designed DeWitt-Chestnut Apartment Building in Chicago, Illinois, completed in 1963 [11].

Beedle's definition for the tubular systems is quiet the same as the other definitions. As mentioned above tube system acts like a hollow cylinder. This means the exterior frame should be as rigid as possible. Although the structure has a tube-like form, its behavior is much more complex than that of a solid tube. Unlike a solid tube, it is subjected to the effects of shear lag, which have a tendency to modify the axial force distribution in the columns.

B. Bundled Tube System

Instead of one tube, a building consists of several tubes tied together to resist the lateral forces. The system allows for the greatest height and the most floor area. In this system, introduction of the internal webs greatly reduces the shear lag in the flanges[11].

Hence, their columns are more evenly stressed than in the single tube structure and their contribution to the lateral stiffness is greater. This allows columns of the frames to be spaced further apart and to be less obstructive.

This structural system was used in Sears Tower in Chicago introduced by Fazlur Rahman Khan. In the Sears Tower, advantage was taken of the bundled form to discontinue some of the tubes, and so reduce the plan of the building at stages up the height. Types of bundle tube system are mentioned below[11].

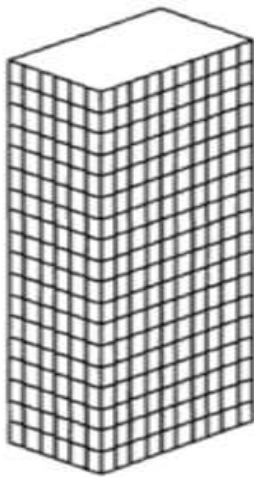


Fig. 1 Framed Tube

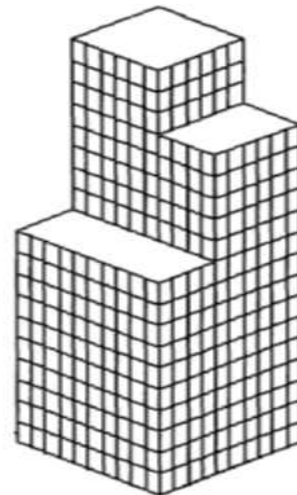


Fig. 2 Bundled Tube

- Framed Bundle Tube System**

Single framed tube is connected with more than one tubes which makes framed bundled tube. Example of Framed Bundle Tube is sears tower shown in fig. 3[1].

- Braced Bundle Tube System**

Same as Framed Bundle Tube, in this system single braced tube connect with more than one tube and make bundle Of braced tube. Example of Braced Bundle Tube shown in fig. 4[1].

- Braced-Framed Bundle Tube**

Combination of Braced Tube and Framed Tube connect with each other and make Bundle Tube. Like two framed tube and two braced tube connect and make bundle tube having four tubes[1].

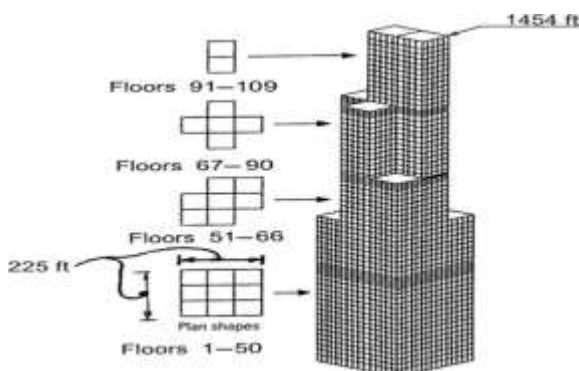


Fig. 3 Framed Bundled Tube System

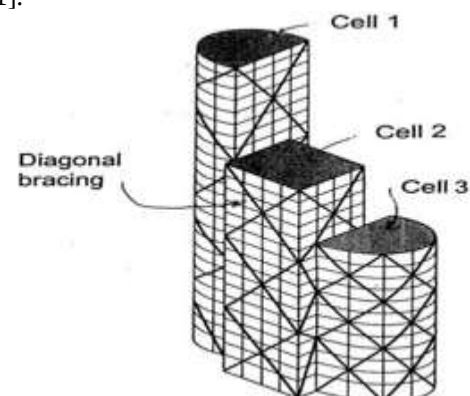


Fig. 4 Braced Bundled Tube System

Y OF BUNDLED TUBE

For the parametric comparison, a symmetrical building is selected. One steel building for 64 story are modelled, analyzed and designed in ETABS for two structural systems; framed bundled tube and framed tube. Analysis and design are carried out for dead load, live load, lateral earthquake load and lateral wind load. For earthquake loads, both static and response spectrum analysis are done. To consider extreme conditions of lateral loads, the buildings are considered to be located in Zone V. The parameters selected for the comparison are fundamental time period, maximum top story lateral displacement, maximum base shear, maximum story displacement and maximum story drift. Further, governing lateral force is also determined.

Building Configuration

General configuration of the building is shown as below:

- All the steel member used in building is Fe250 and for concrete(slabs) use M25 grade.
- Wind and distribution in ETABS calculated according to IS: 875 (Part 3) - 1978 in both direction.
- Earthquake analysis is done using IS: 1893 (Part 1) – 2002 in both direction.
- For general steel frame design used IS: 800 -2007.
- Limiting top story displacement : H/500
- Limiting Inter story drift : 0.004h

Plan area:	80 m × 80 m	Story height:	3 m
Dead load:	1.5 kN/m²	Story:	All typical
Live load:	2.5 kN/m²	Slab thickness:	120 mm
Earthquake zone:	V	Location:	Bhuj
Importance Factor:	1.5	Basic Wind Speed:	50 m/s
Response Reduction:	5	Factor k_1 :	1.06
Analysis::	Static & Response Spectrum	Factor k_2 :	1
Modal Damping:	2%		

III. STRUCTURAL SYSTEMS

The configurations of two structural systems used in this study Bundled Tube and Framed Tube are as below:

A. Framed Bundled Tube Building

For this parametric study, one building is designed for bundled tube structural system with 64 stories. The buildings are modelled as steel structure in ETABS 2015. The structural elements like columns and beams are assigned of structural steel properties while the slabs are considered of RCC.

Building having plan area of 80m × 80m and each tube has plan area of 40m × 40m. Exterior beam length is 5m, while interior beam length is 10m. All sections are optimized for minimum possible design sections of columns and beams. For that, buildings having 64 stories are divided in to four parts along the height of the buildings. For such buildings, there are three types of column and four types of beam shown in figure. These all types of beam and column continue until 16 stories, where only corner column of the whole building is continue throughout all story.

For the design of columns, built-up box sections are used. And for the design of beams, Indian Standard built-up I-Sections are used. The typical plan, elevation and 3D extrude views of a 64 story bundled tube structure are shown in Figure 5,6 & 7 respectively.

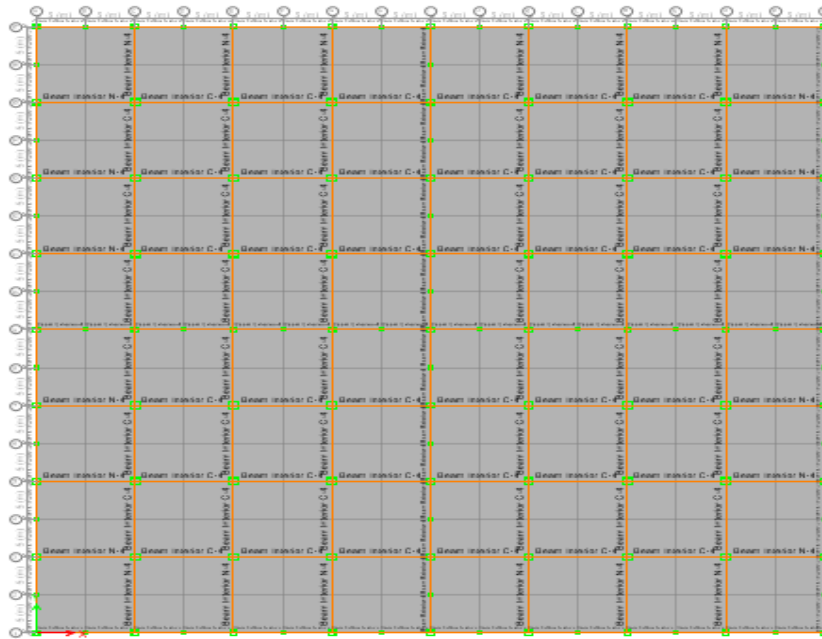


Fig. 5 Plan of Bundled Tube

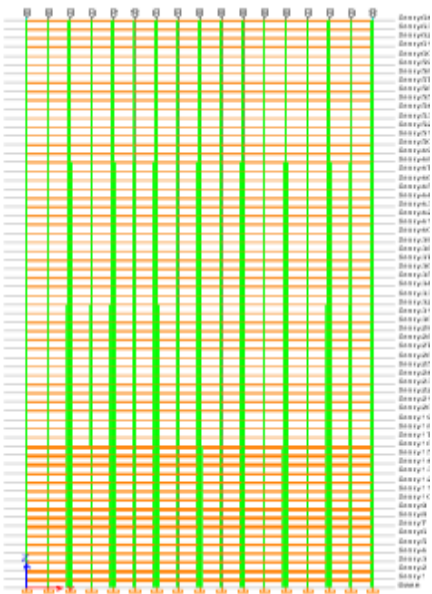


Fig. 6 Elevation of Bundled Tube

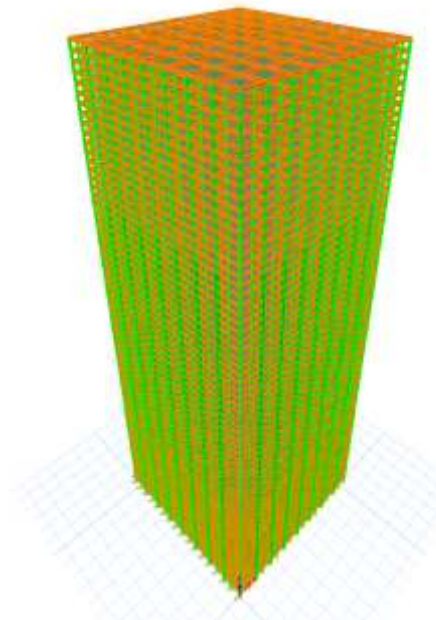


Fig. 7 3D view of Bundled Tube

B. Framed Tube Building

For this parametric study, one building is designed for bundled tube structural system with 64 stories. The buildings are modelled as steel structure in ETABS 2015. The structural elements like columns and beams are assigned of structural steel properties while the slabs are considered of RCC.

All sections are optimized for minimum possible design sections of columns and beams. For that, buildings having 64 stories are divided in to four parts along the height of the buildings. For such buildings, there are three types of column and three types of beam shown in figure. These all types of beam and column continue until 16 stories, where only corner column of the whole building is continue throughout all story.

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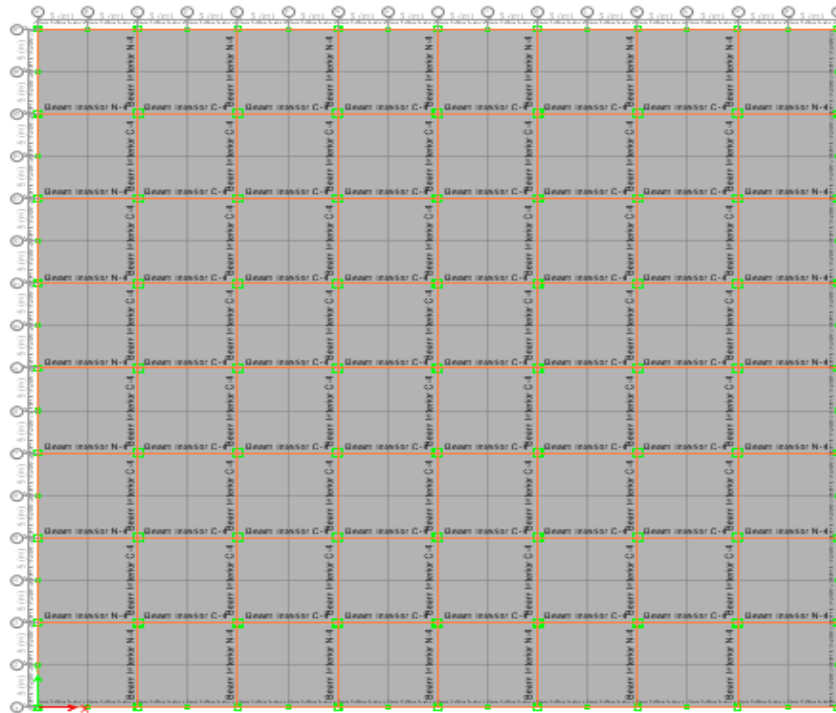


Fig. 8 Plan View of Framed Tube System

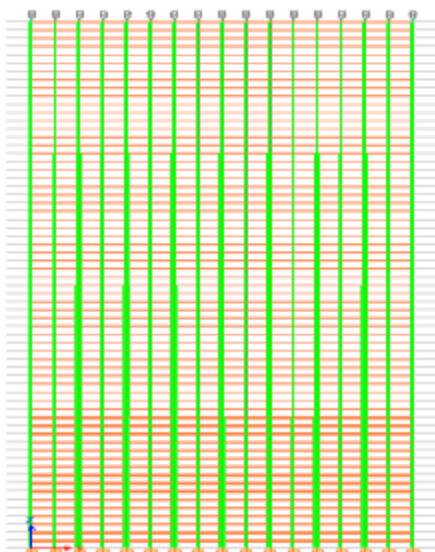


Fig. 9 Elevation of Framed Tube Building

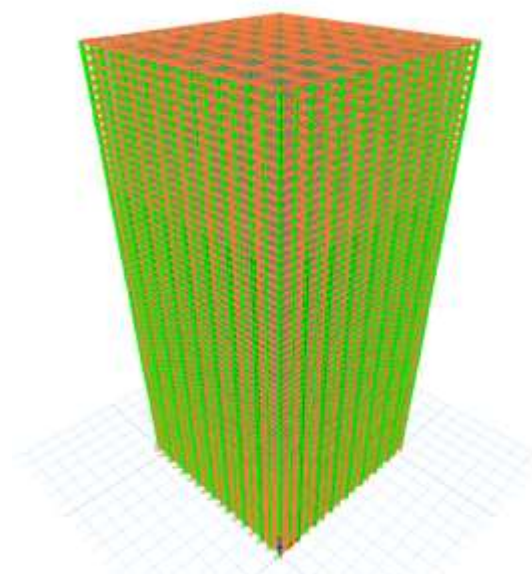


Fig. 10 3D View of Framed Tube Building

IV. RESULTS AND COMPARISON DISCUSSIONS

After analyzing and designing all the structures, the governing loads for each building for both bundled tube and framed tube systems are earthquake load due to its large plan area and heavy steel weight.

A. Parametric Study

In this study parametric comparison of two structural systems is presented.

Time Period

Figure 11 represents the comparison of the time period of both the systems bundled tube and framed tube. It is observed from the figure that as the time period of framed bundled tube is lower than that of the framed tube building. Thus it is observed that the bundled tube building is stiffer than the framed tube.

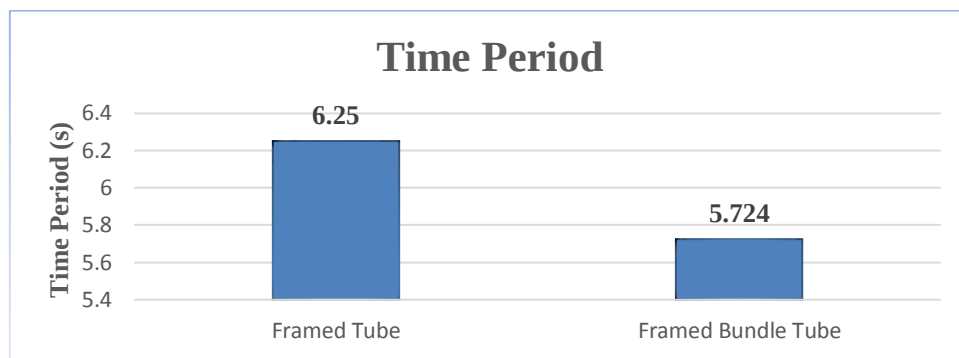
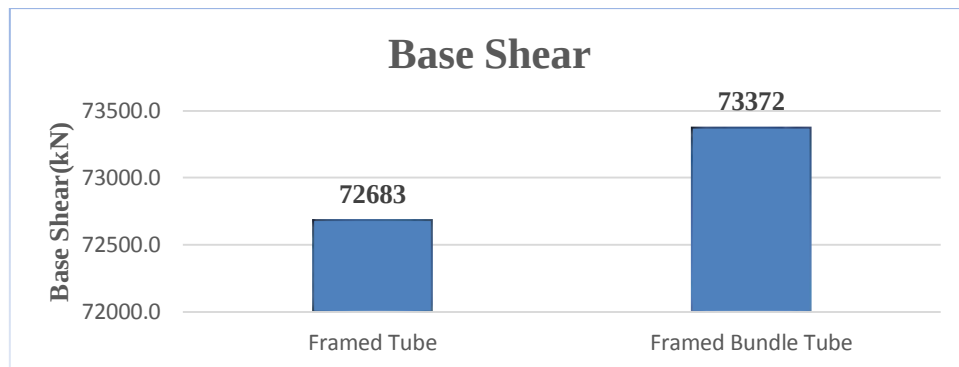


Fig. 11 Time Period

Maximum Base shear

Figure 12 represents the comparison of the maximum base shear for both the systems framed bundled tube and framed tube.



Fia. 12 Base Shear

As the building is symmetric, the base shear will be the same in both the directions. As it is known that the bundled tube system is stiffer than the framed tube system, it attracts more lateral force and hence it has more base shear.

Steel Weight

In the Figure below, the maximum steel weight in Tonnes are compared for both the systems framed bundled tube and framed tube.

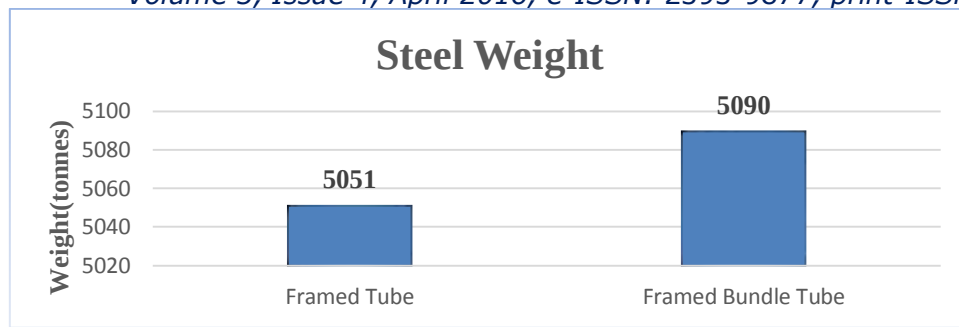


Fig. 13 Steel Weight

The result shows that steel weight of framed bundled tube is slightly higher than the framed tube around 0.75%.

Maximum Story Displacement

Patterns of story displacement curves are observed to be uniform in both the cases. Graph showing typical trend of displacements at each story level for 64 story building are presented in Figure 14.

Maximum story displacement for the framed tube is 306mm and for bundled tube system it is 263mm, so maximum story displacement of the framed tube is higher than the bundled tube system but both values are permissible.

Maximum Story Drift

Uniform story drift curves are observed in both the cases. Maximum story drift are observed at the lower portion of the framed tube building, while in bundled tube system maximum drift is observed in middle of the building. But for both the building maximum drift is within permissible limit.

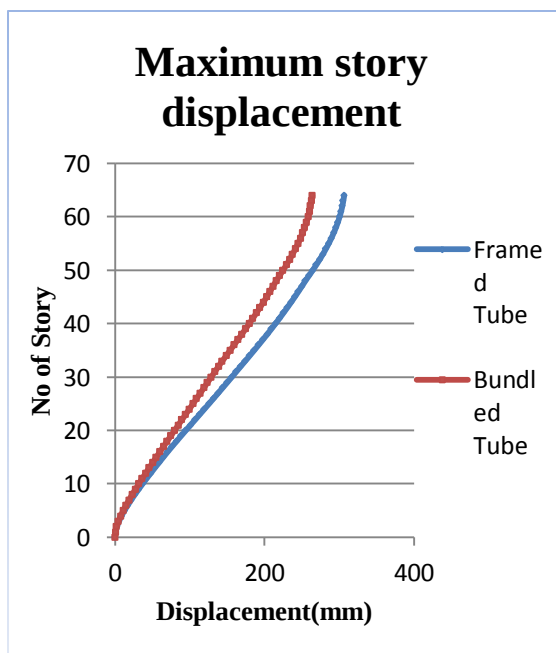


Fig. 14 Maximum story displacement

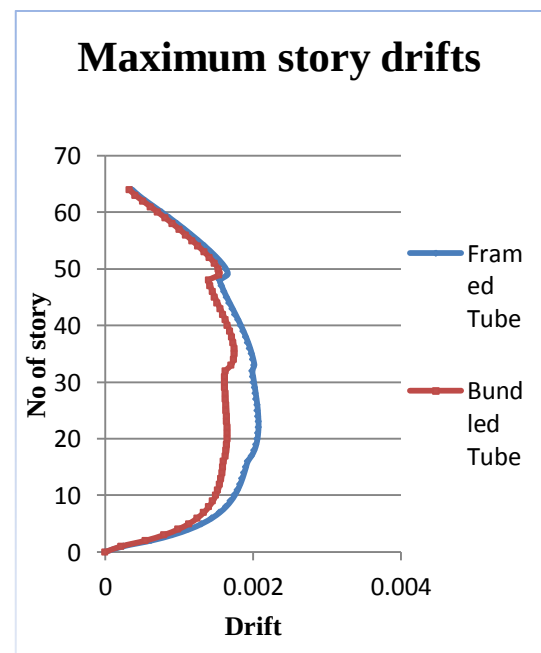


Fig. 15 Maximum story drift

5. CONCLUSION

Based on the numerical study carried out in the present research work, following major conclusions can be drawn:

- Bundled Tube structural system has emerged as a better solution for lateral load resisting system in terms of lateral displacements, story drift, base shear and stiffness. It's stiff enough to resist wind forces upto higher heights.
- Displacements on each story and story drifts are observed to be less in diagrid compared to conventional frame.
- As per aesthetic comparison, provide large spacing between exterior column for bundled tube system in compare to framed tube system and also close tube to give attractive view like shears tower.

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