Study of High Rise Building with Tubular Structure

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Abstract- *Structural Tubular buildings are the new structural concept in the development in high-rise buildings. This system is more efficient and economical in the use of material over a wide range of building heights than others. Out of many types of tubular buildings, two main types are:*

1. *Framed tube buildings*
2. *Tube-in-Tube buildings*

In both types of structures, outer perimeter of columns is designed to resist lateral effects while inner columns & floors are assumed to take gravity loads.

In this project, analysis of buildings will be done by using ETABS, a software package for the analysis and design of civil engineering structures. In this project one 30-storeys and one 40 storeys building is considered for the study purpose. Then, their modeling will be done in ETABS. Finally, the buildings will be analyzed as per IS-codes specification by static analysis.

Thus, by varying the building height (in terms of no. of stories), a parametric study has been done to study the effect on following parameters:

- *Storey Drift (% variation)*
- *Axial forces in columns at the same & different storey levels.*
- *Bending Moment in columns*
- *Axial stresses in columns.*

A comparison has been made using different parameters in framed tube building and tube-in-tube building.

The study is limited to Static analysis. Fixed support conditions are assumed for all columns. All the structures have been designed for seismic zone III and correspondingly basic wind speed has been taken as 33 m/s. Aspect ratio of all buildings have been kept constant and its value is 3:5.

I. INTRODUCTION

1. **GENERAL**

The increasing rate of population, rapid industrialization and consequent shortage of land especially in metro cities has turned designers for construction in vertical direction.

In the past, conventional methods of construction were available, which restricted the buildings up to seven or eight stories. These low to medium- rise structures are normally designed for gravity loads, and then checked fortheir ability to resist lateral loads. However, for tall buildings the gravity load system cannot resist horizontal forces efficiently. Therefore, there was a need of such a type of structural system that can fulfill the requirements of resisting all types of load cases with economic point of view.

1.2 NEED OF HIGH BUILDING

The land available for buildings is becoming scarce resulting in rapid increase in the cost of land. The result is multi-storeyed buildings as they provide large floor area in a relatively small area of land in urban centers. The construction of multi-storeyed buildings is dependent on available materials, the level of construction andavailability of services such as elevator necessary for use in the building. Three major factors to be considered in design of such structures are strength, rigidity and stability. Two ways to achieve these requirements are:

- By increasing the size of the member to achieve strength requirement
- •To change the form of the structure to something more rigid and stable

a. Lateral Load Resisting Systems

Braced frames are cantilevered vertical trusses resisting lateral loads primarily through the axial stiffness of the frame members. The moment resisting frame consists of horizontal and vertical members rigidly connected together in a planar grid form which resists lateral loads primarily through the flexural stiffness of the members. Vertical trusses alone may provide resistance for buildings of up to about 20 stories depending on the height to width ratio of the system. Shear trusses, when combined with moment resisting frames , produce a frame-truss interacting system. Shear walls are a type of structural system that provides lateral resistance to a building or structure. They resist "in-plane" loads that are applied along its height. The applied load is generally transferred to the wall by a diaphragm or collector or drag member. They are built in wood, concrete and masonry. The outrigger systems may be formed in any combination of steel, concrete, or composite construction. These outriggers serve to reduce the overturning moment in the core that would otherwise act as a pure cantilever, and to transfer the reduced moment to columns outside the core by way of a tension compression couple, which takes advantage of the increased moment arm between these columns. This system reduces the associated potential core uplift forces.

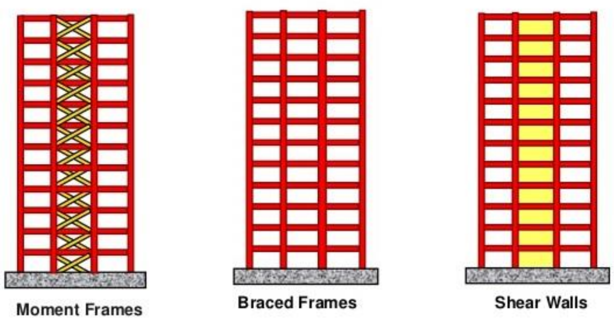

Figure 1.1. Types of Frames

b. Tubular Systems

The tube is the name given to the systems where in order to resist lateral loads (wind, seismic, etc.) a building is designed to act like a three-dimensional hollow tube, cantilevered perpendicular to the ground. The system was introduced by Fazlur Rahman Khan. Tubeframe construction was first used in the DeWitt-Chestnut Apartment Building, designed by Khan and completed in Chicago in 1963. The system can be constructed using steel, concrete, or composite construction (the discrete use of both steel and concrete). It can be used for office, apartment and mixed-use buildings. Most buildings in excess of 40 stories constructed since the 1960s are of this structural type.

1.3 CONCEPT OF TUBULAR SYSTEM

The main idea of tubular system is to arrange the structural elements so that the system can resist the loads imposed on the structure efficiently particularly the horizontal loads. In this arrangement several elements contribute to the system i.e. slabs, beams, girders, columns. Unlike most often, the walls and cores are used to resist the horizontal loads, in tubular system the horizontal loads are resisted by column and spandrel beams at the perimeter of the tubes. Many tall buildings have adopted this system and the very first building designed using tubular concept was sears tower. The exterior framing is designed sufficiently strong to resist all lateral loads on the building, thereby allowing the interior of the building to be simply framed for gravity loads. Interior columns are comparatively few and located at the core. The distance between the interior and the exterior is spanned with beams or trusses and intentionally left column free. This maximizes the effectiveness of the perimeter tube by transferring some of the gravity loads within the structure to it and increases its ability to resist overturning due to lateral loads. Tubular structure is a structure with closed column space between two to four metres and joined by deep spandrel beam at the floor level Group of columns perpendicular to the direction of horizontal load is called flanged frame and group of columns parallel to the direction of horizontal load is called web frames. Since the columns are close to each other and the spandrel beams are deep, the structure can be considered as perforated tube and behaves as cantilevered tube. The flanged frame columns will resist the axial forces (tension and compression) and web will resist the shear forces. Taking a pure rectangular tube, as shown in figure 1. The thickness of the wall is t, the length of tube is b and width is d. The contribution of flanged frame and web to resist the horizontal load for pure rectangular tube can be obtained by calculating exact moment of inertia as When MI of flanges about their own axis is neglected, the MI of tube becomes For square tube, b=d, then the sectionmodulus becomes Stress at extreme fiber where M is the overturning moment at the floor level and d is the between the two extreme fibers Portion of overturning moment carried by flange Portion of overturning moment carried by web Therefore, it is obvious that the largest portion of overturning moment is carried by flanges i.e. 75% of M and the remaining 25% by webs. This is due to the fact that Z of the square tube is a function of the square of the distance between the extreme fiber and width of high rise buildings is usually large. Hence, tubular system is an efficient system to resist horizontal loads.

1.4 TYPES OF TUBE STRUCTURE

a. Framed Tube

The organization of the framed tube system is generally one of the closely spaced exterior columns and deep spandrel beams rigidly connected together, with the entire assemblage continuous along each façade and around the building corners. The system is a logical extension of moment resisting frame whereby the beam and column stiffness are increased dramatically by reducing the clear span dimensions and increasing the member depths.

b. Trussed Tube

In trussed tube structure, the exterior face combines vertical, horizontal and diagonal members all of which are rigidly connected. The diagonal members carry gravity loads as well as lateral loads. The external tube resists entire shear as well as bending and the interior structure carries only gravitational loads. It is also known as the braced tube, it is similar to the simple tube but with comparatively fewer and farther-spaced exterior columns.

c. Tube-In-Tube Structures

This is a type of framed tube consisting of an outer-framed tube together with an internal elevator and service core. The exterior tube and the interior tube are designed to act together. The exterior tube has relatively large width and hence it is designed to resist the entire bending moment caused by lateral forces. The interior tubes are designed to carry shear produced by the lateral forces. This type of structures is also called as Hull (Outer tube) and Core (Inner tube) structures.

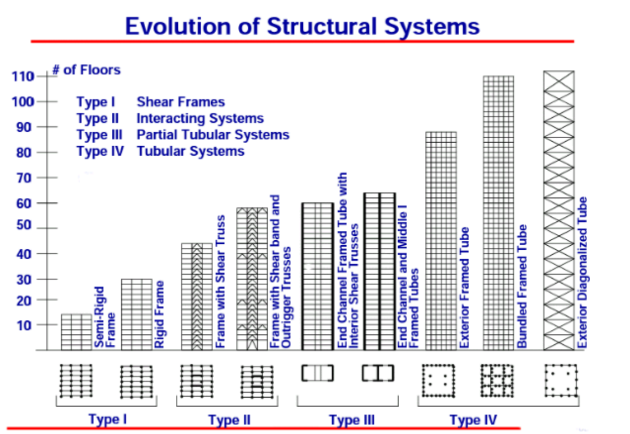

Figure 1.2. Types of structure

d. Bundled Tube

The bundled tube system can be visualized as an assemblage of individual tubes resulting in multiple cell tube to resist the lateral loads. The increase in stiffness is apparent. The system allows for the greatest height and the most floor area. This structural form was used in the Sears Tower in Chicago. The bundle tube design was not only highly efficient in economic terms, but it was also "innovative in its potential for versatile formulation of architectural space.

1.5 ADVANTAGES OF TUBULAR SYSTEMS IN TALL BUILDINGS

Offers some clear advantage from materials standpoint. Designed well, tubular forms have been known to utilize the same amount of material as would have been employed for a structure that is half as large or framed conventionally.

Allows greater flexibility in planning of interior space since all the columns and lateral system is concentrated on the perimeter of structure. This allows a column free space in the interior

Regularity in the column schedule allows off-site fabrication and welding where speed can be achieved while still confronting to quality

Wind resisting system since located on the perimeter of the building meant that maximum advantage is taken of the total width of the building to resist overturning moment Identical framing for all floors because floor members are not subjected to varying internal forces due to lateral loads

COMPARISON OF HIGH-RISE STRUCTURAL SYSTEMS

Fig. 1.3 illustrates different types of high-rise structural concepts to be suitable for certain building heights. Steel & concrete systems are presented separately. The chart is organized according to structural efficiency (i.e. optimization) as measured by the weight per sq. foot; that is, the weight of the total building structure divided by the total square footage of gross floor area.

Fig. 1.4 reveals the drastic' increase in the amount of material needed for resistance of lateral forces for a five-bay rigid steel frame building. With respect to gravity loads, the weight of the structure increases almost linearly with the number of stories. However the amount of material needed for resistance of lateral forces increases at a drastically accelerating rate. The example shows the infeasibility of using the rigid frame principle with about 55 lbs/ft2 (2.63 kN/m2) for a 90-story building, instead of the tubular system with only 34 lbs/ft2 (1.63 kN/m2) (e.g. Standard Oil Building, Chicago). The selection of a particular structural system for a certain building height approaches that condition, as indicated by the broken line in Fig. 1.3.

Weight-to-area ratios for some typical high-rise buildings are given in the following table.

TABLE 1.1 SOME IMPORTANT HIGH-RISE BUILDINGS

Year	Stories	Height/Width	kN/m2	Building
1930	102	9.3	2.02	Empire State Building, New
1968	100	7.9	1.42	John Hancock Center, Chicago
1972	110	6.9	1.77	World Trade Center, New York

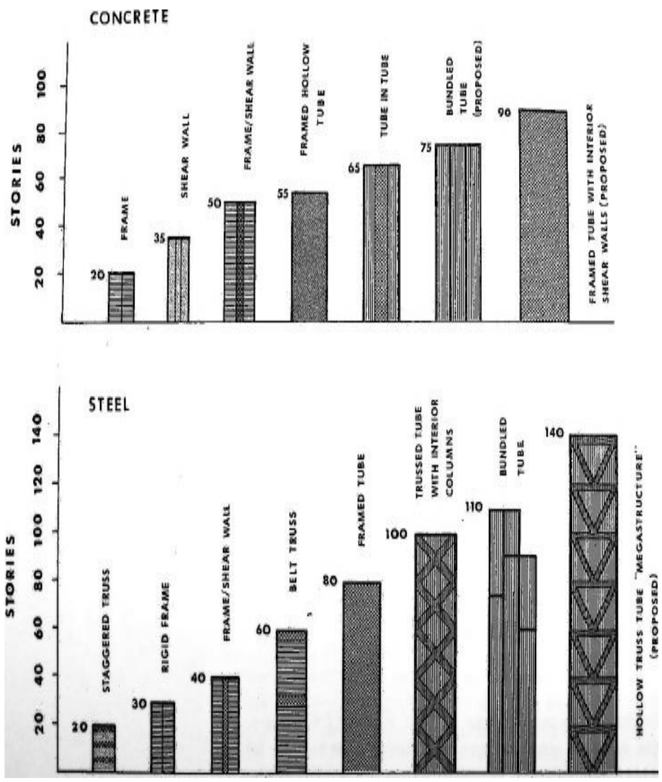

Figure 1.3. High-rise structural concepts Vs No. of stories

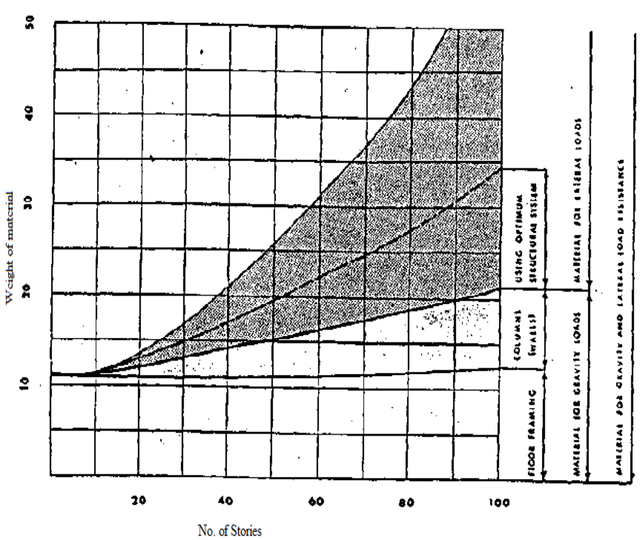

Figure 1.4. Plot between Weight of the structural material Vs No. of Stories

The frame-shear wall system of the Empire State Building is far from an optimum solution, as indicated by 2.02 kN/m2 in contrast to the 1.42 kN/m2 of the tubular John Hancock Center

1.7 OBJECTIVES AND SCOPE OF THE PRESENT DISSERTATION

The present study deals with the analysis & design of symmetric framed tube structure by ETABS.

To study the effect on following parameters:
Storey Drift (% variation)
Axial forces in columns at the same & different storey levels.
Bending Moment in columns
Axial stresses in columns.
The study is limited to Static analysis. Fixed support conditions are assumed for all columns. All the structures will be design for seismic zone III and correspondingly basic wind speed has been taken as 33 m/s. Aspect ratio of all buildings have been kept constant and its value is 3:5.

II. CONCLUSION

GENERAL

This chapter deals with the concluding remarks drawn from the results of all the analysis and design made for 30-storey & 40-storey framed tube & tube-in-tube buildings. The results have been presented in tabular form along with the graphical mode in previous chapter. This chapter contains only the conclusions drawn on the basis of discussion made in previous chapter. The conclusions are valid under the consideration that the aspect ratio of building is 3:5 and analysis is static.& response spectrum.

CONCLUSION

- The equivalent static and response spectrum analysis were conducted on 30 & 40 storey frame tube and tube in tube structures.
- From analysis results the tube in tube structure shows better result than that of frame tube structures. In static and response spectrum analysis, tube in tube structures shows least values in story displacement, story drift and base shear.
- From the above study we can observed that tube-in-tube structure will get maximum reduction in displacement and drift. As compared with framed tube structure.
- Compare to frame tubed structure, tube-in tube frame structure reduces the displacement by 12.76% in 30 storey structure & by 14.547% in 40 storey structure.
- The variation in increase in storey drift obtained in 30-storey & 40-storey tube-in- tube building for seismic load only is random, initially it decreases then it increases with storey height.
- Time period for framed tube structure is more than that of tube in tube structure due to which it will take more sec so it is subjected to more damage. Time

period for tube-in-tube structure decreases by nearly 20% compared to frame tube structures.

- From the comparison of analysis result tube in tube structure with center tube is recommended as a better structural system for tall building than frame tube structures

III. ACKNOWLEDGMENT

I hereby declare that all information in this dissertation report entitled, "Study Of High Rise Building With Tubular Sructure", has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, this is my original work and it was not previously submitted for the award of any degree and diploma or similar title in any other examining body or university.

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