Comparative Study On Tube In Tube And Tubed Mega Frames On Different Building Geometry Using ETABS

Shilpa Balakrishnan
PG Student, Department of Civil Engineering
Vimal Jyothi Engineering College
Kannur, Kerala, India

Rona Maria James
Assistant Professor, Department of Civil Engineering
Vimal Jyothi Engineering College
Kannur, Kerala, India

Abstract—The tube in tube structures and tube mega frame structures are the innovative and fresh concept in the tubular structures. Generally tube in tube structures are formed by connecting peripheral frame tube and inner core tube so closely, it is not seen as a solid system but it act like a solid surface. The total loads acting on the structures to be collectively shared between the inner and outer tubes. The tubed mega frames are new concept for tall building. In tubed mega frames instead of one central tube several vertical tubes are carrying the lateral loads. In this project, a comparative study of tube in tube structures and tubed mega frame system with different building geometry has been done using ETABS software.

Keywords — tube in tube, tubed mega frames, peripheral frame

I. INTRODUCTION

In recent days high rise buildings and tall structures are becoming more slender which increases the possibility of extreme sway compared to prior high-rise buildings. This is bringing more challenges for the engineering field to resist both lateral loads i.e., wind and earthquake loads as well as gravity loads. Earlier structures were being designed only for the gravity loads but in recent years because of increase in height and seismic zone, the engineers are taking care of lateral loads due to wind and seismic forces. In tall buildings the tallness is comparative term. There is no exact definition for tall structures which can be applied through worldwide. From the structural engineering point of view all tall structures must resist gravity as well as lateral loads.

Different types of structural systems are to be used to resist the effect of lateral loads on the buildings. They are rigid frame structures, braced frame structures, shear wall frame structures, outrigger systems, and tubular structures. Out of these the tubular systems are extensively used and which is considered as a better lateral structural systems for high rise buildings. The tubular structures are further classified as frame tube, braced tube, bundled tube, tube in tube, and tube mega frame structures. The tube in tube structures and tube mega frame structures are the innovative and fresh concept in the tubular structures. The tube in tube structures are to be widely used in tall buildings. And the tubed mega frame structures are the new concept in the field of tubular structures for tall buildings. Generally Tube in tube structures are formed by connecting peripheral frame tube and inner core tube. These tubes are interconnected by system of floor slabs and grid beams. As the columns of outer and inner core tubes are placed so closely, it is not seen as a solid system but it act like a solid surface. In the tube in tube structure the high strength concrete central tube carries the major load. The total loads acting on the structures to be collectively shared between the inner and outer tubes. The tubed mega frames are new concept for tall building. It is formed by avoiding central core tube and peripheral tubes connected by perimeter wall instead of one central core. The main function of perimeter wall is to transfer load between the long vertical tubes. In tubed mega frames instead of one central tube several vertical tubes are carrying the lateral loads. And the space utilization is maximum in tubed mega frames compare to tube in tube structure.

A. Objectives

1. To determine the effect of lateral loads on buildings with tube-in-tube and tubed mega framed structure.
2. To study the lateral storey displacement, story drift and base shear in tube-in-tube and tubed mega framed structure.
3. To summarize the advantages of tube in tube and tubed mega frames under different geometry using the obtained results
4. To identify the most vulnerable building among the models considered for seismic action

B. Scope

The construction of multistorey building is to be increased day by day. The scope of this project is to suggest a better structural system for the construction of multi storied building by investigating the performance of a tube in tube structure and tube mega frame structures on various geometry of structures.

II. TUBE IN TUBE AND TUBED MEGAFRAME

Tubular structure have been successfully utilized and are becoming a common feature in tall buildings. Basic forms of tubular systems are
1) Framed tube
2) Braced tube
3) Bundled tube
4) Tube-in-tube
5) Tubed mega frames

A. Tube in Tube Structures

The term “tube in tube” is largely self-explanatory in that second ring of columns, the ring surrounding the central service core of the building, are used as an inner framed or braced tube. The purpose of the second tube is to increase resistance to overturning and to increase lateral stiffness. The tubes need not be of the same character: that is, one tube could be framed, while the other could be braced. The system has been used for very tall buildings in both steel and concrete. Since outer-framed tube, “hull” is connected together with an internal elevator and service core, hence this system is also termed as hull-core structure.

![Fig.1 Typical tube in tube structure](image1)

Behaviour of Tube in Tube Structures:

In the tube in tube structure, the inner tube bends with the same horizontal deflection as the outer tube, owing to the high inplane stiffness of the floor slab, and carries a proportionate share of the lateral load. When the core is symmetric, adding one quarter of it in the same planer model may include it, connected by pin-ended axially rigid links to the web-frame system.

If the core acts as a simple cantilever, it may be modelled as a single equivalent column. If it is perforated, it may be treated as a wall with openings. Provided that the internal core can be modelled by an equivalent plane structure, it may always be linked to the outer framed-tube model to obtain the distribution of lateral forces on each component.

If the core cannot be treated as a plane element, or if the outer framed tube is not symmetrical, a three dimensional analysis must again be performed. The nodes of the interior core must either be constrained by a “rigid floor” option to deflect horizontally with the nodes of the exterior frame, or be connected to them by a fictitious horizontal frame of axially stiff links. Either of these techniques will simulate the rigid-plane actions of the floor slabs.

B. Tubed Megaframe Structures

The tubed mega frame system will contain huge vertical tubes placed at the perimeter of the building connected together by belt walls or cross walls at certain stories. These tubes will be the main load carrying elements in this structural system. With the tubed mega frame system, no floor space has to be assigned for a central core and the building can therefore be made more slender. This will in turn lead to increased rentable space and function flexibility at each floor level. Less land-usage will also be needed when building this kind of tall building.

![Fig.2 Typical tubed mega frame structure](image2)

The main purpose of this system is to transfer all loads to the perimeter of the building and thereby achieve higher stability since the leverarm between the load bearing components will be longer than in a core system. With this structural system there will be no central core.

III. MODELLING AND ANALYSIS

A. Structure Idealization

1. It is assumed that the beams and columns are of uniform section throughout the height of the building.
2. The floor slabs are considered as rigid diaphragms in their own plane so that the relative displacements between tubes are restricted.

B. Structural Details

The models created using ETABS software are tabulated below:

<table>
<thead>
<tr>
<th>Group</th>
<th>Models</th>
<th>Description</th>
<th>Plan dimension</th>
</tr>
</thead>
<tbody>
<tr>
<td>G1</td>
<td>STT</td>
<td>Square tube in tube structure</td>
<td>40X40 m</td>
</tr>
<tr>
<td></td>
<td>STM</td>
<td>Square tubed mega frame</td>
<td></td>
</tr>
<tr>
<td>G2</td>
<td>RTT</td>
<td>Rectangular tube in tube structure</td>
<td>40x30 m</td>
</tr>
<tr>
<td></td>
<td>RTM</td>
<td>Rectangular tubed mega frame</td>
<td></td>
</tr>
<tr>
<td>G3</td>
<td>HTT</td>
<td>Hexagonal tube in tube</td>
<td>40x40 m</td>
</tr>
<tr>
<td></td>
<td>HTM</td>
<td>Hexagonal tubed mega frame</td>
<td></td>
</tr>
<tr>
<td>G4</td>
<td>OTT</td>
<td>Octagonal tube in tube</td>
<td>40x40 m</td>
</tr>
<tr>
<td></td>
<td>OTM</td>
<td>Octagonal tubed mega frame</td>
<td></td>
</tr>
<tr>
<td>G5</td>
<td>CTT</td>
<td>Circular tube in tube</td>
<td>40x40 m</td>
</tr>
<tr>
<td></td>
<td>CTM</td>
<td>Circular tubed mega frame</td>
<td></td>
</tr>
</tbody>
</table>
2) Tubed mega frame
   Concrete tubes-3000x3000mm
   Outer girders-400x1200 mm
   Inner columns-800x800mm
   Inner beams-300x600mm
   Slab thickness-250mm

C. Analysis
   ETABS is an engineering software product that caters to multistorey building analysis and design. Modelling tools and templates, load prescriptions, analysis method and solution techniques, all coordinate with the grid like geometry unique to this class of structure. ETABS is used to evaluate basic or advanced system under static or dynamic conditions. In this study for the assessment of seismic performance Response spectrum method of analysis is used. Response spectrum analysis is a dynamic linear method in which maximum structural response is plotted as a function of structural period for a given time history recorded and level of damping.

IV. Results
A. Storey Displacement
   Storey displacement is the total displacement of the storey with respect to ground. The storey displacement values for each model are given below:

<table>
<thead>
<tr>
<th>Model</th>
<th>Storey displacement (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>STT</td>
<td>511.793098</td>
</tr>
<tr>
<td>STM</td>
<td>3267.433436</td>
</tr>
<tr>
<td>RTT</td>
<td>614.477522</td>
</tr>
<tr>
<td>RTM</td>
<td>759.058114</td>
</tr>
<tr>
<td>HTT</td>
<td>2177.191114</td>
</tr>
<tr>
<td>HTM</td>
<td>2255.159944</td>
</tr>
<tr>
<td>OTT</td>
<td>604.516168</td>
</tr>
<tr>
<td>OTM</td>
<td>1857.487068</td>
</tr>
<tr>
<td>CTT</td>
<td>461.007762</td>
</tr>
<tr>
<td>CTM</td>
<td>552.071326</td>
</tr>
</tbody>
</table>

B. Input Parameters

Building data:
   Type of structure-Concrete moment resisting frame
   Number of stories-G+39
   Height of each floor-3m
   Height of building-120m

Material properties:
   Grade of concrete-M30
   Reinforcement bars-Fe 415

Gravity and lateral load consideration:
   (a) Gravity load
      Live load-4kN/m²
      Floor finish-1kN/m²
      Wall load-15kN/m
   (b) Earthquake inputs as per IS 1893(part I):2002
      Zone factor-0.16 (zone III)
      Soil type- Type II
      Importance factor-1.0
      Response reduction factor-5
   (c) Wind inputs as per IS 875(part III):1987
      Wind speed-39m/s
      Terrain category-3
      Structure class-B
      Topography factor-1.0

Section properties
   1) Tube in tube structure
      Column size-800x800mm
      Beam size-300x600mm
      Slab thickness-250mm
The comparison of storey displacement of various models are given below:

![Storey Displacement](image)

**Fig.13 Comparison of storey displacement**

**B. Storey Drift**

Storey drift is the difference of displacement between the two consecutive stories divided by the height of that storey. The values of storey drift for each models are given in table 3.

<table>
<thead>
<tr>
<th>Model</th>
<th>Storey drift</th>
</tr>
</thead>
<tbody>
<tr>
<td>STT</td>
<td>0.0069</td>
</tr>
<tr>
<td>STM</td>
<td>0.037423</td>
</tr>
<tr>
<td>RTT</td>
<td>0.001178</td>
</tr>
<tr>
<td>RTM</td>
<td>0.008455</td>
</tr>
<tr>
<td>HTT</td>
<td>0.023058</td>
</tr>
<tr>
<td>HTM</td>
<td>0.026346</td>
</tr>
<tr>
<td>OTT</td>
<td>0.007319</td>
</tr>
<tr>
<td>OTM</td>
<td>0.021312</td>
</tr>
<tr>
<td>CTT</td>
<td>0.002573</td>
</tr>
<tr>
<td>CTM</td>
<td>0.006294</td>
</tr>
</tbody>
</table>

The comparison of storey drift for various models are given below:

![Storey Drift](image)

**Fig.14 Comparison of storey drift**

**C. Storey Shear**

The design seismic load applied to each floor level is called storey shear. The value of storey shear for each models are tabulated below:

<table>
<thead>
<tr>
<th>MODEL</th>
<th>STOREY SHEAR (kN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>STT</td>
<td>54123.35136</td>
</tr>
<tr>
<td>STM</td>
<td>87229.651632</td>
</tr>
<tr>
<td>RTT</td>
<td>44416.441788</td>
</tr>
<tr>
<td>RTM</td>
<td>61744.272669</td>
</tr>
<tr>
<td>HTT</td>
<td>43572.730721</td>
</tr>
<tr>
<td>HTM</td>
<td>61744.272667</td>
</tr>
<tr>
<td>OTT</td>
<td>47075.709205</td>
</tr>
<tr>
<td>OTM</td>
<td>67078.699818</td>
</tr>
<tr>
<td>CTT</td>
<td>19612.90598</td>
</tr>
<tr>
<td>CTM</td>
<td>62002.284418</td>
</tr>
</tbody>
</table>

The comparison of storey shear for various models are given in fig.15.

![Storey Shear](image)

**Fig.15 Comparison of storey shear**
V. Conclusion

The following conclusion can be drawn from the present investigation:

1. Storey displacement, storey drift and storey shear are higher for tubed mega frames when compared with tube in tube under different geometry.

2. STM has 84.33% increase in storey displacement when compared to STT and when compared to RTT, RTM has 19.24% increase in storey displacement and HTM shows a 3.46% increase in storey displacement than HTT and storey displacement of OTM is 67.46% greater than OTT and also CTM has a increase of 16.5% in storey displacement when compared to CTT.

3. STM has 37.95% increase in storey shear when compared to STT and when compared to RTT, RTM has 28.06% increase in storey shear and HTM shows 29.43% increase in storey shear than HTT and storey shear of OTM is 29.82% greater than OTT and also CTM has a increase of 84.5% in storey shear when compared to CTT.

4. STM has 83.72% increase in storey drift when compared to STT and when compared to RTT, RTM has 86.07% increase in storey drift and HTM shows 12.48% increase in storey drift than HTT and storey drift of OTM is 65.75% greater than OTT and CTM has an increase of 59.12% in storey drift when compared to CTT.

5. Tube in tube will act as a better structural system than tubed mega frames for tall buildings.

6. Circular tube in tube is a better option for high rise buildings since it has less storey displacement, storey drift and storey shear.

7. The most vulnerable building is square tubed mega frame since the storey displacement is large.

8. It is better not to choose hexagonal and octagonal geometry for buildings since it has high storey displacement and storey shear.

References


