

Comparative Analysis of RCC Structure and Tube-In-Tube Structure

Swetha Singh¹, Nandeshwar Lata², Dr. Bharat Nagar³, Rajesh Kumar⁴

¹Swetha Singh, M-Tech Research Scholar, Department of Civil Engineering, Jagannath University, Jaipur, Rajasthan

²Nandeshwar Lata, Assistant Professor, Department of Civil Engineering, JNIT, Jaipur, Rajasthan

³Dr. Bharat Nagar, Professor & Head of Department of Civil Engineering, Jagannath University, Jaipur, Rajasthan

⁴Rajesh Kumar, Freelancer Faculty for Civil Engineering in Engineers Academy

Abstract - The study is based on the comparative analysis of rcc structure and tube-in-tube structure, and the primary objectives are to investigate effects of varying design parameters on the tube action and shear lag behavior of a typical reinforced concrete tube in tube building, and compare this tube-in-tube structure with traditional rcc buildings. A parametric study was conducted with necessary design variables on the performance of a 20 story building using softwares namely STAAD.Pro and ETABS. The design variables considered for the parametric study include the column depth, spandrel beam depth and shear wall thickness. The performance of each model was assessed in terms of overall and critical story drifts, and shear lag behavior using linear dynamic analysis. Overall, the effects of the column depth on the tube action and shear lag behaviour were more prominent than the other member dimensions. The reduction in the percentage of steel and also the concrete amount can be seen as compared to the regular rcc structure.

Key Words: shear lag behaviour, STAAD.Pro, ETABS, spandrel beam depth, story drift, linear dynamic analysis

1. INTRODUCTION

The advancement in construction field is increased day by day. The numbers of buildings, height of building are increased. The effect of lateral load is increased with respect to the increase of height. Modern construction methods and structural systems are to be introduced to enhance the structural safety. There are different types of structural systems which are to be used to resist the effect of lateral loads on the buildings. Rigid frame structures, braced frame structures, shear wall frame structures, outrigger systems, tubular structures are the different types of structural systems used in the buildings to enhance structural safety by reduce the effect of lateral loads on the buildings. The tubular systems are widely used and considered as a better structural system for tall buildings. There are different types of tubular structural systems which are given as framed tube, braced tube, bundled tube, tube in tube, and tube mega frame structures.

1.1 Motivation and Objective

While constructing tall buildings we have to consider some extra safety measurements like structure should be designed for seismic and wind considerations, type of foundations adopted to structure, life of the structures. The tall buildings

are more affected to lateral loads, to withstand the loads we have to consider the parameters for the building. This study consists the tubular concept which will give more spacing for accessible and which is more resistant to the lateral loads. By using this form of structures we can go for high rise structures. The objectives are:

1. Comparative analysis between tube in tube structure and RCC structure.
2. To study the behavior of the RCC structure and tubular structure in seismic conditions.
3. Results are compared between the models with respect to Base shear, Displacement and Drift.

1.2 Advantages of Tube-in-tube structure over RCC structures:

- Efficient structural system: The tube-in-tube structure with central tube provides stability against lateral loading as well as gravity loading. Also this system provides enough opening for stairways, elevators and ducts etc.
- It is suitable for high rise structure: This system holds good for 40-100 storied structure.
- The use of tube-in-tube structure allows speedy construction.
- It is suitable for RC, steel and composite constructions.

2. CLASSIFICATION OF STRUCTURAL SYSTEMS

There are many structural systems such as:

1. Rigid frame System (Moment Resisting Frame System)
2. Braced frame System
3. Shear-walled frame System
4. Coupled Wall System
5. Advanced Structural forms- Tubular Systems

The tubular system is to arrange the structural elements in such a way that the system can resist the imposed loads on the structure efficiently especially the lateral loads. This system comprises of various elements i.e. slabs, beams,

girders, columns. The walls and cores are engaged to resist the lateral loads, in the tubular system the horizontal loads are resisted by column and spandrel beams at the perimeter level of the tubes.

2.1 Tubular Structures

Tubular structures have been successfully utilized and are becoming popular in tall buildings construction. The basic forms of tubular systems are:

1. Framed tube system
2. Braced tube system
3. Tube-in-tube structure
4. Bundled tube system
5. Tubed mega frame

The tube could be a structural engineering system that's utilized in high-rise buildings, enabling them to resist lateral loads from wind, seismic pressures and so on. It acts like a hollow cylinder, cantilevered perpendicular to the ground. The system was developed within the Sixties by the engineer Fazlur Rahman Khan, and has been used to construct most high-rise buildings since then. The tube system may be created mistreatment concrete, steel or a composite of both. In its simplest form, closely-spaced columns are tied together with deep spandrel beams through moment connections as part of the external perimeter of the building. The rigid frame that this assembly of columns and beams forms leads to a dense and powerful structural 'tube' round the exterior.

3. LITERATURE REVIEW

1. Hamid Mirzahassemi (2015) has given the "Optimal Design of Tube in Tube Systems" to investigate effects of varying the design parameters on the tube action and the shear lag behavior of a typical reinforced concrete tube in tube building and to propose optimal design approaches for similar tube in tube structures.

A parametric study was conducted with selected design variables on the performance of a 40 story building. The design variables considered for this study include the column depth, beam depth, interior walls of the moment frames. The performance of each model was assessed in terms of overall and critical story drifts and shear lag behavior. However, the effects of the column depth on the tube action and shear lag behavior were more prominent than the other member dimensions.

2. Coull A and Ahmed AA (1978) has studied the "Simple Analysis of Tube Frame System of Tall Building by Using of Deformation" in which two relation groups suggested in this paper area unit capable of considering shear lag each in

projection and net frames within the base of frame. The simplicity and accuracy of the proposed method is demonstrated through the numerical analysis of several structures. In addition, the results of these proposed deformation functions are compared to previous relations considered by other researchers to find the best relations.

3. Kwan AKH (1994) has given "Simple method for approximate analysis of framed tube structures". The focus of this article is to present a new and simple mathematical model that may be accustomed verify the optimum location of a belt truss reinforcing system on tall buildings such the displacements because of lateral loadings would generate the smallest amount amounts of stress and strain in building's structural members. The result of belt truss and shear core on framed tube is sculpturesque as a targeted moment applied at belt truss location, this moment acts during a direction opposite to rotation created by lateral loads.

4. Lavanya. T and Satyanarayana Sridhar R studied the "Dynamic Analysis of Tube-in-Tube Tall Buildings", which aimed at developing simple methodology for the free vibration analysis of tall buildings based on Transfer Matrix Approach with the aid of FORTRAN programming to make the solving process of the complex problems ease and develop simplified solutions in the form of design.

4. RESULTS

For the study twenty storied masonry in filled RCC building and tube-in-tube structures are considered. The geometry and dimensions of plan are shown in Figure.

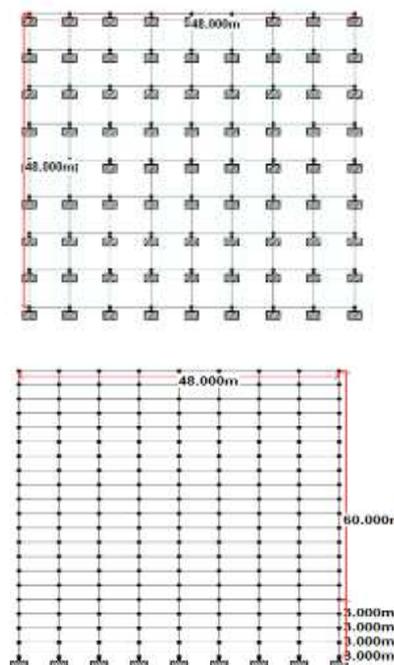


Fig 1. Plan and Elevation of RCC structure

- Number of Stories - G+19 (20 Storied)
- Number of Stories - G+19 (20 Storied)
- The height of story is 3 m.
- Total height of the building is 61.5 m.
- Number of bays in each direction of X and Y is 8.
- Bay width is 6 m in X and 6 m in Y direction.
- Spacing between each column, for model is 6 m
- Plan Configurations - Square, Rectangular
- Building type- Office Building
- Column size - 0.6 m X 0.6 m
- Beams size - 0.6 m X 0.5 m
- Slab Thickness - 0.200 m
- Brick wall Thickness -0.230 m
- Unit weight of PCC - 24 KN/m³
- Unit weight of Brick wall is - 20 KN/m³
- Unit weight of RCC - 25 KN/m³
- Modulus of Elasticity for Brick wall - 10.5KN/m²
- Young's Modulus of steel – 210000 MPa
- Young's Modulus of Concrete, Ec = 27386 Mpa
- Characteristic strength of concrete is, fck = 30 Mpa
- Yield stress for steel is, fy = 415 Mpa
- Ultimate strain in bending, ϵ_{cu} = 0.0035
- Grade of concrete : M30
- Grade of steel : Fe415
- Dead loads according to IS 875: Part I
- Live loads according to IS 875: Part II
- Live Load on Typical floors 3 KN/m²
- Live Load on Terrace - 2 KN/m²
- Earth quake inputs as per IS 1893 (Part I):2002
- Location of Building- in Moderate intensity (Zone-II and V)
- Soil type- Type II
- Importance factors- 1.0
- Response reduction factors - 5.0

Table -1: Analysis result of Max Story Displacement

Structure Type	Max displacement (mm) ETABS		Max displacement (mm) STAAD.Pro	
	SA	RSA	SA	RSA
RCC Frame	4.5	5.2	4.8	5.3
Tube-in-Tube Frame	2.4	2.7	2.8	3.1

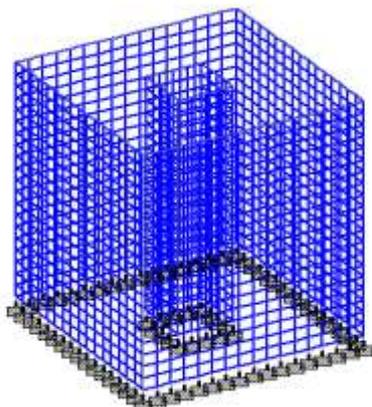
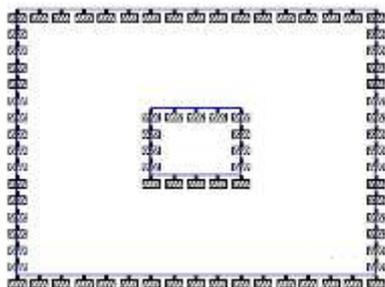
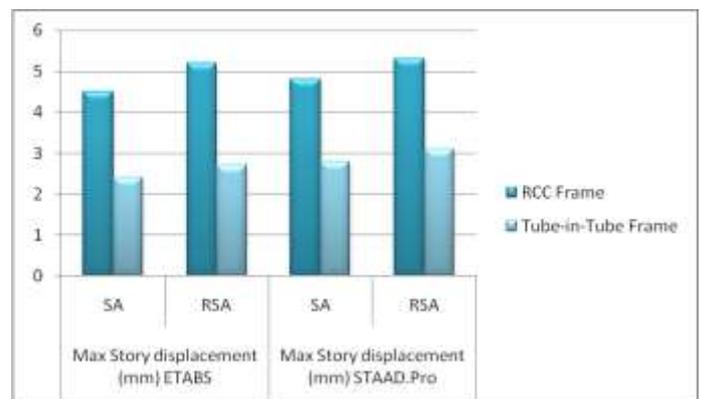


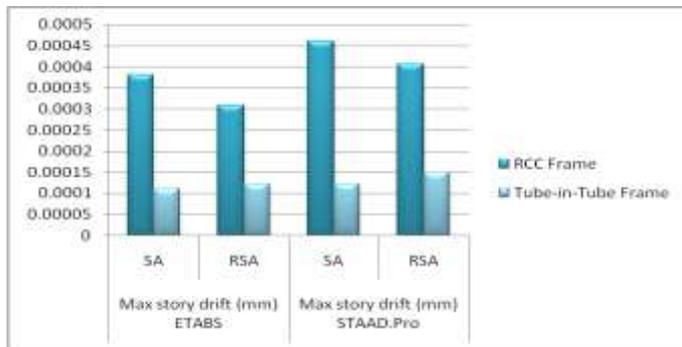
Fig 2. Plan and 3D view of Tube-in-tube structure



From the comparison the tube in tube structure shows a 41.67% of displacement reduction than that of RCC frame. And in response spectrum analysis the tube in tube structure shows a 41.51% of displacement reduction than that of RCC frame.

Table -2: Analysis result of Max Story Drift

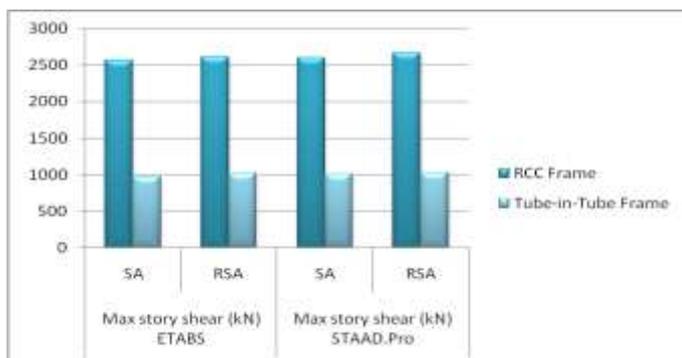
Structure Type	Max story drift (mm) ETABS		Max story drift (mm) STAAD.Pro	
	SA	RSA	SA	RSA
RCC Frame	0.00038	0.00031	0.00046	0.00041
Tube-in-Tube Frame	0.00011	0.00012	0.000123	0.00015



From the comparison the tube in tube structure shows a 73.26% of drift reduction than that of RCC frame. And in response spectrum analysis the tube in tube structure shows a 63.39% of drift reduction than that of RCC frame.

Table -3: Analysis result of Max Story Shear

Structure Type	Max story shear (kN) ETABS		Max story shear (kN) STAAD.Pro	
	SA	RSA	SA	RSA
RCC Frame	2567	2612	2598	2665
Tube-in-Tube Frame	973.12	1018.16	1001.12	1028.61



From the comparison the tube in tube structure shows a 61.47% of shear reduction than that of RCC frame. And in response spectrum analysis the tube in tube structure shows a 61.40% of shear reduction than that of RCC frame.

5. CONCLUSIONS

- The effect of geometric configurations on behavior of tall tubular structures is summarized using the obtained results, by concluding the optimum geometric configuration for tall tubular structures.
- While constructing tall buildings we have to consider some extra safety measurements like structure should be designed for seismic and wind considerations, type of foundations adopted to structure, life of the structures.
- Efficiency of tall tubular concrete structures with respect the base shear, story displacement, drift and time period are found out for all geometric configurations.
- From the study it can be concluded that the RCC frame shows higher story displacement as compared to Tube-in-Tube structure.
- It can also be seen that the story drift is drastically reduced when the structure is tube-in-tube frame as compared to RCC frame.
- Further, it can be noticed that the story shear is also higher in RCC frame as compared to tube-in-tube structure.
- The study also concludes that there is reduction in the volume of concrete used in tube-in-tube structure in comparison to the RCC structure and also there is reduction in the percentage of steel used.
- The tall buildings are more affected to lateral loads, to withstand the loads we have to consider the parameters for the building. This study consists of the tubular concept which will give more spacing for accessible and which is more resistant to the lateral loads. By using this form of structures we can go for high rise structures.

6. REFERENCES

- [1] IS:456-2000, "Code of Practice for Plain and Reinforced Concrete", Bureau of Indian Standards, New Delhi, India.
- [2] IS:1893 (part1):2002, "Criteria for Earthquake Resistant Design of Structures", part 1-General provisions and buildings, fifth revision, Bureau of Indian Standards, New Delhi, India.
- [3] Hamid Mirza Hosseini, "Optimal Design of Tube in Tube systems", Indian Journal of Fundamental and Applied Life Sciences ISSN: 2231- 6345 2015 Vol. 5 (S3), pp. 119- 138/MirzaHosseini.

- [4] Archana J & Reshmi P R, "Comparative Study on Tube-in-Tube Structures and Tubed Mega Frames", vol. 5, Issue 8, August 2016.
- [5] Myoungsu Shin, Thomas H.-K. Kang and Benjamin Pimentel, "Towards Optimal Design of High-rise Building Tube Systems", Thomas H.-K. Kang, School of Civil Engineering and Environmental Science, University of Oklahoma, 202 W. Boyd Street, Room 334, Norman, ok 73019, USA Struct. Design Tall Spec. Build. 21, 447–464 (2012)
- [6] Jignesha Patel and Roshni J John, "Seismic Analysis of Framed Tube Structure"
- [7] Reza Mehjoub, RehaRahgozar and HamedSaffari, "Simple Analysis of Tube Frame System of Tall Building by using of Deformation Functions"
- [8] Kang Kung Lee, Yew-ChayeLoo and Hong Guan, "Simple Analysis of Framed Structures with Multiple Internal Tubes"
- [9] Lavanya. T and Satyanarayana Sridhar R, "Dynamic Analysis of Tube-in-Tube Tall Buildings"
- [10] Kwan AKH (1994), "Simple method for approximate analysis of framed tube structures"
- [11] Coull A and Ahmed AA (1978), "Simple Analysis of Tube Frame System of Tall Building by Using of Deformation"