Performance of Tube in Tube Structures: A Review

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Abstract: In present time due to less availability of land and increasing population so the tall buildings is better as it takes less space.Tubular structures is a comman feature in tall buidings.Tubular structures include frame tube,braced tube,tube in tube,bundled tube structures.The concept of tubular structure is that the building can be designed to resist lateral loads by designing it like a hollow cantilever perpendicular to the ground.Tube in tube structures are better compared to other tubular systems because it have less storey shear,storey displacement,storey drift.For obtaining better results X Bracings can be used in tube in tube structures.In this study we will see the effect of X Bracing on tube in tube structures by comparing tube in tube structures with and without X bracing.

Keywords*:* Shear Wall, Storey Displacement, Storey drift, Storey Shear, Tube in Tube Structure.

I. INTRODUCTION

Different types of structural systems are used to resist the effect of lateral loads on the buildings. The tubular systems are mostly used for tall buildings because they are considered as a better structural systems.The different types of tubular structural systems are frame tube, braced tube,bundled tube,tube in tube.Frame tube is a structural system which is made by closely spaced columns on the outer side of the building.This closely spaced columns, 2 to 4 m between centers, with deep girders joining them. A braced tube system is an advancement in frame tube structures which is done by providing X bracings to stories of buildings.The bundled tube system is a system in which there is group of individual tubes which are connected in a form of a bundle to form a multiple cell tube. Tube in tube structures are widely used in tall buildings.It consists of two tubes ie outer tube and inner tube.The inner tube is shear wall which is made for lifts and outer tube consists of dense columns and deep beams which takes the gravity and lateral loads.Tube in Tube structures are also called as hull core structures.The diagram of Tube in Tube structures are shown in (fig 1)

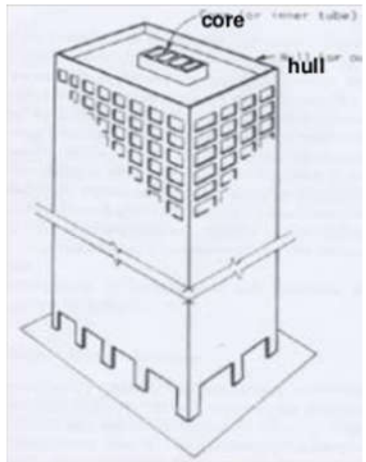

Fig 1: Tube in Tube system

The outer and the inner tubes act together to resist both gravity and lateral loads in steel framed buildings. However, outer tube always plays an important role because of its greater structural depth**.**

II. REVIEW OF LITERATURE

1. "Investigation of the shear lag phenomenon and structural behavior of frame tube and braced tube tall structures" by Farshid Nouri and Payam Ashtari et al, 2013.

"Framed-tube and braced tube are widely used structural systems.In this systems shear lag is an important factor to be considered..Framed-tube and braced-tube structural systems are popular structural systems among the exterior lateral load resisting systems. Shear lag phenomenon because of rigidity levels of the spandrel beams. Flexibility of the spandrel beams is done to increase axial force in corner columns and decrease in interior columns. Shear lag is of two types:- Positive shear lag,Negative shear lag. In positive shear lag the axial force is higher at corner columns and in negative shear lag axial force increases in the middle columns and it occurs in the upper levels of tall buildings. Spandrel beam rigidity level is one of the main reasons of shear lag. Two examples including both framed-tube and braced-tube have studied. Edge columns are the members which affected by the shear lag. In the case of positive shear lag axial force of edge column is in a higher level compared to the ideal distribution of axial force in columns.The axial forces on this columns can be reduced by lowering the stiffness of lower column.Diagrid angle is the another key for designing braced tube structure.Diagrid angles of 30,36,48 storey frame are compared in this study".

2. "Structural Forms Systems for Tall Building structures" by Er. Nishant Rana and Siddhant Rana et al, 2014.

."The different type of structural systems are braced frame structural system, Framed tube Structural System, Outrigger braced Structural System. braced system is efficient and economical way to improve the lateral stiffness and resistance of rigid frame system and other benefit of this system is that it eliminates the bending of columns and beams by resisting lateral loads primarily through axial stress. The "Framed Tube" structural system in tall building structures has been widely used resist lateral loads. It consists of closely spaced wide exterior columns connected at each floor level with relatively deep spandrel beams through moment connections.Outrigger are rigid horizontal structures which are designed for improving building overturning stiffness and it increases the strength by connecting the core to distant columns. The benefits of an outrigger system is that building deformations resulting from the overturning moments are reduced. Shear wall structural system are provided along both length and width of buildings. Shear walls are like vertical wide beams that carry earthquake loads downwards to the foundation.This paper reviews some major types of structural forms for tall structures".

3. " Braced tube structural system" by Hardik J. Patel ,A.R Darji and DR. K.B Parikh et al, 2015

"Braced tube is an improvement of frame tube structure made by cross bracings the frame with X bracings over the stories. Diagonal of braced tube are connected to the column at each intersection, they eliminate the effect of shear lag in flange and web .As a result, the structure behaves under lateral loads like a braced frame reducing bending in the members of the frame. In braced tube structure, the distribution of axial forces along the flanged frame columns at one floor is not uniform and the distribution of shear forces along the web is not linear this is to the flexibility of the tubular structures and is called shear lag effect.The aim of this study is to optimize the variable angle of X braced pattern under gravity and lateral loading and applying best x bracing angle on different configuration of column".

4. "Seismic analysis of frame tube structures" by Jignesha Patel and Roshni J John et al, 2015

"The Frame tube structure was analysed and it was able to resist lateral load The efficiency of frame tube was because of large number of rigid joints along the periphery, creating a large tube. Exterior tube carries all the lateral load The framed-tube is better than a rigid frame because it have material on the exterior of the building..Recent earthquakes have concluded that conventional construction is effected by destruction due to high story displacement. Frame tube structures are better than moment resisting frames because it places the material on the exterior of the building.The tube buildings.In tube buildings the interior floor space is free of core bracing and heavy columns.This reduction in material makes the building economical.For twenty-five storey frame Tube Structure is modelled with rigid diaphragm. This system was analyzed by various type of slab like membrane for varying zones III, IV, V".

5. “Shear lag in tube structures” by Sharadrao Patil and Uttam Kalwane et al, 2015

“Framed-tube structure have multiple internal tube or tubes in tube structure so they are mostly used because of their high stiffness in resisting lateral load and internal tubes are there for supporting the vertical tubes.When this structures are subjected to lateral load such as wind load the corner columns are experience high axial force due to shear lag phenomenon..The bending of a tabular frame is similar to bending of box girder which are neglected in box girder plays an important role in tubular frame building.The flexiblity spandral beams create “ shear lag effect.The assumption is true for box section only if the shear stiffness is infinite or no shear stress.The panels displace longitudinally such that the middle portion of flange comes closer to the box section this displacement is called shear lag effect which reduces the effectiveness of box structure by increasing decreasing axial stresses at the middle of frame panels.The accuracy of the results depends upon the geometry and loading of the structure.The exterior frames resist lateral loads while internal frames carry gravitational loads.Modelling methods are used which explains that frame panels is taken as orthotropic equivalent members in a such a way that perimeter frame could be analyzed as a continuous structure.Two flange frames which are orthogonal out of plane behaviour with respect to stiffness of floors are negligible compared to in-plane behaviours of plane.Frame tube structures are efficient because of its perimeter configration.It is similar to that of a box girder.It is also affected by shear lag.The non linear stress distribution in frame tube creates wraping of floor slab.Positive shear lag occurs generally under uniform and point loads.Negative shear lag occurs only in uniform loading”.

6. “Analytical investigation on the performance of tube in tube structures subjected to lateral loads” by Nimmy Dileep and Renjith R et al, 2015

“The tubular structures is best for buildings. Tubular systems consists of framed tube, core tube, tube-in-tube and bundled tube. A tube-in-tube structure consists of a peripheral framed tube and a core tube interconnected by floor slab. Each of these vertical components, various simplified models have been developed to analyze structure’s behavior under lateral loads.The interior and exterior columns of a tube in tube structures are very close which makes them to act as a solid surface.The main objective of this thesis is to investigate the performance of a tube in tube structure with different positioning of the internal tube which is done in 3D models developed in SAP 2000. The displacement at each floor level is done by equivalent static, Response spectrum and Time history are were plotted for comparative study. By this three methods of analysis the results were are compared between the three models to study the effect of lateral load pattern on displacements of buildings”.

7. "Concept of tubular design in high rise buildings" by Vikram J and Geetu Varghese et al, 2015

"A tubular systems include frame tube,trussed tube,tube in tube,bundled tube.frame tube have closely spaced exterior columns and deep spandrel beams which are rigidly connected together. In trussed tube structure, the exterior face is combined with vertical, horizontal and diagonal members which are rigidly connected.In trussed tube structure, the exterior face is combined with vertical, horizontal and diagonal members which are rigidly connected.The frame tube system is a three dimensional structural system which utilizes the entire building inertia to resist the lateral loads. The tube system is based on the concept that building is designed to resist lateral loads by making it like a hollow cantilever perpendicular to the ground.A plan for the bundled tube is created using Auto-cad software. The modeling of the 70 storey bundled tube system is done by staad pro.The member property and supports are assigned.The live loads are assigned for all floors and wind load is calculated for Coimbatore zone.The analysis of structure is done to obtain results for design.Tube structure, any tall building multi-storeyed building is a good idea for reduction of land use. In tube system curtain walls are used which reduces the cladding cost".

8. "Comparative study of tube in tube structures and tube mega frames" by Archana J and Reshmi P R et al, 2016.

"The purpose of this study is to select the better structural system for tall buildings. The two types of methods. Equivalent static analysis and response spectrum analysis.This two methods were used in frame,tube in tube structures and tube mega frames.The tube in tube structures with centre tube showed better results compared to frame system or tube mega systems.Tube in tube structures shows 46.98% and 48.6% reduction in displacement and frame structures and tube mega frame structures showed 18.84 & 26.5% displacement reduction".

9. "Comparative analysis between tube in tube structure and conventional moment resisting system" by Bipin H Naik and Suresh Chandra et al, 2017.

"The purpose of this analysis was to study the behavior of tubular structure in variation of column spacing and X bracings. On comparing conventional structure with tube in tube structure in performance tube in tube structure is more stable to resist lateral loads.Tube in Tube is most common used type of tubular structure structure consist of which internal tube can be used for movement between the floors i.e. can be used to for providing stair case lift room.The main objective of this study is to compare tube in tube structure and moment resisting frame with static and dynamic loads and its behaviour with variation in column spacing and with X bracing. By equivalent,static,dynamic time history methods tube in tube and conventional moment resisting frame was analyzed".

10.”Analysis of different forms of tube in tube structures subjected to lateral loads” by Mohan K T,Rahul Y and Virendra Kumara K N et al, 2017.

“Advancements in structural systems include increase in building height and use of high strength materials, building weight reduction etc.Types of tubular systems are Framed tube, Braced tube,Bundled tube,Tube-in-tube and Tubed mega frame. The tube system concept is that a building can be designed to resist lateral loads by designing it as a hollow cantilever perpendicular to the ground.Modeling of framed tube-in-tube structure was done by using SAP 2000 for 5 geometrical configurations i.e., square, rectangle, triangle and hexagon shape frame tube structures and regular moment resisting frame section included in it. For obtaining the consistent results, floor height kept constant for all buildings.For lighting,ventilation and service criteria a central core is provided in it”.

11. “Earthquake and Wind Analysis of Braced Tube Structure with Different Plans in Configuration” by Shubhangi V Pawar,M.S Kakamare and M.B Pendhari et al, 2017.

“This research paper includes the effects of earthquake and wind force on steel Braced Tube Structure with different shapes in plan. The Indian standard code of practice IS- 1893 (Part I: 2002), IS- 875:1987(Part III), IS-800-2007 are used to analyse the design of building.ETAB software was used to analyse the building under wind and earthquake forces in zone 3.Equal area with 1296 sq m was used for Circular, Square,rectangular plan. In this research comparative analysis of 60 storey building with Square, Rectangular and circular plans are done by Linear static method”.

12. “Dynamic Analysis of tube in tube tall structures” by Lavanya T, Sathyanarayana Sridhar et al, 2017.

“The dynamic characteristics of tall buildings like Natural Frequency (ω, radians/sec) or Fundamental Time Period (T, seconds) is obtained in range of tube-in-tube tall buildings using transfer matrix method. This method enables us to calculate the natural frequency of tube-in-tube tall buildings accurately with the help of computer programming. It is important to estimate the natural frequency of tall buildings because they are usually flexible and are sensitive to dynamic loads. The dynamic behavior of structures is done by three-dimensional analyses such as Finite Element Analysis (FEM).Comman types of structural system include Rigid Frame System (Moment Resisting Frame System),Braced frame system,Shear Wall System,Coupled Wall System ,Tubular System. Rigid Frame System utilizes the moment resisting connection between columns and beams along its total perimeter to resist the applied lateral loads. Braced frames resist lateral deflections through its diagonal bracing or X-bracing.In shear wall the lateral loads are assumed to be concentrated at floor levels.This floors spread these forces to the columns or walls in the building.In couple shear wall total stiffness exceeds the summation of individual stiffness due to individual cantilever action.

The tubular system is to arrange the structural elements in such a way that the system can resist the lateral load.The transfer matrix method is used for finding the static and dynamic properties of an elastic system. The Principle behind this method is that of breaking up a complicated system into individual parts".

13."Effect of geometry of plan on shear lag of frame tube tall buildings subjected to the earthquake load" by Mostafa Moghadasi, Soheil Taeepoor and Mehdi Mahmoudi et al, 2017.

"Frame tube structures is better for both concrete and steel tall buildings.In frame tube the overturning moment is resisted by the tube which cause compression and tension in columns.The gravity loads are taken by exterior frames and interior columns.In this structure the axial force in the flange frames lag behind those of corners due to nature of frame tube structure which is different from solid tube.This phenomenon is called shear lag phenomenon which reduces the cantilever efficiency.In this investigation six reinforced concrete framed tube are modeled and analyzed. In terms of height into two groups: the first one has 40 stories and the second group has 60 stories tube frames. Tall buildings of each groups included three different type of plan shapes: a) Rectangular, b) Triangular, c) Hexagonal.The values of shear lag was observed in each of this shapes".

14. "Comparative Study of Triangle Tubes Bundled System and Square Tubes Bundled System" by Jay P. Patel, Vishal B. Patel and Elizabeth George et al,2017.

"In this study 48 storey building is analysed structure using ETABS software in triangle tubes bundled system and square tubes bundled system. Bundled tube system is system consists of number of tubes tied together which acts as one system. Columns in Bundled system are more evenly stressed and provide greater lateral stiffness to structure. bundled tube system tube have different shapes like square, triangle, trapezoidal, rectangle etc. The main objective of this study is to comparing different parameters like Maximum storey displacement, Base shear, Maximum storey drift, Time period and steel weight between triangle tubes bundled system and square tubes bundled system and to find that which shape tubes bundled system is economical.Modelling of this systems are done on ETAB software to determine the maximum storey displacement, Maximum storey drift, Time period, Base shear and steel weight".

15. "Push over analysis of tube in tube structure with different plan configuration" by Megha Jaiswal ,Dr Jain vyas et al,2018.

"The behavior of specific type of tall structure in which tubular structure is studied with constant plan area with different plan irregularity. .The main objective of push over analysis is to achieve the desired seismic performance of a building.The performance based (pushover analysis) study of tube-in-tube structure shows better result against the lateral loading based on ATC-40 and FEMA-356 which is dependent on material of components of structure.

The modelling of tube in tube structure was constructed as a rigid frame structure with central core of shear wall in which shear wall is modeled as an equivalent column placed at the central line of shear wall for analysis purpose according to the FEMA-273. Three models are generated with different plan having a constant area of 1200 sq m".

III. CONCLUSION

Researches have been carried out to study the behaviour of different types of tubular structures.Based on this work following conclusions were made.

1 .Lateral stiffness of braced tube is reduced in twisted tall buildings. Most of the lateral load is resisted by diagonals members on the periphery, while gravity load is resisted by both internal columns and peripheral diagonal members
2. Frame Tube Structure has significant advantages over conventional structure.
3 .Time history analysis predicts the structural response more accurately then equivalent static analysis
4. Tube in tube structures with centre tube is best for a better structural system.
5. Steel tube structures are more better than regular steel moment resisting frame, since they have additional time period and less frequency.
6.Tube in tube structure with core wall will get maximum reduction in displacement and drift. Square frame tubed structure is better for lateral loads and traingular geometry is most vulnerable to lateral loads.
7.Square and circular braced tube buildings have lower maximum storey Displacement and storey drift values than rectangular braced tube building and circular braced tubes have lower Maximum Storey Displacement and Storey Drift values compared to Square Braced tube building.
8.Framed tube with rectangular plan shapes have the most amount of shear lag while the structures with triangular and hexagonal plans have a better behavior in case of shear lag
9.The shear value of triangle tubes bundled system is 18.76% higher as compared to square tubes bundled system and time period of triangle tubes bundled system is 11.97% higher than square tubes bundled system.

IV. REFERENCES

[1].Farshid Nouri , Payam Ashtari , "Investigation of the shear lag phenomenon and structural behavior of framed-tube and braced-tube tall structures", International Conference on Civil Engineering,Tabriz. November 2013.

[2] Er. Nishant rana Siddhant Rana , "Structural Forms Systems for Tall Building Structures", International Journal of Civil Engineering (SSRG-IJCE) – volume1 issue4,pp 36-39, September 2014

[3] Hardik J. Patel, Prof. A. R. Darji, Prof K.B. Parikh, "Braced tube Structural System"International Journal of Scientific & Engineering Research, Volume 6, Issue 12, pp 484-489,December 2015.

[4] Jignesha Patel,Roshni J John, "Seismic analysis of frame tube structures" International Journal of Scientific & Engineering Research, Volume 6, Issue 12, pp 54-57, December 2015.

[5] Sharadrao Patil,Uttam Kalwane, "Shear Lag in Tube Structures" International Journal of Innovative Science, Vol. 2 ,Issue 3, pp 509-512, March 2015.

[6] Nimmy Dileep , Renjith R, "Analytical investigation on the performance of tube in tube structures subjected to lateral loads" International Journal of research and Applications, Volume 3,Issued 4, pp 284-288, July-August 2015.

[7] Vikram J, Geethu Varghese, "Concept of tubular design in high rise buildings",International Conference on Advances in Civil, Structural and Mechanical Engineering,USA, pp 7-11,2015

[8] Archana J , Reshmi P R, "Comparative Study on Tube in Tube Structures and Tubed Mega Frames" International Journal of Innovative Research in Science, Engineering and Technology, Volume 5, Issue 8, pp 14745-14752, August 2016

[9] Bipin H Naik, B S Suresh Chandra, "Comparative Analysis between Tube in Tube Structure and Conventional Moment Resisting Frame" International Research Journal of Engineering and Technology, Volume: 04 Issue 10, pp 808-812, October 2017.

[10] Mohan K , Rahul Y and Virendra Kumara K N, "Analysis of Different Forms of Tube in Tube Structures Subjected to Lateral Loads" International Journal of Innovative Science, Engineering & Technology, Volume 4,Issue 2, pp 56-64. July 2017.

[11] Shubhangi V. Pawar,M. S. Kakamare, M.B.Pendhari, "Research Paper on Earthquake and Wind Analysis of Braced Tube Structure with Different Plans in Configuration" International Journal for Research in Applied Science & Engineering Technology, Volume 5 Issue VII, pp 1579-1591, July 2017.

[12] Lavanya T, Sathyanarayana Sridhar, "Dynamic analysis of tube in tube tall buildings" International Research Journal of Engineering and Technology, Volume: 04 Issue: 04, pp 2357-2362, Apr -2017.

[13] Mostafa Moghadasi, Soheil Taeepoor and Mehdi Mahmoudi, "The Effect of Geometry of Plan on Shear Lag of Framed Tube Tall Buildings Subjected to the Earthquake Load" International Journal of Structural and Civil Engineering Research Vol. 6, Issue 4, pp 268-271, November 2017.

[14] Jay P. Patel , Vishal B. Patel and Elizabeth George, "Comparative Study of Triangle Tubes Bundled System and Square Tubes Bundled System" . International Conference on Research and Innovations in Science, Volume 1, pp 484–489, 2017

[15] Megha Jaiswal ,Dr Jain vyas, "Push over analysis of tube in tube structures with different plan configuration" International Journal of Reasearch, Volume 05, Issue 15, pp 485-488, May 2018.