ISSN: 2230-9926

Available online at http://www.journalijdr.com

IJDR

International Journal of Development Research
Vol. 09, Issue, 04, pp.26863-26865, April, 2019

ORIGINAL RESEARCH ARTICLE **OPEN ACCESS**

ANALYSIS OF TUBULAR STRUCTURE IN HIGH RISE BUILDINGS

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ARTICLE INFO

Article History:
Received 06th January, 2019
Received in revised form
20th February, 2019
Accepted 03rd March, 2019
Published online 29th April, 2019

Key Words:
Tube-In-Tube structure,
Peripheral tube, Inner core,
Floor slab.

ABSTRACT

In the construction of high rise buildings, the tubular structure is more effective way of stable and economic construction. The tube system resists lateral loads i.e. wind load, earthquake load, impact loads, etc. The tube system is formed by outer perimeter tube made of closely spaced columns which acts like a dense and strong structural wall and inner core connected by spandrel beams and floor slabs with moment connections. The building behaves like a hollow cylinder cantilevered perpendicular to the ground. The load is carried by the outer peripheral tube and inner core which resist the ability of the structure to overturn. The remaining structure is column free so that this structural system improves stability and floor space to be utilized. Tubular structure is more common since few decades. It has many types but tube-in-tube structure is more suitable in those. In this study, 8 models are prepared by changing the position of the core and shape of the building and the comparative analysis is done in SAP 2000:V18, use structural analysis programming tool.

Citation: Chinmayee Kulkarni. 2019. "Analysis of tubular structure in high rise buildings", *International Journal of Development Research*, 09, (04), 26863-26865.

INTRODUCTION

There is lack of space now-a-days for the construction purpose. That's why the demand for the high rise buildings are increased. The lateral load effect is increased as the height of the building is increased. To overcome this, tubular structures are the best system of construction of high rise building. Tubular structures have different types such as Framed Tube system, Tube-In-Tube system, Bundled Tube system, Braced Tube system, Tubed Mega Frame. Out of these types, Tube-In-Tube structure is more stable against lateral load, allows more interior space and helps in saving 30% steel. These are usually steel, concrete and composite structures. The Tube-In-Tube structure consists of outer peripheral tube made of closely spaced columns and inner core tube. This core tube generally takes gravity loads and outer peripheral tube takes mainly lateral loads. The inner core is used to provide stair case, lift rooms also. This system is invented by Mr. Fazlur Rahman Khan and the first residential building constructed by using this system is 43-storey DeWitt-Chestnut Apartment in Chicago, constructed in 1966. The other structures constructed by using this system are John Hancock Centre, Willis Tower, World Trade Centre, Petronas Towers, etc.

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There are some papers published in various journals. Xinzheng Lu, LinlinXie, Cheng Yu, Xiao Lu developed models for two systems i.e. fully braced and half braced. They compared the results of modal analysis, static analysis, time history analysis and also plastic energy dissipation over height of building. The results of their research were plastic energy dissipation in fully braced system was uniform and in radially replaceable components while in half braced system, it is at upper 4 zones and core tube will suffer significantly. Thus the conclusion of their research work was fully braced system is more preferable over half braced against seismic performance. Another author Kyoung Sun Moon prepared a stiffness-based design methodology for determining preliminary no. of sizes of braced tubes for tall buildings. They studied the influence of diagonal angle on structural design of braced tube structures and his findings were that 40^0-50^0 were close to optimum. LunhaiZhi, Pan Yu, Qui-Sheng Li, Bo Chen, Mingxin Fang carried out wind tunnel test and field measurements of wind effects on super tall buildings. They found that the wind loads from field and wind tunnel test are constituent with each other and appeared to represent an envelope of estimated results.

MATERIALS AND METHODS

In this study, The Tube-In-Tube structure having different shapes i.e. square and rectangular are analysed with different positions of inner core as shown in Fig 1. The inner core is placed at centre, edge, inner part. The inner core consists of bracing at two opposite sides and steel plate shear wall at other two opposite sides. The steel plate shear walls are nothing but the infill plates bounded by boundary elements. The analysis is done by using software. SAP 2000: V18. In the analysis part, equivalent static analysis, response spectrum analysis, stiffness analysis (modal analysis) and wind analysis are done. Equivalent static analysis is linear static analysis and response spectrum analysis is linear dynamic analysis. Similarly, pushover analysis is nonlinear static analysis having inelastic nature and time history analysis in stiffness analysis is nonlinear dynamic analysis.

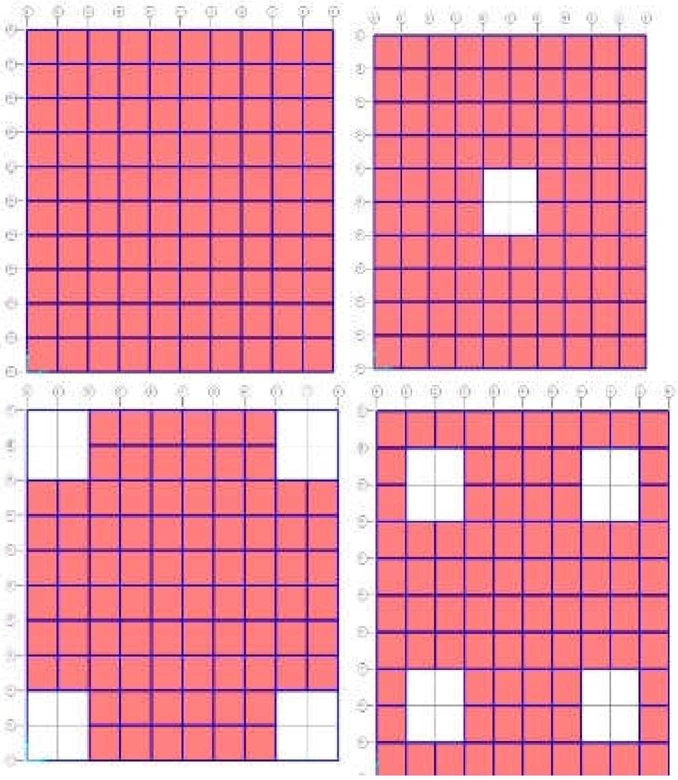

Fig. 2.1. Models used in the analysis

Problem Statement

Type of structure: Steel moment Resisting
No. of storeys: G+49
Floor Area: 400 sq. m.
Height of each floor: 3.5m
Live load: 4kN/m^2
Grade of concrete: M30
Grade of steel: FE 415.

RESULTS

The parameters compared are base shear, max. storey displacement, max. storey drift, stiffness (k) and wind deformation.

Base Shear:

Table 1. Results of base shear with different positions of the inner core

Base Shear	Bare Frame	Central Core	Edge Core	Inner Core
Square	118500	129600	117600	122400
Rectangle	96300	94800	90300	90300

Maximum Displacement

Table 2. Results of max. displacement with different positions of the inner core

Max. Disp.	Bare Frame	Inner Core	Edge Core	Central Core
Square	0.2186	0.2281	0.2683	0.1771
Rectangle	0.2773	0.3515	0.3656	0.2429

Time Period

Table 3. Results of time period with different positions of the inner core

Time Period	Bare Frame	Inner Core	Edge Core	Central Core
Square	3.39394	4.65865	3.8394	2.77271
Rectangle	4.78536	5.79016	5.56836	3.46801

Wind Deformation

Table 4. Results of wind deformation with different positions of inner core

Wind Deformation	Bare Frame	Inner Core	Edge Core	Central Core
Square	0.2164	0.203	0.1813	0.1751
Rectangle	0.2883	0.203	0.33	0.2676

Max. Storey Drift

Table 3.5. Results of max. storey drift with different positions of inner core

Max. Storey Drift	Bare Frame	Inner Core	Edge Core	Central Core
Square	0.00982	0.00986	0.00984	0.00981
Rectangle	0.00983	0.00985	0.00984	0.00982

DISCUSSION

The results of the parameters analysed in this study are given above.

Base Shear: Base shear is the rough calculation of maximum lateral force expected to occur on the structure due to seismic ground motion at the base of the structure. In other words, it is the sum of the lateral forces on each storey of the building structure above the base. In this case, the base shear for the square shaped structures is more than the rectangular shaped structure. The base shear for inner core system is less than the other systems.

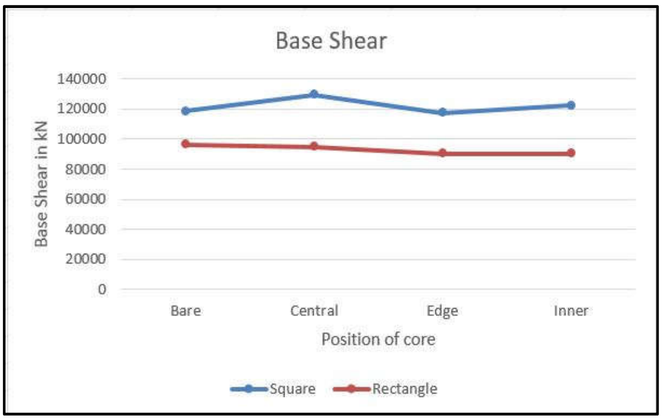

Fig. 1. Graph of Base Shear

From this graph, it is seen that the base shear of rectangular system with inner core at the edges is minimum and the square system with central core is maximum.

Max. Storey Displacement: It is the maximum displacement of the storey. In this study, the square shaped system showed less displacement than the rectangular shaped system. The storey displacement is minimum for the central core system.

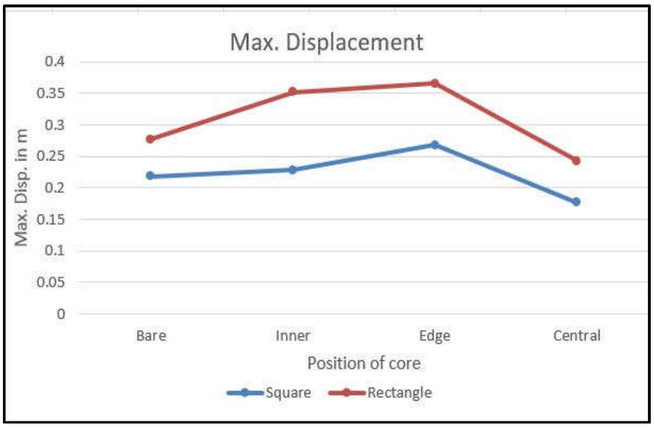

Fig. 2. Graph of Max. Storey Displacement

From the graph, it is seen that the maximum displacement is for the rectangular shaped system having inner core at the edges and the minimum displacement is for the square shaped system having core at the central side.

Time Period: The natural time period of the structure is the time needed for one cycle of vibration to pass in a given point. The time period is maximum for rectangular shaped system than square shaped system. The square shaped system having core at central position is having minimum natural time period.

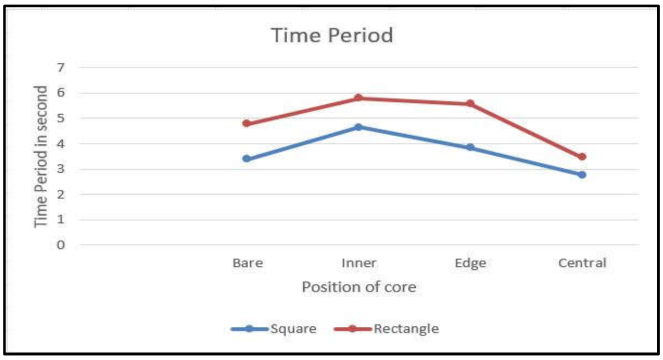

Fig. 3. Graph of time period

Lesser the time period, the structure is stiffer.

Wind Deformation: It is the deformation of the structure due to wind loads acting on the structure and it should be < 800 mm for 50 storey building. The wind deformation for central core is least.

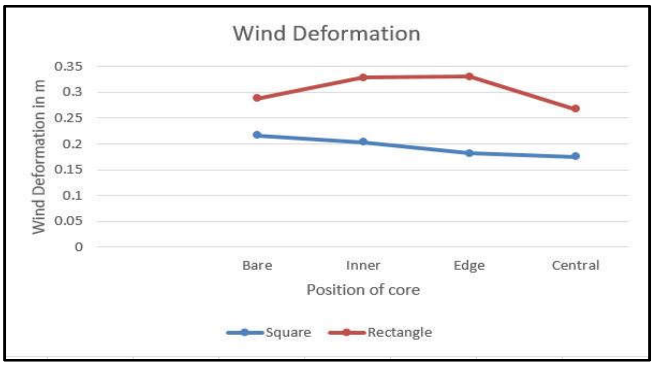

Fig. 4. Graph of wind deformation

The wind deformation for the core at the central side is least.

Max. Storey Drift: It is the relative displacement between the floors above and/or below the storey under consideration. The storey drift is minimum for square shaped system with core at central side.

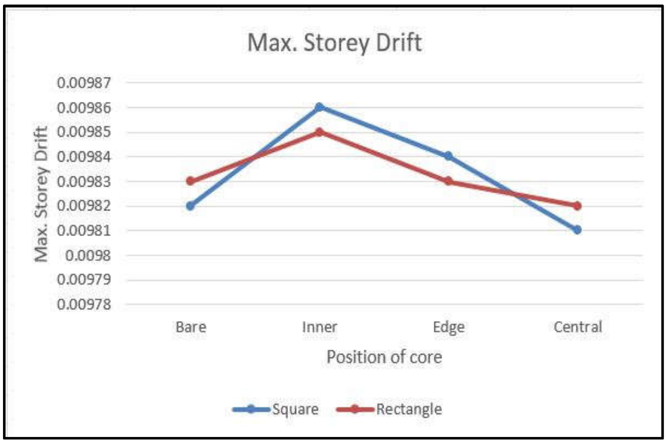

Fig. 5. Graph of max. storey drift

Conclusion

- The maximum displacement for the response spectrum and equivalent static analysis is least for the square shaped system having core at the central side.
- The time period for the square shaped system having inner core at the central side is less; so that this structure has more stiffness as compared to the other structures.
- The wind deformation for the square shaped system with core at central side is minimum compared to other systems.
- The square shaped system having core at the central side is the best suited system.

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