Analytical Study of Vertical Geometric Irregular Diagrid Structure and Comparison with Tubular Structure

Anju Krishna[1], Arathi S[2]

[1]PG Scholar, Department of Civil Engineering, Sree Buddha College of Engineering, Pathanamthitta, Kerala, India

[2]Assistant Professor, Department of Civil Engineering, Sree Buddha College of Engineering, Pathanamthitta, Kerala, India

Abstract: ***The rapid growth of high rise buildings leads to the evolution of new structural concepts. Structural systems nowadays are becoming stiffer and lighter. It is very important that the selected structural system is such that the structural elements are utilized effectively while satisfying design requirements. Recently diagrid structural system is adopted in tall buildings due to its structural efficiency and flexibility in architectural planning. Structural design of high rise buildings is governed by lateral loads due to wind or earthquake. Lateral load resistance of structure is provided by interior structural system or exterior structural system. Compared to closely spaced vertical columns in framed tube, diagrid structure consists of inclined columns on the exterior surface of building. Due to inclined columns, lateral loads are resisted by axial action of the diagonal compared to bending of vertical columns in framed tube structure. In most of situations, buildings become vertically irregular at the planning stage itself due to some architectural and functional reasons. A large number of vertical irregular buildings exist in modern urban infrastructures, and so the area of vertically irregular type of building is now having a lot of interest. This paper presents analysis of diagrid structure and tubular structure of irregular vertical geometry using ETABS software. Comparison of analysis results in terms of storey displacement and inter-storey drift under wind loading is presented in this paper.***

Keywords: Diagrids, tubular structures, ETABS, Storey displacement, Storey drift

1. Introduction

The rapid growth of urban population and limitation of available land leads to the evolution of taller structures. As the height of building increase, the lateral load resisting system becomes more important than the structural system that resists the gravitational loads. The lateral load resisting systems that are widely used are rigid frame, shear wall, wall frame, braced tube system, outrigger system and tubular system. Recently, the diagrid structural system is widely used for tall buildings due to its structural efficiency and aesthetic potential provided by the unique geometric configuration of the system. The diagrid systems can be called the evolution of braced tube structures because both systems are able to carry lateral loads due to the axial action of structural members. In case of braced tube structures, the bending rigidity is provided primarily by vertical perimeter columns whereas in diagrid structures, bending rigidity is provided by diagonal members which also provide shear rigidity. The diagrid structural system is considered as a promising solution for high-rise steel buildings.

2. Objective of the Study

- Comparative analysis of diagrid structures with tubular structures based on vertical geometric irregularity
- Study maximum storey displacement and inter storey drift to predict the behavior of structures under wind loading

3. Analysis of 36 storey Vertical Geometric Irregular Diagrid Structure

3.1 Building Configuration

The 36 storey tall building having 129.6m of total height with storey height of 3.6 m. Typical floor plan of sizes 36m×36m and 12m×12m are used as shown in Figure1 and Figure2. The slab thickness is taken as 120mm. In diagrid structures, pair of braces is located on the periphery of the building. The angle of inclination is kept 74.5^0 throughout the height. The inclined columns are provided at six meter spacing along the perimeter. The interior frame of the diagrid structures is designed only for gravity load. The design dead load and live loads on floor slab are 3.75 kN/m^2 and 2.5kN/m^2 respectively. The wind loading is computed based on the basic wind speed of 30 m/sec and terrain category III as per IS: 875(III)-1987. For linear static analysis the beams and columns are modelled by beam elements and braces are modelled by truss elements. The support conditions are assumed as hinged. The sizes of typical members are shown in Table1. Figure3 shows the details of interior column C1.

International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2013): 6.14 | Impact Factor (2015): 6.391

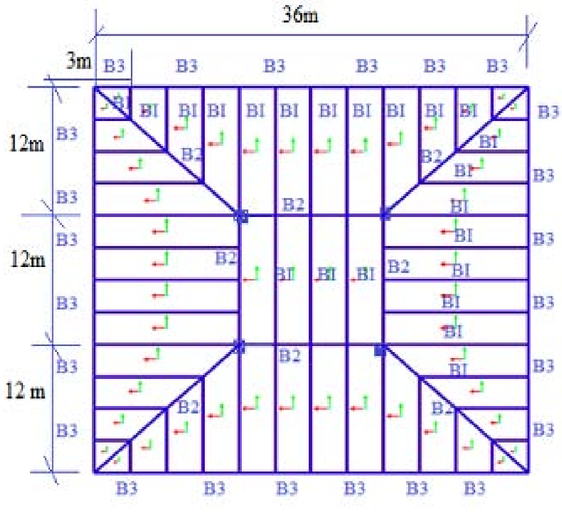

Figure 1: Typical floor plan 36m×36m

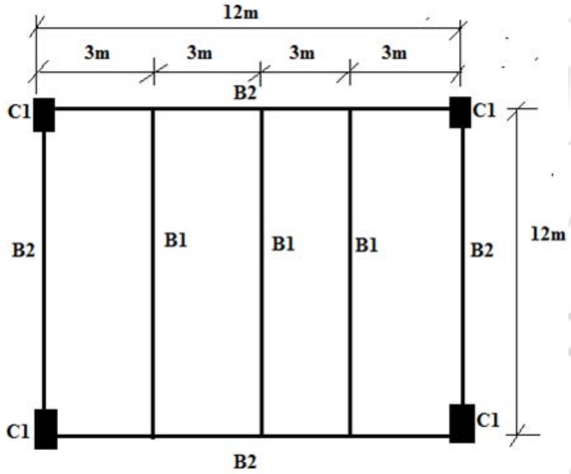

Figure 2: Typical floor plan 12m×12m

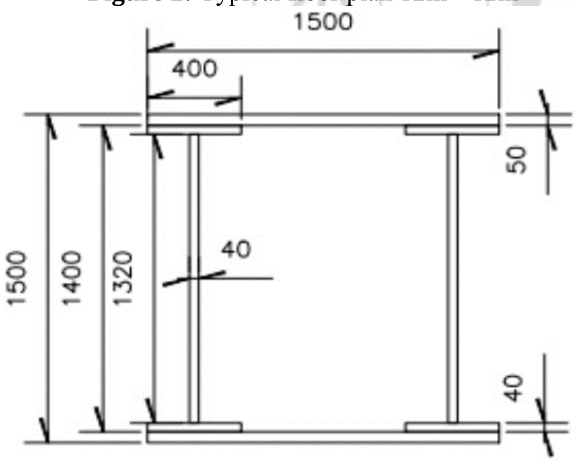

Figure 3: Details of interior column

Table 1: Typical Column and Beam Sections

Diagonal columns	*Interior columns*	*Beams*
375mm pipe sections with 12mm thickness (from 19 to 36 storey)	1500mm x 1500mm (figure 2)	B1 and B3 = ISMB550
450mm pipe sections with 25mm thickness (from 1 to 18 storey)		B2 = ISWB 600 with top and bottom cover plate of 220 × 50 mm

Three models are considered according to certain height proportions as shown in Figure4.

1) Model 1: 75% of total height (H) having regular plan of 36mx 36m as shown in Figure1 and remaining portion having plan dimension 12m x 12m as shown in Figure 2.
2) Model 2: 50% of total height (H) having regular plan of 36mx 36m as shown in Figure1 and remaining portion having plan dimension 12m x 12m as shown in Figure 2.
3) Model 3: 25% of total height (H) having regular plan of 36mx 36m as shown in Figure1 and remaining portion having plan dimension 12m x 12m as shown in Figure 2.

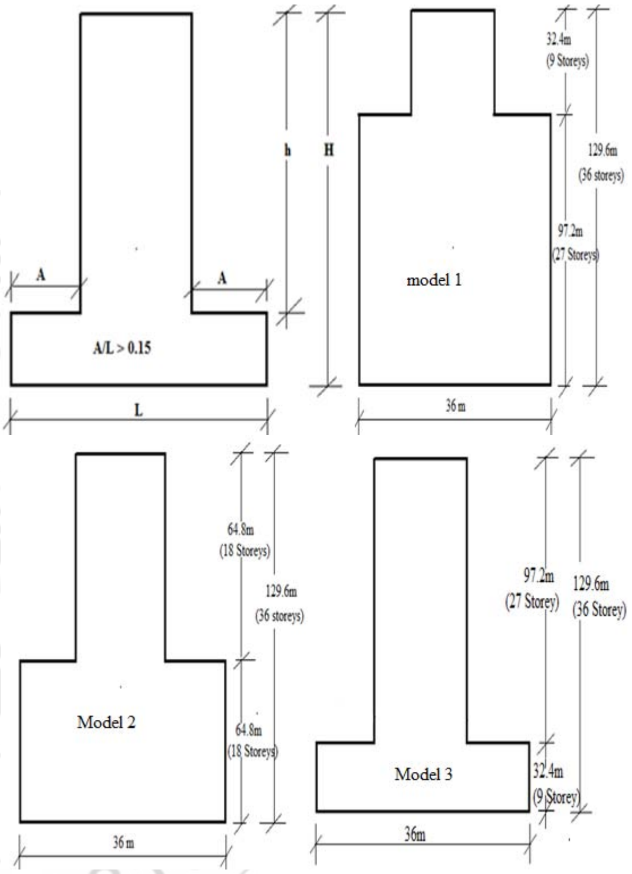

Figure 4: Vertical geometric irregular models for analysis

3.2 Modelling and Analysis Results of Model 1 Diagrid Structure

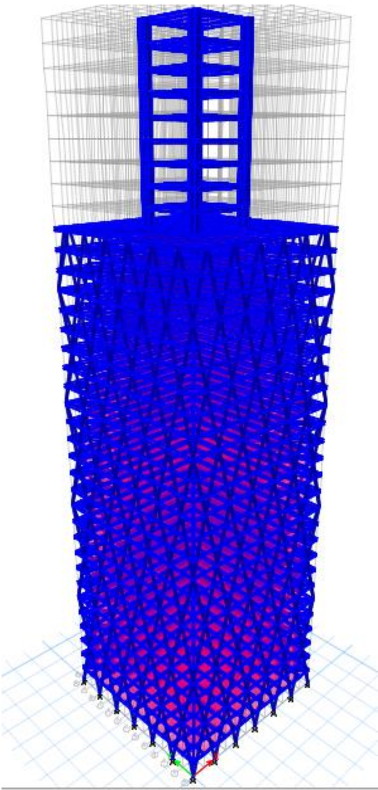

Figure 5: Modelling of Model 1 Diagrid

The storey displacement and inter storey drift due to wind load is shown in Figure6 and Figure7 respectively.

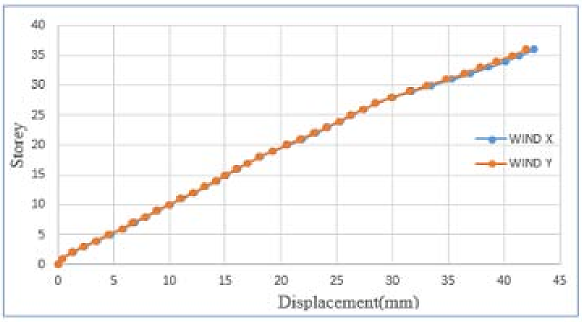

Figure 6: Storey displacement of Model 1

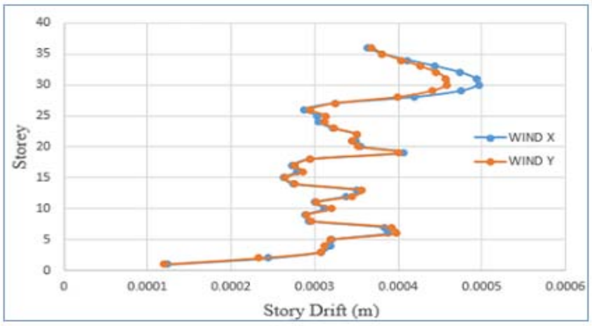

Figure 7: Storey drift of Model 1

It is observed that the top story displacement in x-direction and y-direction due to wind load is 42.7mm and 42mm respectively and inter storey drift of top storey in x-direction and y-direction due to wind load is 0.000363m and 0.000368m respectively. Maximum inter storey drift is 0.000496 and is obtained between 29th and 32nd storey.

3.3 Modelling and Analysis Results of Model 2 Diagrid Structure

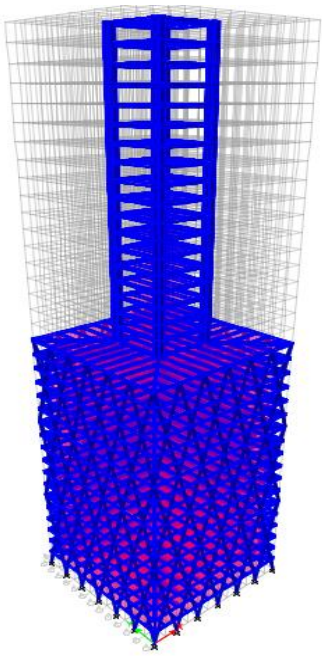

Figure 8: Modelling of Model 2 Diagrid

The storey displacement and inter storey drift due to wind load is shown in Figure9 and Figure10 respectively.

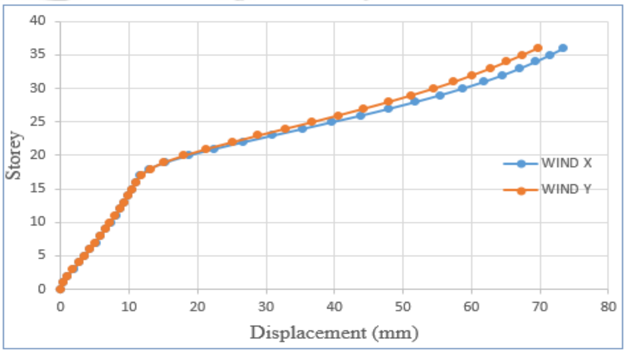

Figure 9: Storey displacement of Model 2

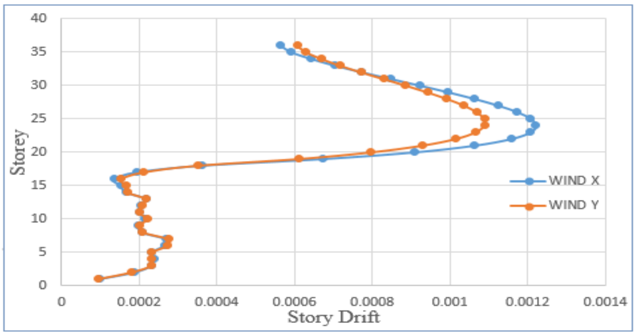

Figure 10: Storey drift of Model 2

It is observed that the top story displacement in x-direction and y-direction due to wind load is 73.4mm and 69.6mm respectively and inter storey drift of top storey in x-direction and y-direction due to wind load is 0.000563m and 0.000606m respectively. Maximum inter storey drift is 0.00122 and is obtained between 22nd and 25th storey.

3.4 Modelling and Analysis Results of Model 3 Diagrid Structure

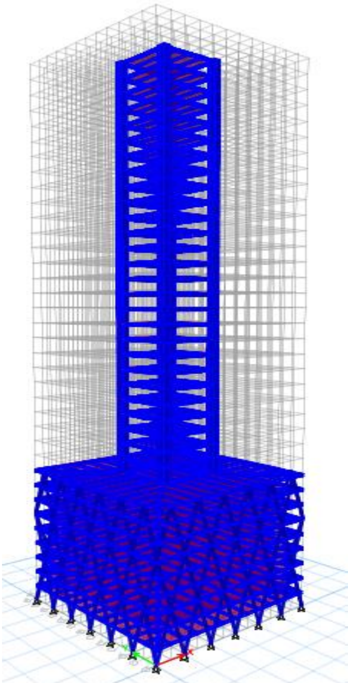

Figure 11: Modelling of Model 3 Diagrid

The storey displacement and inter storey drift due to wind load is shown in Figure12 and Figure13 respectively.

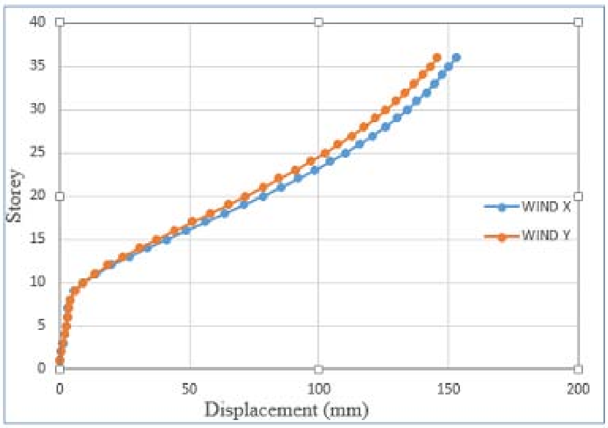

Figure 12: Storey displacement of Model 3

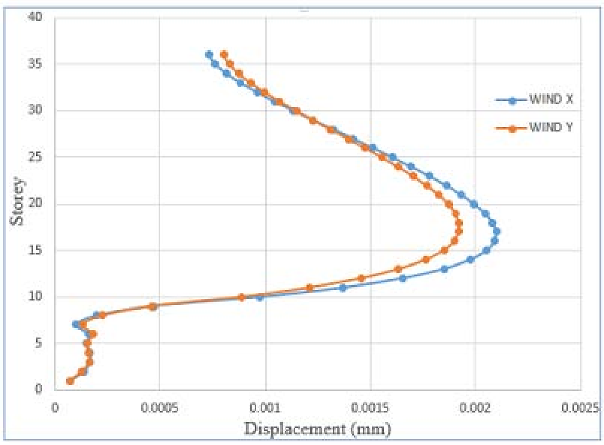

Figure 13: Storey drift of Model 3

It is observed that the top story displacement in x-direction and y-direction due to wind load is 152.8mm and 145.6mm respectively and inter storey drift of top storey in x-direction and y-direction due to wind load is 0.000732m and 0.000803m respectively. Maximum inter storey drift is 0.0021 and is obtained between 14th and 18th storey.

4. Analysis of 36 storey Vertical Geometric Irregular Tubular Structure

Same plan dimensions as shown in Figure1 and Figure2 are adopted in modelling of tubular structure. Also a same model as shown in figure 4 is used for the analysis of vertical geometric irregular tubular structure. In the tubular structure, external columns are placed at 6m spacing along the perimeter. The exterior columns of 375mm filled steel tube sections with 12 mm thickness from 19th to 36th storey and 450 mm filled steel tube sections with 25 mm thickness from 1st to 18th storey are used. The support conditions are assumed as fixed. All other modelling data and loading conditions are same as that of diagrid structure.

4.1 Modelling and Analysis Results of Model 1 Tubular Structure

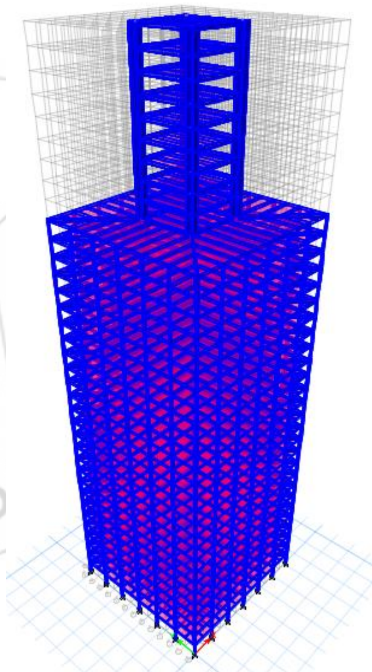

Figure 14: Modelling of Model 1 Tubular

The storey displacement and inter storey drift due to wind load is shown in Figure15 and Figure16 respectively.

International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2013): 6.14 | Impact Factor (2015): 6.391

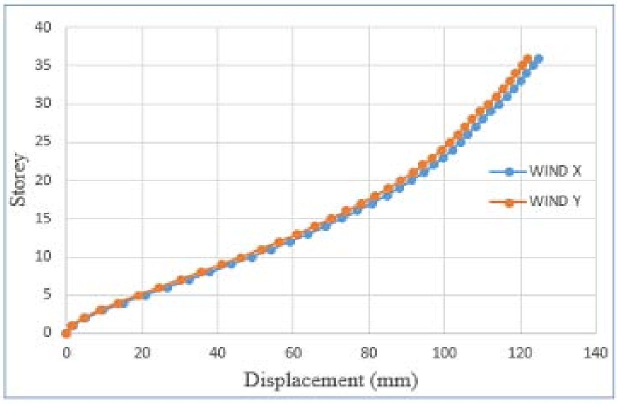

Figure 15: Storey displacement of Model 1 Tubular

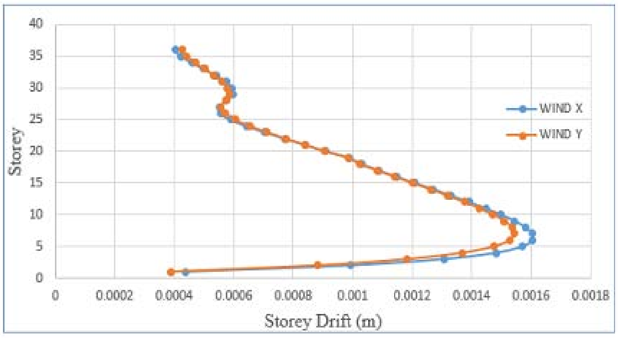

Figure 16: Storey drift of Model 1 Tubular

It is observed that the top story displacement in x direction and y-direction due to wind load is 124.8mm and 122mm respectively and inter storey drift of top storey in x-direction and y-direction due to wind load is 0.000403m and 0.000426m respectively. Maximum inter storey drift is 0.001604 and is obtained between 4th and 7th storey.

4.2 Modelling and Analysis Results of Model 2 Tubular Structure

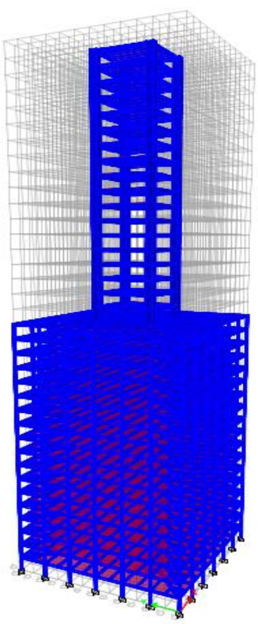

Figure 17: Modelling of Model 2 Tubular

The storey displacement and inter storey drift due to wind load is shown in Figure18 and Figure19 respectively.

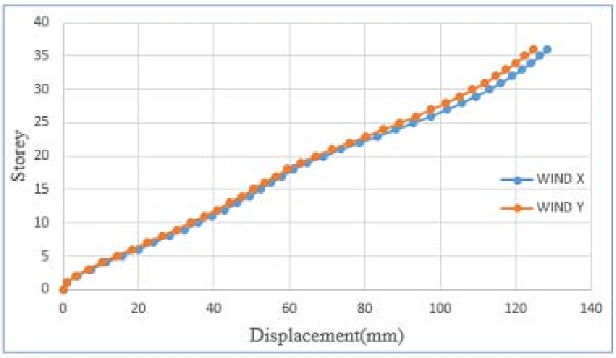

Figure 18: Storey displacement of Model 2 Tubular

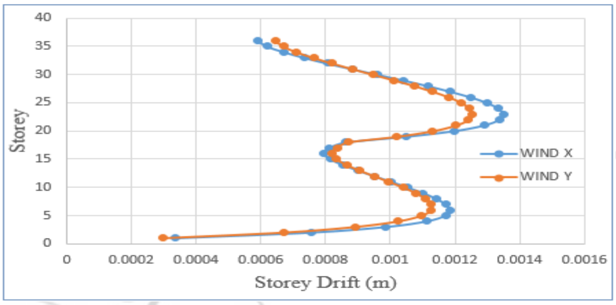

Figure 19: Storey drift of Mode 2 Tubular

It is observed that the top story displacement in x-direction and y-direction due to wind load is 128.4mm and 124.7mm respectively and inter storey drift of top storey in x-direction and y-direction due to wind load is 0.00059m and 0.000646m respectively. Maximum inter storey drift is 0.001349 and is obtained between 22nd and 25th storey.

4.3 Modelling and Analysis Results of Model 3 Tubular Structure

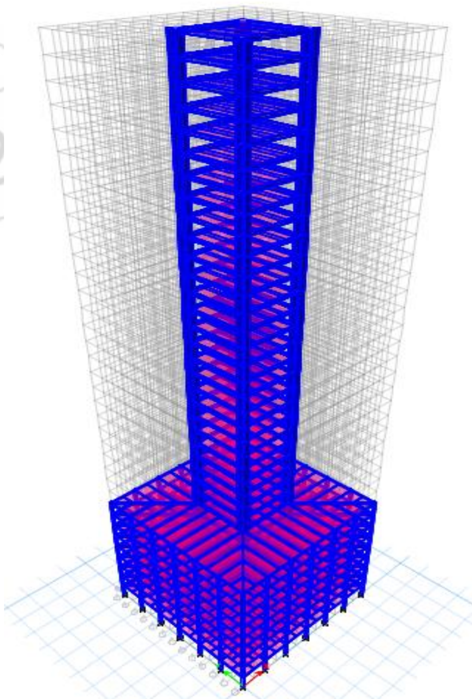

Figure 20: Modelling of Model 3 Tubular

The storey displacement and inter storey drift due to wind load is shown in Figure21 and Figure22 respectively.

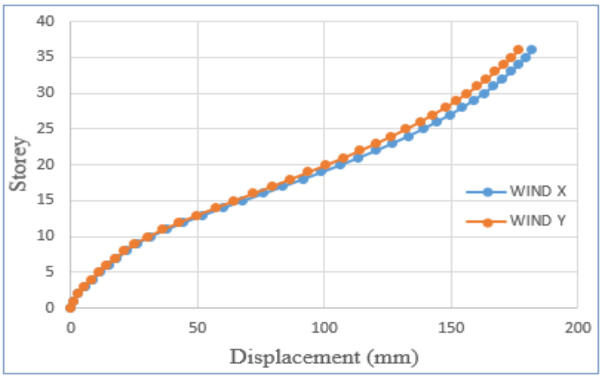

Figure 21: Storey displacement of Model 3 Tubular

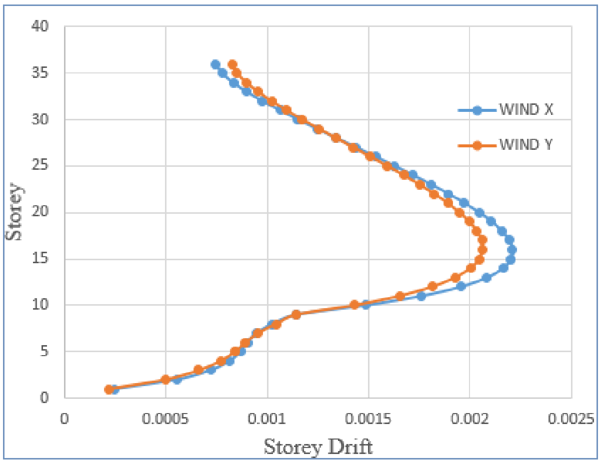

Figure 22: Storey drift of Model 3 Tubular

It is observed that the top story displacement in x-direction and y-direction due to wind load is 181.9mm and 176.5mm respectively and inter storey drift of top storey in x-direction and y-direction due to wind load is 0.000747m and 0.000825m respectively. Maximum inter storey drift is 0.002207 and is obtained between 14th and 18th storey.

5. Summary of Results

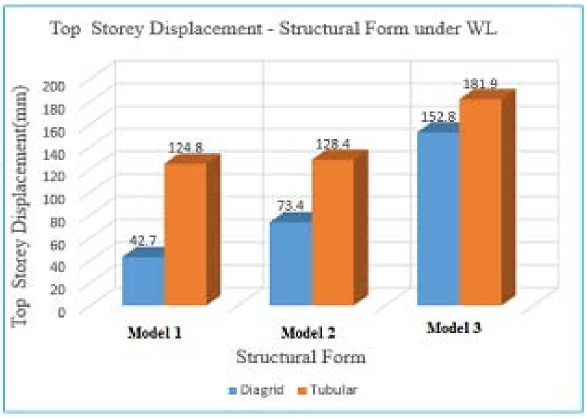

Figure 23: Structure type –Storey displacement Plot for Wind Loading

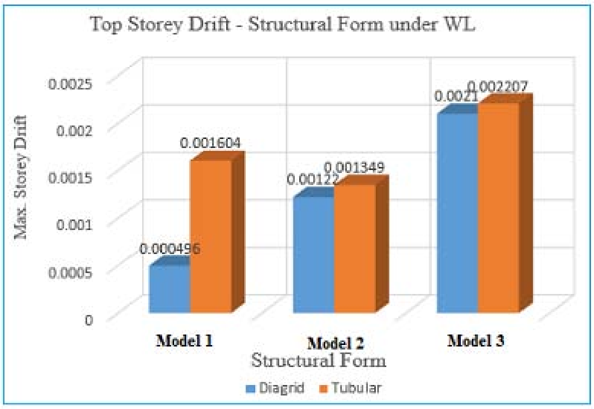

Figure 24: Structure type –Storey drift Plot for Wind Loading

Table 2: Wind Analysis Results - Comparison

Building type	Top storey displacement (mm)	Max. inter-storey drift(m)
Diagrid structure of vertically irregular geometry model 1	42.7	0.000496
Tubular structure of vertically irregular geometry model 1	124.8	0.001604
Diagrid structure of vertically irregular geometry model 2	73.4	0.00122
Tubular structure of vertically irregular geometry model 2	128.4	0.001349
Diagrid structure of vertically irregular geometry model 3	152.8	0.0021
Tubular structure of vertically irregular geometry model 3	181.9	0.002207

Obtained values under wind loading for maximum top storey displacement and inter-storey drift is given in Table 2. It is observed that vertical geometric irregular diagrid structure having lower displacement than that of vertical geometric irregular tubular structure having various height proportions. Also vertical geometric irregular diagrid structure having lower inter storey drift than that of vertical geometric irregular tubular structure.

6. Conclusion

1) Diagrid structure system having vertical geometric irregularity shows less top storey displacement and inter-storey drift than that of vertically irregular tubular structure.
2) Diagrid structural system provides better flexibility in interior space planning and façade of the structure.

So the diagrid system is more efficient in case of vertical geometric irregular tall building system under wind loading.

References

[1] Harish Varsani , Narendra Pokar and Dipesh Gandhi (2015) “Comparative Analysis of Diagrid Structural System and Conventional Structural System for High Rise Steel Building” International Journal of Advance Research in Engineering, Science & Technology , No.1, pp 1-4

[2] Jinkoo Kim, Young-Ho Lee(2012) "Seismic performance evaluation of diagrid system buildings" ,The Structural Design Of Tall And Special Buildings, ", No.21 ,pp 736-749
[3] Khushbu Jani and Paresh Patel (2013). "Analysis and Design of Diagrid Structural System for High Rise Steel Buildings" Procedia Engineering, 51, pp 92-100
[4] Nishith B. Panchal, Dr. V. R. Patel, Dr. I. I. Pandya (2014). "Optimum Angle of Diagrid Structural System" , International Journal of Engineering and Technical Research Technology, 2 ,No.6 ,pp150-157
[5] Poonam, Kumar Anil and Gupta Ashok K, 2012, " Study of Response of Structural Irregular Building Frames to Seismic Excitations,'' International Journal of Civil, Structural, Environmental and Infrastructure Engineering Research and Development (IJCSEIERD), ISSN 2249-6866 Vol.2, Issue 2 (2012) 25-31
[6] Rohit Kumar Singh, Dr. Vivek Garg, Dr. Abhay Sharma (2014) "Analysis and Design of Concrete Diagrid Building and Its Comparison with Conventional Frame Building" International Journal of Engineering and Technical Research Technology, 2 , No.6 ,pp 1330-1337
[7] Sree Harsha J, K Raghu, G Narayana (2015) "Analysis Of Tall Buildings For Desired Angle Of Diagrids" International Journal of Engineering and Technical Research Technology, 4 , No.4 ,pp 635-639