COMPARATIVE ANALYSIS OF HIGH RISE STEEL BUILDING WITH HEXAGRID, DIAGRID AND CONVENTIONAL STRUCTURAL SYSTEM

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Abstract - *Development of tall buildings have been rapidly increasing in number worldwide. The trends in tall building design is now towards the integration of optimal building form with the structure to produce an efficient design. Diagrid system is an innovative technology that is widely used now a days which promise better lateral load efficiency. Hexagrid system is an extension to the diagrid structural system which also efficient in lateral load resisting system. In these systems, the lateral loads are resisted by the axial action of diagonal columns compared to bending of vertical columns. Analysis of 48 storied Steel building with diagrid system and hexagrid system is presented. Modelling and analysis of structural member is done using finite element software ETABS. Loads, load combinations and seismic data are provided according to* IS 875:1987*and IS 1893:2002 respectively. Comparison of analysis results with conventional system is done in terms storey displacement, storey shear, storey drift and time period.*

Key Words: Diagrid structural system, Hexagrid structural system, Lateral load resisting system, Storey displacement, Storey drift, Storey shear, Time period.

1. INTRODUCTION

Construction of tall buildings concerns the building architecture and systems and requirement of construction materials. For a very tall building, lateral stiffness is the main consideration in structural design. Compared to conventional orthogonal system, buildings with framed tubes, braced tubes, diagrid system etc., show more efficiency in lateral wind loads. The diagrid system has been widely used for tall buildings due to their structural efficiency and aesthetic potential with unique geometric configuration. The idea for developing a diagrid system is to eliminate the vertical columns which does not provide lateral stability. Diagrid structural system is an innovative lateral loading resisting system. Diagrid performs better across all the criterions of performance evaluation, Cost effective and Eco-friendly. Structure has comparatively less deflection and weight is reduced to greater extent [2]. The optimum angle of columns for maximum bending rigidity is 90^0 and that of diagonals for maximum shear rigidity is 35^0. Hence it is expected that optimum angle should lie in this range. The results show that angles between 35^0 and 90^0 are recommended with 63^0 being the optimal angle [7]. After the invention of diagrid, a new structural system called hexagrid structural system is introduced as an extension of diagrid system. A conventional structure is composed of beam, slab, vertical columns etc. subjected to bending, shear and torsion whereas in diagrid and hexagrid structure all vertical columns on the perimeter except corner columns are eliminated and diagonal columns inclined at specific angle is used. Hexagrid structure consists of four diagonal members. The angle of both diagrid and hexagrid member is depended on the storey height. The material conception is less than conventional structural system since the number of columns in structure is reduced. Overall both the grid systems prove very effective in lateral load resisting system.

This paper presents a comparative study of both diagrid and hexagrid structure with conventional system. The main objective of this paper is to study the performance of grid system in an irregular building and to find out the response of the structure towards lateral load resistance.

2. METHODOLOGY

In this study comparison of diagrid and hexagrid system is compared with conventional system in terms of displacement, storey drift, shear force and modal time period.

Following steps are adopted in this study.

Step 1: Selection of building geometry and modelling of diagrid, hexagrid and conventional structural system using ETABS 2016 software for the same plan.

Step 2: Selection of site condition and seismic zone.

Step 3: Application of loads and load combination to the structural model according to the standard codes.

Step 4: Analysis of each building frame models.

Step 5: comparative study of results in terms of storey displacement, storey drift, storey shear and time period.

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3. STRUCTURAL MODELLING AND ANALYSIS

A 48 storied steel framed structure with different plan dimensions upto certain storey levels is chosen. Height of each storey is 3.5 m. plan dimensions are 42 m x 42 m upto 24 stories, 30m x 30 m for next 12 stories and 18 m x 18 m for the last 12 stories. Fig. 1 shows the elevation selected for building.

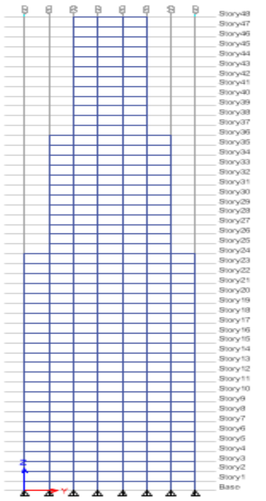

Fig. 1 Elevation of 48 storied building

There are total 11 models for comparative study. One is for conventional building frame, five models each for diagrid and hexagrid system for getting the optimized structure. Each models are differ in terms of their connection between the storey levels. The building data is kept same for all the models. The slab thickness is 120 mm. Column is selected as wide steel flange ISWB550. Column spacing is 6 m. Primary beams are ISWB400 and secondary beams are ISLB600. For diagrid and hexagrid structure, the diagonal member section is also ISWB550. The design dead load and live load on floor slab are 3.75 kN/m2 and 2.5 kN/m2 respectively. Interior frame of structures is designed for only the gravity load. The design wind load is computed based on location Thiruvananthapuram, Wind speed 39 m/s, Terrain category 3, Class C, Risk coefficient 1.06, Topography factor 1 as per IS: 875 (III)-1987. The design earthquake load is computed based on Zone factor 0.16, Soil type I, Importance factor 1, Response reduction factor 5 as per IS 1893-2002. Support condition is chosen as fixed.

The angle of diagonal member is different with respect to the height they connected. Thus the angular orientation of five models of diagrid structures are 30°15'23'', 49°23'55'', 60°15'18'', 66°48'5'' and 74°3'17'' respectively. Similarly for hexagrid structures, angle between the diagonal member and horizontal member are 139°23'52'', 138°48'50'', 130°36'5'', 119°45' and 105°56'43'' respectively. From these models, an optimum model which gives maximum performance is chosen for comparison.

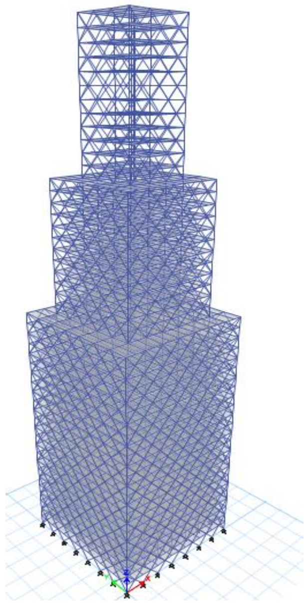

Fig. 2 3D Modelling of a particular diagrid structure

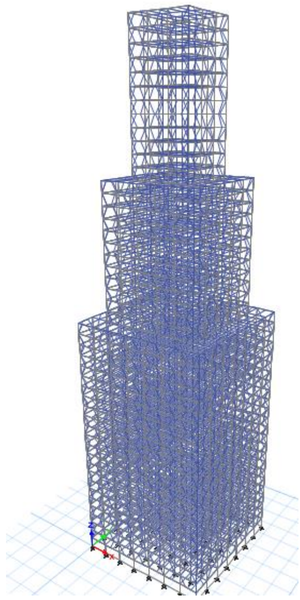

Fig. 3 3D modelling of a particular hexagrid structure

Fig. 2 and Fig. 3 show 3D modelling of diagrid structure and hexagrid structure using ETABS 2016.

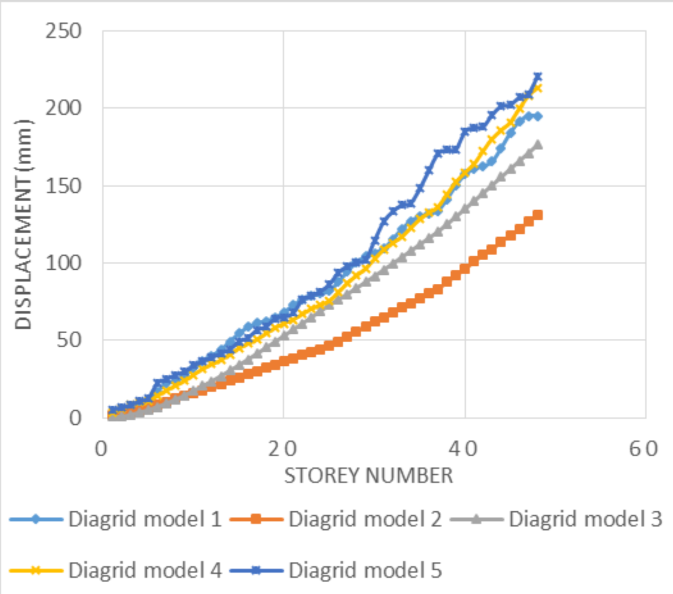

Fig. 4 Comparison of displacement due to wind in diagrid structural models

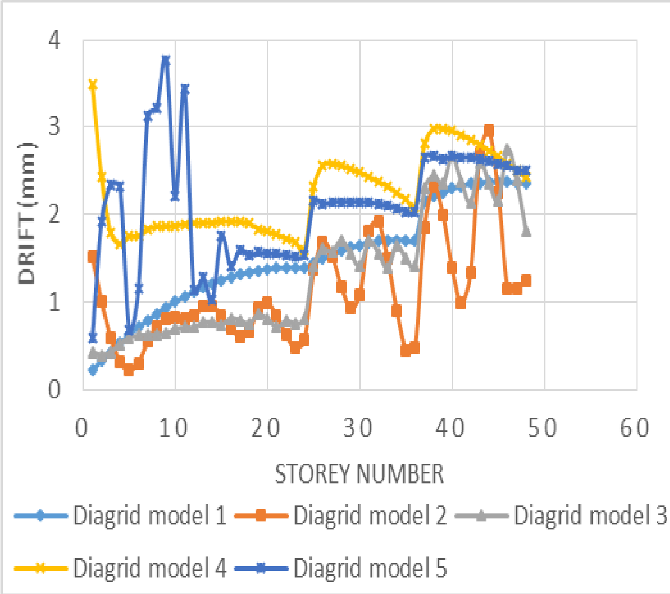

Fig. 6 Comparison of storey drift in diagrid structural models

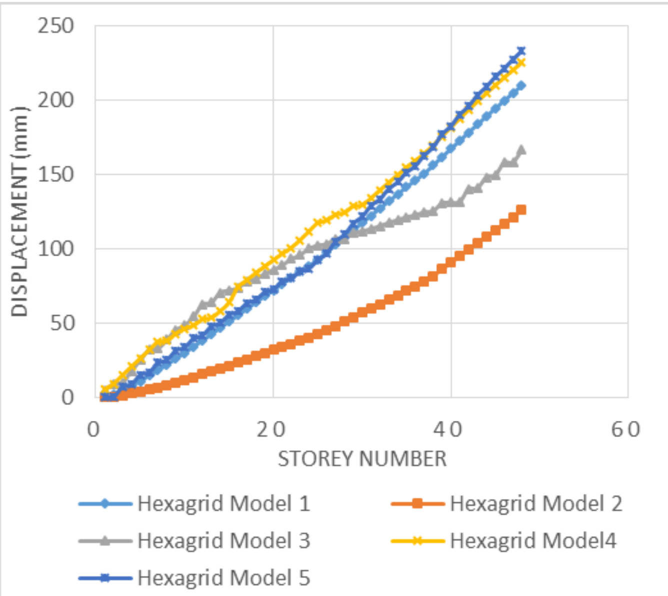

Fig. 5 Comparison of displacement due to wind in hexagrid structural models

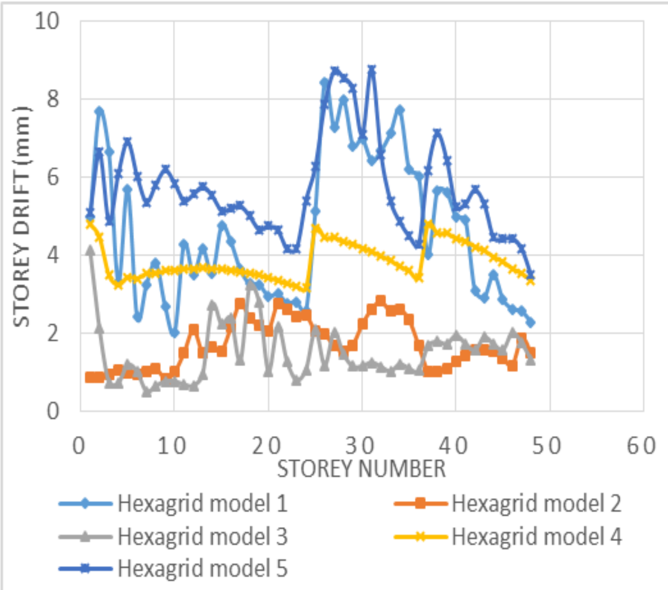

Fig. 7 Comparison of storey drift in

hexagrid structural models

Fig. 4 and Fig. 5 show the graph of storey displacement due to wind in diagrid and hexagrid structures whereas Fig. 6 and Fig. 7 show the graph of storey drift of the same. By comparing the results in terms of storey displacement and storey drift which is a parameter of lateral load resisting system, the optimum diagrid structure with the angle 49°23'55'' connecting two stories and optimum hexagrid structure with angle 138°48'50'' which connects one storey are obtained.

4. PERFORMANCE COMPARISON

The comparative analysis of diagrid and hexagrid system with conventional system in terms of storey displacement, storey drift, storey shear and time period is presented in this section.

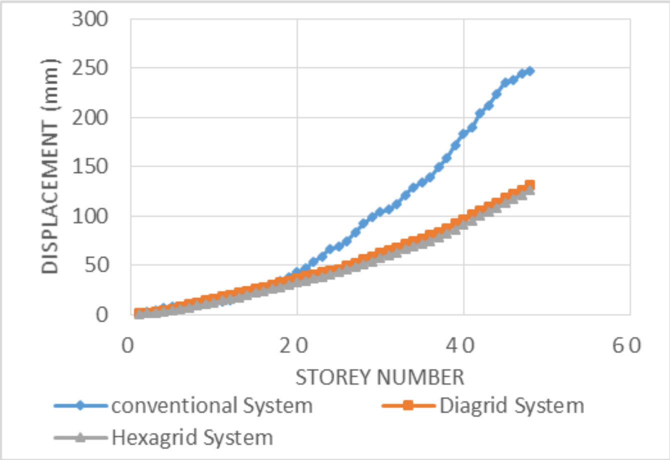

Fig. 8 Comparison of storey displacement

In Fig. 8 the value of storey displacement represent on Y axis and Number of stories in X axis. Structure undergoes maximum displacement at the top storey level. The maximum displacement in diagrid and hexagrid system is 131.16 mm and 126.04 mm respectively. Whereas in conventional system it is 246.92 mm.

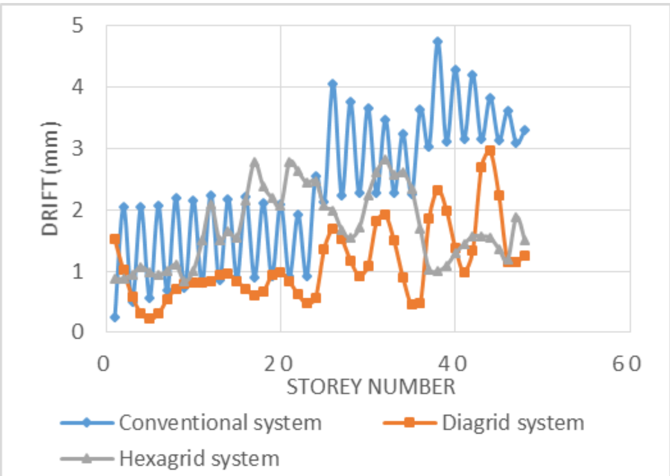

Fig. 9 Comparison of storey drift

Fig. 9 shows the variation of drift in the three structural systems. In the case of lateral load resisting system drift is a matter of concern. Here X axis represents number of stories and Y axis represents Storey drift. It is observed that drift for conventional system due to response is higher compared to diagrid and hexagrid systems.

The distribution of storey shear along the the height of conventional structure is shown in Fig. 10.

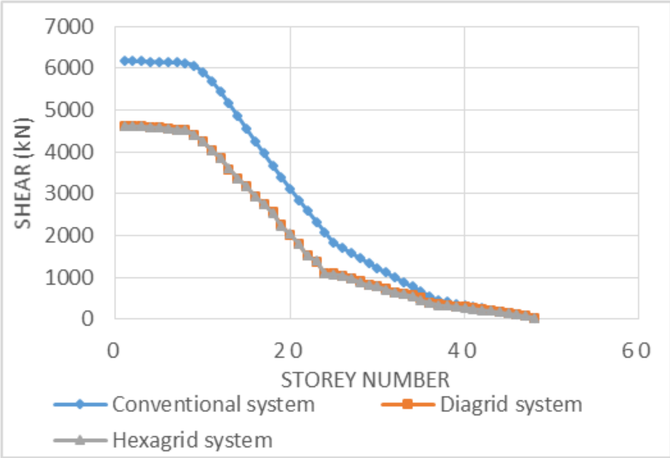

Fig. 10 Comparison of storey shear

It is observed that the storey shear force for diagrid and hexagrid structure is lower compared to conventional system. This is due to proper distribution of force by the diagonal action. For conventional structure the base shear is obtained as 6188.395 kN while the diagrid and hexagrid system offer 4614.68 kN and 4615.348 kN respectively.

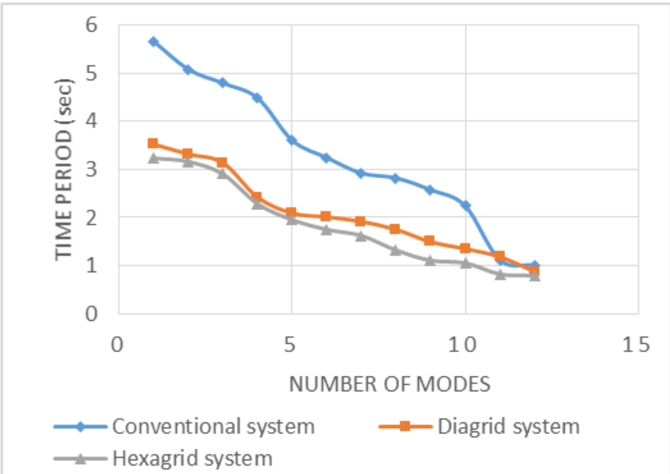

Fig. 11 Comparison of time period

The comparative time period for diagrid, hexagrid and conventional system are shown in Fig. 11. The first mode time period of conventional structural system is 5.66 seconds and for diagrid and hexagrid system are 3.52 and 3.23 seconds respectively.

5. CONCLUSION

The main conclusion obtained from the analysis of building frames are:

1. The top storey displacement is very much less in diagrid and hexagrid compared to the conventional system since the diagonal columns resist lateral load of the structure.
2. Both diagrid and hexagrid system promise an effective shear distribution than conventional system.
3. The storey drift and modal time period is very much less for both the grid system.
4. Length of the diagonal member should be minimum as possible to attain the optimum performance.
5. Both diagrid and hexagrid system promise highly efficient structure. However hexagrid system is recommended for making an economical structure, since the material conception depends on the number of sides.

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