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STUDY ON STRUCTURAL BEHAVIOUR OF HEXAGRID STRUCTURAL SYSTEMS IN MULTI STOREY BUILDINGS

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ABSTRACT

The advancement of technology and development of economy of the world have brought the new era of tall buildings. The most efficient building system for high rises has been the tube-type structural systems. Now-a-days, a particular structural system called a diagrid system has caught the attention of engineers. In order to improve the efficiency of tube-type structures in tall buildings, as both structural and architectural requirements are provided well, a new structural system, called "Hexagrid", is introduced in this study. It consists of multiple hexagonal grids on the face of the building. However limited academic researchers have been done with focus on the structural behaviour, design criteria and performance assessment of this structural system. In this research, a set of structures using hexagrid system of various geometrical attributes of the module (width, height, angle and scale), by changing the angle of diagonals (variable angles of 100, 110, 120, 130, 140 degrees) as well as by varying storey height along the building height were analysed and designed on a strength based approach by Finite Element Analysis software. The resulting hexagrid structures are assessed under gravity and lateral loads and various performance parameters are evaluated on the basis of the analysis results. The impact of different geometric configurations of structural members on the maximum lateral displacement, steel material density on facade, capacity of load carrying, time period and inter storey drift in hexagrid systems is to be studied and compared. The comparison in terms of performances finally allows for discussing efficiency potentials of the different patterns.

Key words: Hexagrid, Optimal design structure, Displacements profile, Structural systems.

INTRODUCTION

Recent design trends in tall buildings pose new challenges to structural designers, in addition to the traditional requirements for strength, stiffness, ductility and system efficiency. Structural configurations best addressing the traditional requirements of strength and stiffness for tall buildings are the ones employing the tube concept, whose efficiency is strictly related to the involved shear resisting mechanism, and in fact the historical evolution

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of the tube concept has been marked by the attempts of reducing the occurrence of efficiency loss due to shear deformations.

More recently, the diagrid structural system with tubular behaviour is being employed as structurally efficient as well as architecturally satisfying structural system for tall buildings. Perimeter diagonals act as a facade, which governs the aesthetics of the building to a great degree. In order to improve the efficient of tube-type structures in tall buildings, a new structural system called Hexagrid (Beehive) is introduced in this paper. In the hexagrid structure system, almost all the conventional vertical columns are eliminated. Hexagrid structural system consists of Hexagrid perimeter which is made up of a network of multi-storey tall hex-angulated truss system. Hexagrid is formed by intersecting the diagonal and horizontal components. The project is focused to horizontal hexagrid pattern which aims to investigate the optimal angle and a topology of diagonal members in a hexagrid frame using finite element analysis and to study the structural properties of hexagonal structures so as to compare their potential efficiency with the conventional systems. This effect can be better appreciated by analyzing the results in terms of interstorey drift, time period and displacement. The horizontal hexagrid pattern is given in Fig. 1.

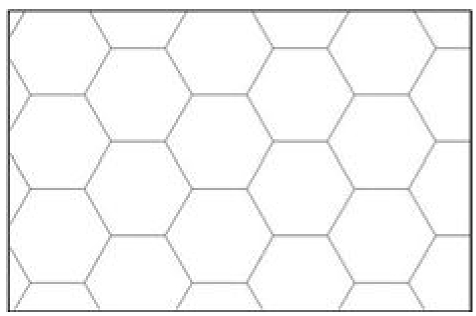

Fig. 1: Horizontal hexagrid

Research significance

The topology of the hexagrid system is an important design variable since the degree of an angle between diagonal members consisting of hexagrid determines stress distribution resisting internal forces. Therefore the effects of diagonal angles in the hexagrid system should be considered in order to obtain an optimal hexagrid topology with the highest stiffness in design phases. The unit cell of the hexagrid module is extending over multiple floors, which repeats horizontally along the building perimeter and stacks vertically along elevation. The geometrical parameters of the module are: the diagonal angle, the diagonal member length, the module height, the number of storeys covered by a single module, the number of modules along elevation and the number of modules along the perimeter. This research should help the structural designers to obtain more insight in the complex behaviour of the special structures like free-formed structures and should offer the structural designers more design freedom in the end of the design process.

Analysis

Building configuration

The 15 storey tall building is having 36 m x 36 m plan dimension. The storey height is 3.6 m. The typical plan and elevation of the structure is shown in Fig. 2. The design dead load and live loads on floor slab are 3.75 kN/m^2 and 2.5kN/m^2, respectively. The diagonal member section is a box section of 1500 mm x 1500 mm for hexagrid structure. For conventional frame building, the perimeter beam sizes are also ISWB 550 and ISWB 600 with a cover plate of 220 mm x 50 mm at top and bottom. The vertical columns are box sections of 2000 mm x 2000 mm. The design earthquake load is computed based on the zone factor of 0.16, medium soil, importance factor of 1.5 and response reduction factor of 5 as per IS 1893-2002. Modelling, analysis and design of hexagrid structure are carried out by finite element analysis using ETABS software. The support conditions are assumed as hinged. All structural members are considered using IS 800:2007 considering all load combinations.

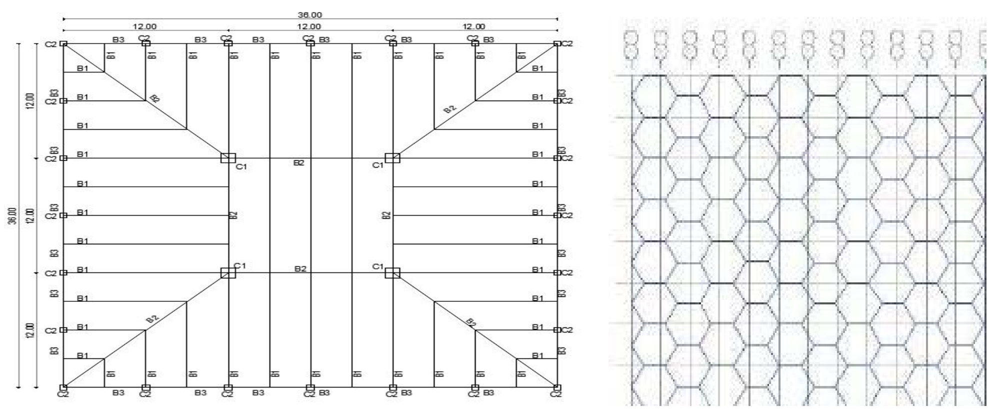

Fig. 2: Typical plan and elevation of the building

In the present work, different models are considered which consist of 15 storey building with the provision of different angle of diagonals in the range of 100°, 110°, 120°, 130° and 140°. All these angles are again modelled for hexagrid module which fits to 1 storey module and 2 storey module and a 15 storey conventional frame. So, total 11 (twelve) models are analysed and design to overcome the problems. The geometrical solutions considered for the horizontal hexagrid are modelled with varying angles and varying storey height. Comparison of analysis results in terms of time period, displacement and interstorey drift with conventional building is presented in this paper.

Analysis results

The static and dynamic analysis results for all the models are presented here in terms of storey displacement, interstorey drift and time period.

Displacement Result

The displacement results for 100°, 110°, 120°, 130°, 140° is as shown in Figs. 3, 4, 5, 6 and 7. As per code IS: 800:2007, the maximum top storey displacement due to lateral load should not exceed H/500, where H = total height of the building. The displacement results for all the models are within the permissible limit.

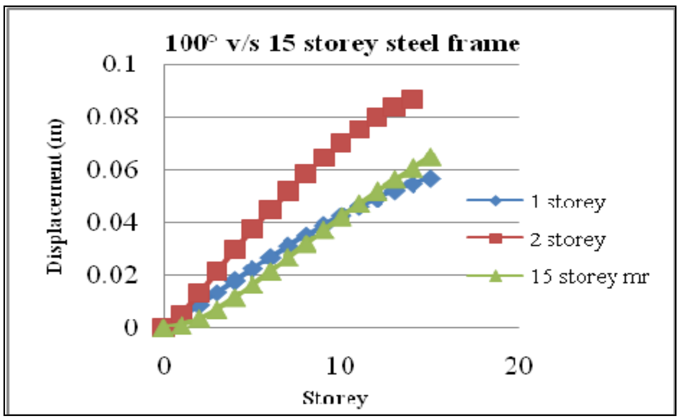

Fig. 3: Displacement profile of 100°

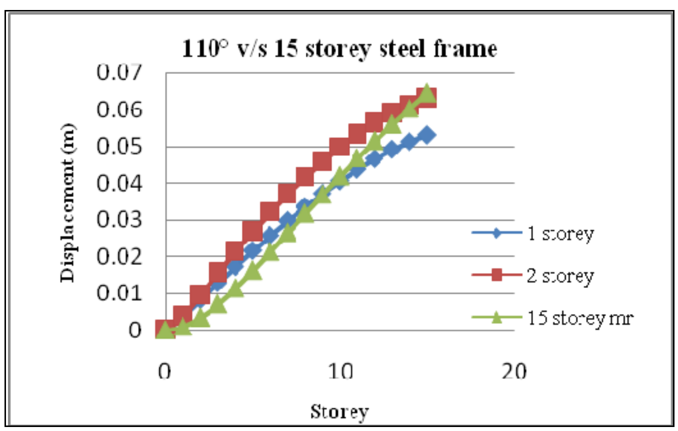

Fig. 4: Displacement profile of 110°

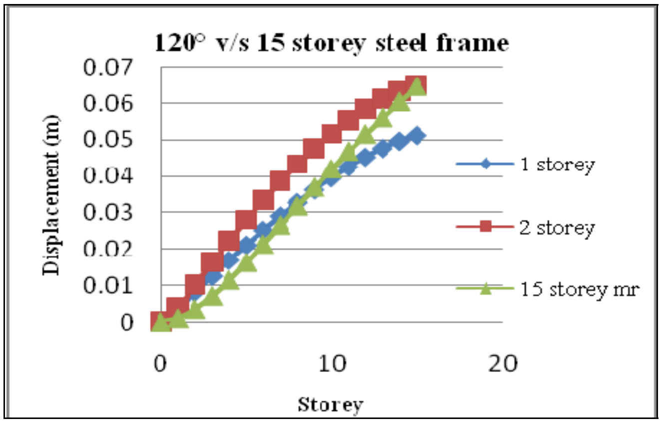

Fig. 5: Displacement profile of 120°

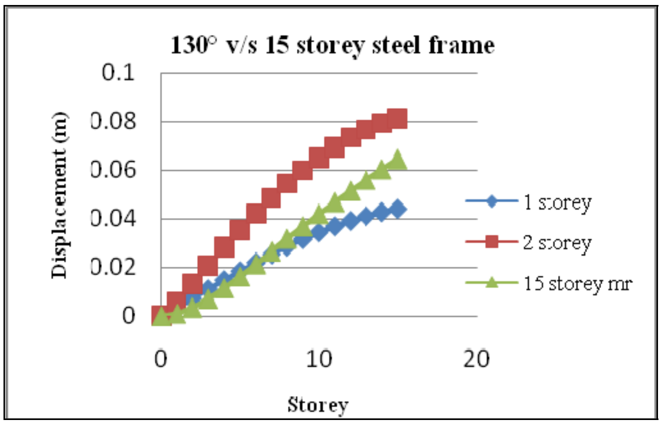

Fig. 6: Displacement profile of 130°

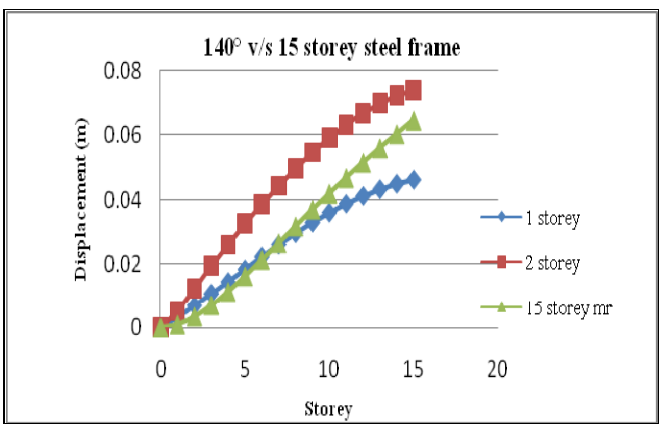

Fig. 7: Displacement profile of 140°

Storey drift

Here, the storey drift results for 100°, 110°, 120°, 130°, 140° is as shown in Figs. 8, 9, 10, 11 and 12. As per code IS: 1893-2002, the storey drift in any storey should not exceed 0.004 times storey height. The storey drift values obtained is within the permissible limit.

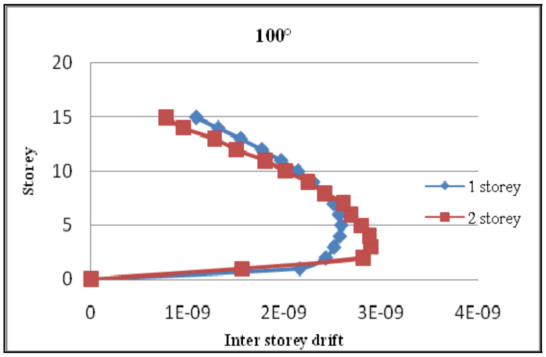

Fig. 8: Interstorey drift profile of 100°

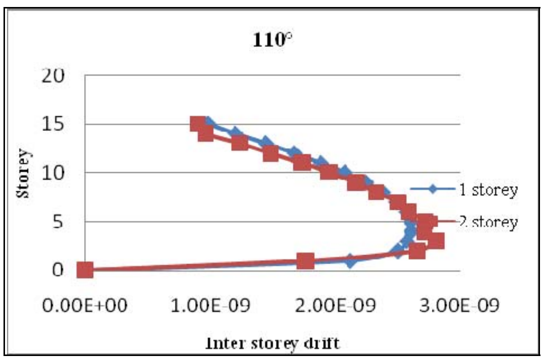

Fig. 9: Interstorey drift profile of 110°

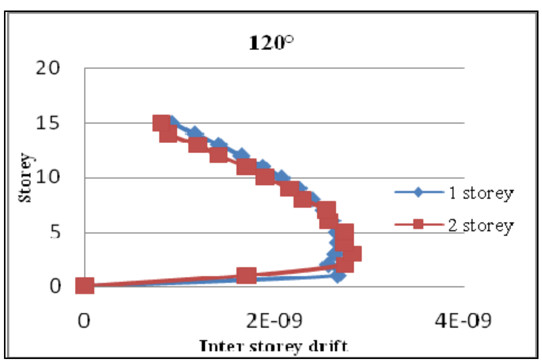

Fig. 10: Interstorey drift profile of 120°

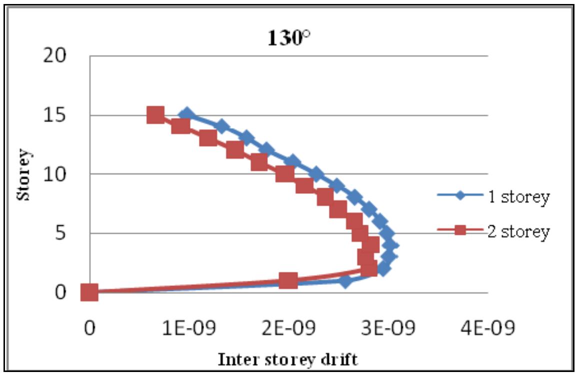

Fig. 11: Interstorey drift profile of 130°

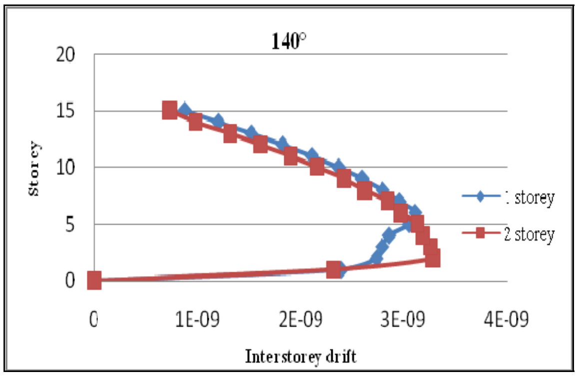

Fig. 12: Interstorey drift profile of 140°

Time period

By performing the dynamic analysis, time period is found out by considering 12 mode shapes for all models, is presented here. Figs. 13, 14, 15, 16 and 17, respectively.

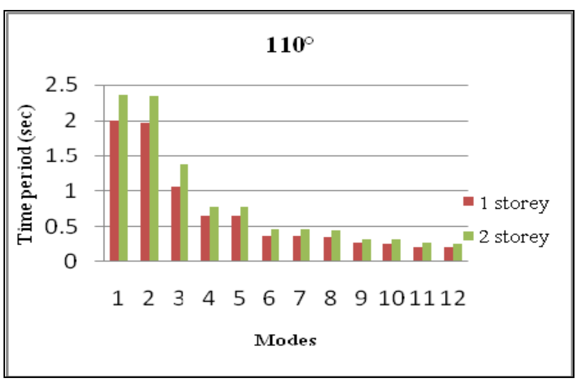

Fig. 13: Time period of 100°

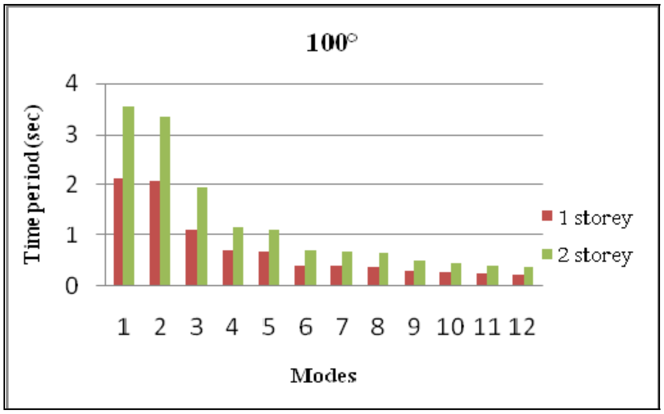

Fig. 14: Time period of 110°

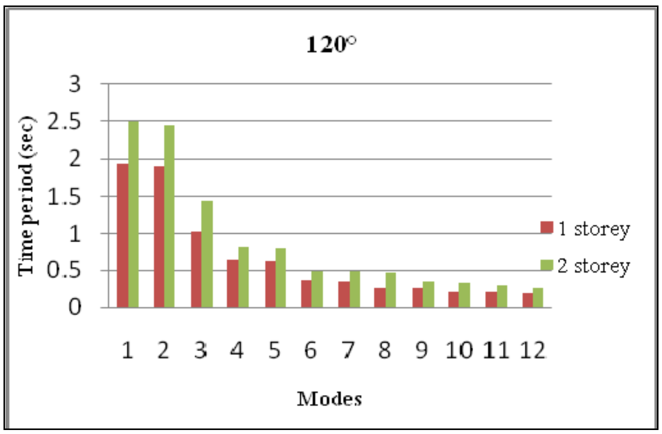

Fig. 15: Time period of 120°

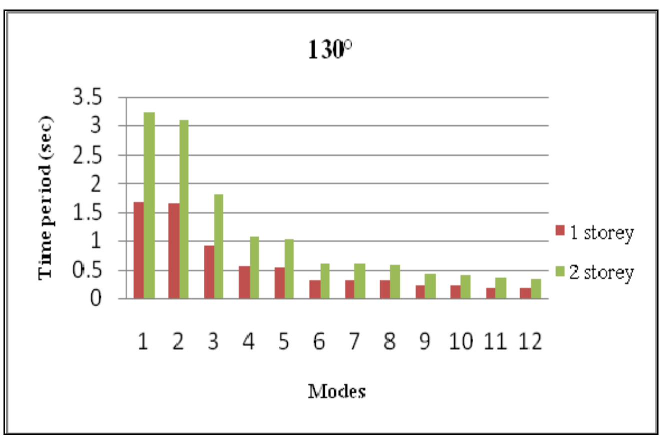

Fig. 16: Time period of 130°

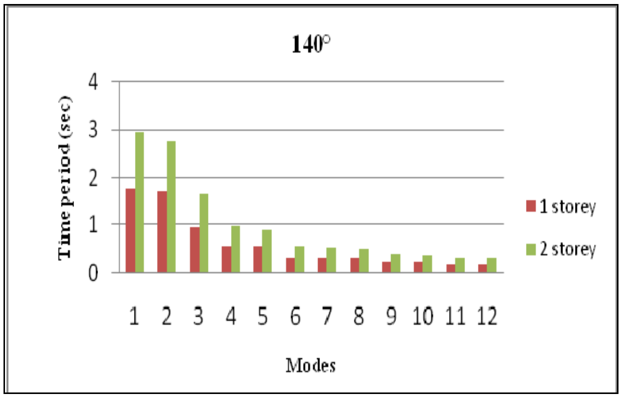

Fig. 17: Time period of 140°

As we know time period depends upon the mass and stiffness of the structure. If the time period is more, the modal mass is more but the stiffness of the building is less vice-versa. It can been noticed that the time period is minimum for 130°,so the stiffness is more when compared to others.

CONCLUSION

The current study is carried out by considering the varying angles of hexagrid and also varying storey heights of the building. A comparative study is carried out for a plan of 36m x 36m with varying angles of diagonals as 100°, 110°, 120°, 130°and 140° also by considering 1 storey unit and 2 storey unit. The connection between the members is yet to be studied.

We conclude from the study that,

(i) The hexagrid system is a particular form of belt trusses mixed tubular system and resists lateral loads acting in tension or compression.

(ii) The hexagrid structures show good performance against vertical and lateral loads. The fully hexangulated structure has higher stiffness in all direction.

(iii) The hexagrid structure whose diagonal angle in the region of 130° provides more stiffness to the structural system which reflects the less top storey displacement.

(iv) As time period is less, lesser is mass of structure and more is the stiffness, the time period is observed less in the region of diagonal angle 130°.

(v) Optimum angle of diagonals in the hexagrid is observed in the region of 130°.

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