Deepak Laata et al. 2019, 7:3
ISSN (Online): 2348-4098
ISSN (Print): 2395-4752

International Journal of Science, Engineering and Technology

An Open Access Journal

Results and Analysis of Hexagrid and Diagrid Systems in Multi Storey Buildings

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Abstract- More recently, the diagrid structural system with tubular behavior 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.

Keywords: Hexagrid, Diagrid, Displacements profile, Structural systems.

I. INTRODUCTION

In nature, bees have a fascinating, meticulous way of forming their beehives, which serve as their homes, their protection and their source of life.
There is nothing new under the Sky. This does not mean that everything has been built already but that the principle behind the design already exists. By examining structures in nature we can see where the principle exists and see how these principles are incorporated in structures today. One thing we have to keep in mind when comparing natural and manmade structures is that nature uses live materials while a man uses inert ones and the two do not always behave in the same manner. The beehive's internal structure is a densely packed matrix of hexagonal cells called a honeycomb. The bees use the cells to store food, and to house the "brood".

The hexagonal shape perfectly distributes and disperses the external man-made or environmental forces thus protecting its contents. The hexagon also allows simple expandability by adding hexagon segments to the perimeter of the honeycomb. The simplicity of the hexagonal shape creates an incredibly strong and smart design which provides great stability and security for the bees.

2. CHORD

Chord is a scalable peer-to-peer look up protocol designed to construct an overlay network based on DHT. As described earlier, each node as well as resource in the system is identified by a m-bit long node-id and resource-id (key) respectively, with each node maintaining a subset of the resources. By constructing and maintaining efficient routing structures, a resource can be located in a maximum of $O(\log_2(N))$ hops, where N is the number of nodes in the Chord overlay.

The mechanism for mapping resources to nodes and routing queries over the network. On bootstrapping, each node contacts the bootstrapping server and receives a list of existing nodes. It then connects itself in the chord overlay and starts to populate its routing tables by exchanging information with other nodes. Chord supports multiple joins and can bootstrap large- scale DHT networks.

Fig. 1: The beehive's internal structure.

The Hexagrid structural system recently evolved, rarely executed is inspired by the 'Beehive' (one of the stable structure of nature). This structural system is made by arranging several hexagons of height equal to story height in a unique way as in Beehive.

Fig. 2: Hexagrid System.

Hexagrid system rests on a regular polygon with six elements system. This system has an advantage of uniform distribution of stresses in itself due to uniform angle of 120 degree between any two elements but has disadvantage of very less lateral stiffness.

II. LITERATURE REVIEW

Akshat and Gurpreet Singh (2018) reviewed research published on the structural performance of diagrid system. A first step toward a systematic and comprehensive study is that regular patterns are compared to alternative geometrical configurations, obtained by changing the angle of diagonals (variable-angle, VA) as well as by changing the number of diagonal (variable-density, VD) along the building height. Further it discusses about the different diagrid patterns generated and designed for an assumed building; and how the resulting diagrid structures are assessed under gravity and wind loads and various performance parameters are evaluated on the basis of the analyses results.

Md. Arman (2018) analysed the performance of high-rise buildings, it is especially important that an effective modeling technique be involved because of the complexity of the real structural behavior and the difficulties of full scale measurement. The lateral performance of multi-storey buildings under different loading conditions is greatly influenced by various parameters such as structural stiffness and base to height ratio of the building. Optimization and refinement of such performance has become the focus as well as the constraint for structural engineers in their design practice.

Avnish Kumar Rai & Rashmi Sakalle (2017) analysed a regular eleven storey RCC building with plan size 16 m × 16 m located in seismic zone V & III is considered for analysis. STAAD. Pro software is used for modeling and analysis of structural. Seismic zone is considered as per IS 1893(Part 1): 2002. The Comparison between the diagrid and conventional building analysis results presented in terms of a node to node displacement, bending moment, storey drift, shear forces, an area of reinforcement, and additionally the economical aspect.

Kona Narayana Reddy and Dr. E. Arunakanthi (2017) studied on the Oblique columns of different shapes in high rise building. In this work a high rise building with Normal Columns & with different locations of Oblique columns is considered for analysis. In this paper, response spectrum & Linear Static analysis were executed combined with a Numerical Building Model by this program, which were also compared following the analysis results. The results of the analysis on the Axial forces, Base shear, Time period, Storey drift and Displacements are compared. The results are presented in tabular and graphical form. The results on the displacement are checked with serviceability conditions and are compared and presented in tabular form.

Ravi Sorathiya and Prof. Pradeep Pandey (2017) presented a stiffness-based design methodology for determining preliminary member sizes of RCC diagrid structures for tall buildings. A G+24, G+36, G+48, G+60 storey RCC building with plan size 18 m × 18 m located in surat wind and seismic is considered for analysis. STAAD.Pro software is used for modeling and analysis of structural members. All structural members are designed as per IS 456:2000 and load combinations of seismic forces are considered as per IS 1893(Part 1): 2002. Comparison of analysis results in terms of beam displacement, Storey Drift, Bending Moment. This cause economical design of diagrid structure compared to conventional structure.

Harshada A. Naik (2017) presented the literature review of different authors on behavior of diagrid structures under wind loading and seismic loading to understand the performance of diagrid structures. This study gives good indications on parameters in terms of time-period, top-storey displacement, inter-storey drift and storey shear.

Viraj Baile (2017) analysed a 36-storeyed diagrid building, simple frame building and a building with various bracing systems have been modeled and analyzed. The bracing systems are X-type, V-type and Inverted V- type. The positions of the bracings have also been varied. A total of 15 buildings have been modelled and analysed to compare which system performs better a lateral load resisting system. The modelling and analysis has been performed on ETABS. The dynamic analysis is performed by using Response Spectrum Method. All the loadings and the checks are provided as per Indian Standards.

III. STRUCTURAL MODELS

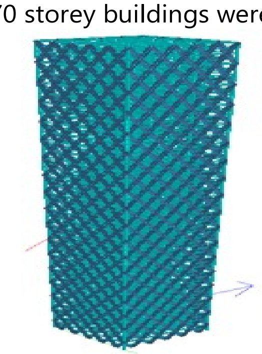
A regular floor plan of 30 m x 30 m is considered in both buildings. Storey height is 3m. The design dead load and live load are 5 KN/m2 and 4 KN/m2 respectively. Exterior wall load is taken negligible in both the buildings. Both the building frames are analyzed for seismic zone IV. Seismic parameters are taken as per Indian code IS 1893 (Part 1): 2002.

Table 1: Geometry and load consideration

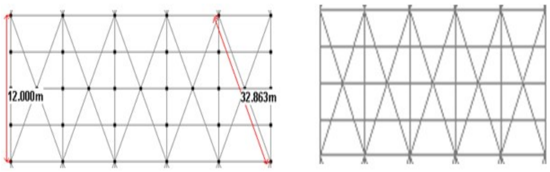
Type of structure	**Residential building (G+69)**
Plan dimension	30 x 30 m
Total height of building	210 m
Height of each storey	3 m
Diagrid section	Steel section
Seismic load (as per IS code 1893 part-1)	Zone IV
Dead load (5 KN/m^2)	875- part 1
Live load (4 KN/m^2)	875- part 2
Thickness of slab	150 mm
Beam size	200 x 400 mm
Column size	400 x 400 mm

IV. GENERATION OF BUILDING MODELS

The diagrid structure is composed of diagonal members and hexagrid structure is composed of diagonal and vertical members have been modeled in staad pro. The pattern and size of hexagrid and diagrid was used as a study parameter. To examine the structural behavior of tall buildings with a diagrid and hexagrid system, 210 m high, 70 storey buildings were designed.

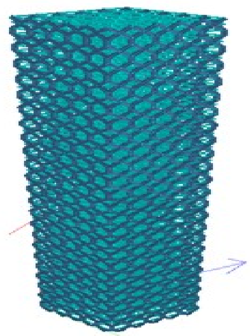


(a) Render view

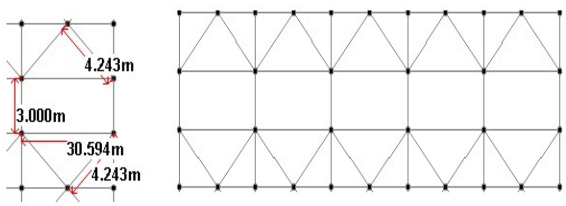


(b) Size and pattern

Fig. 3: Diagrid system.



(a) Render view



(b) Size and pattern

Fig. 4: Hexagrid system.

V. RESULTS AND DISCUSSION

Support Reaction

Magnitude of support reaction for various models has been plotted in figure number 5, it is determined that in this comparative study maximum support reaction is in diagrid system whereas hexagrid system shows minimum support reaction value.

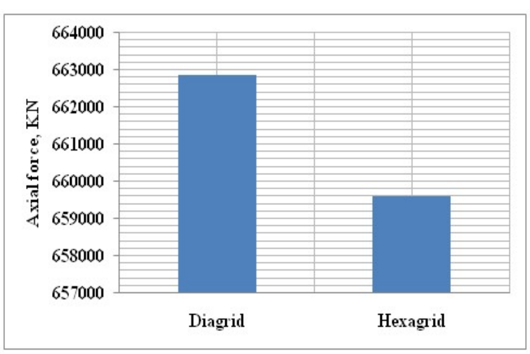


Fig. 5: Axial force.

Shear Force

Magnitude of shear force for various models has been plotted in figure number 6, it is determined that in this comparative study maximum shear force is in diagrid system whereas hexagrid system shows minimum shear force value which results in balanced structure

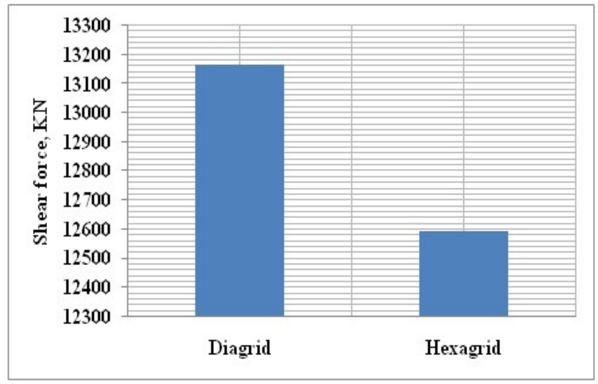


Fig. 6: Shear force comparison.

Bending Moment

Magnitude of bending moment for various models has been plotted in figure number 7, it is determined that in this comparative study maximum bending moment is in hexagrid system whereas diagrid shows minimum bending moment value which results in balanced section.

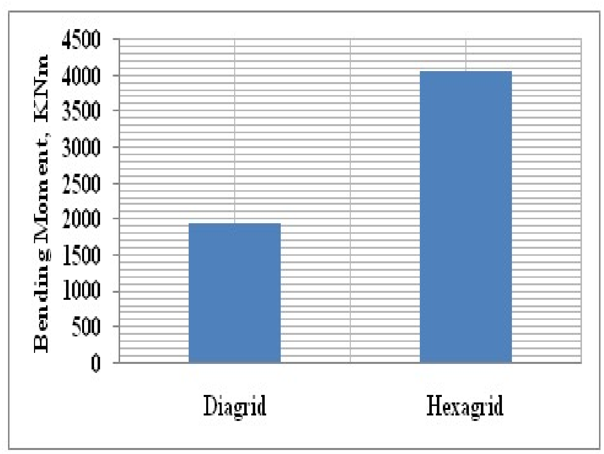


Fig. 7: Bending moment comparison.

Deflection

Magnitude of maximum displacement for various models has been plotted in figure number 8, below it is determined that deflection is maximum in hexagrid system whereas minimum in diagrid which indicates that hexagrid system will require more supports as compared to diagrid system.

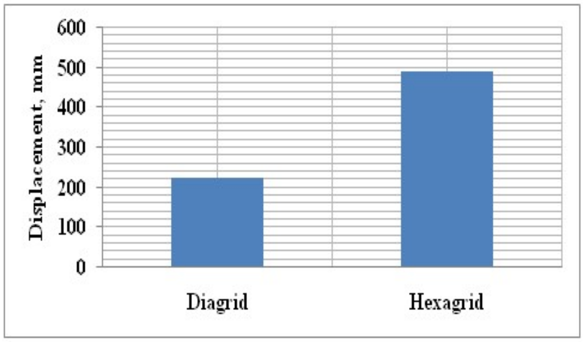


Fig. 8: Displacement comparison.

Concrete Take Off

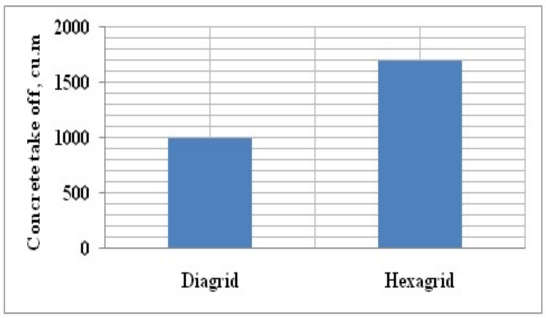


Fig. 9: Concrete comparison.

As shown in above chart amount of concrete in a hexagrid system will be comparatively higher than diagrid structure as outer R.C.C. columns are replaced by steel sections in diagrid frame. So the concrete consumption in two cases for the hexagrid system is much higher than the diagrid frame which makes the hexagrid system more costly than the diagrid frame.

Steel Take Off

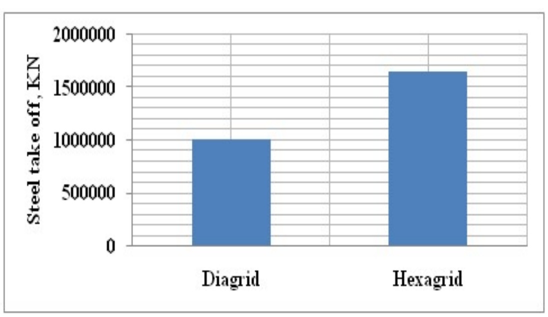


Fig. 10: Steel take off comparison.

As shown in figure above it is clearly determined that as outer column are removed by diagrid system it manages bending moment properly that reinforcement requirement including steel for diagrid is comparatively less than bare frame. The overall cost for the diagrid is reduces which makes it more economical than the hexagrid system.

VI. CONCLUSION

The following points are concluded from above study about diagrid and hexagrid structure.

- Study shows that diagrid structure decreases bending moment which in results decreases reinforcement requirement.
- It shows that lateral displacement can be minimized by using diagrids.
- Although volume of concrete used in building is different, but diagrid shows more economical in terms of steel used. Diagrid building saves about 33.21% steel without affecting the structural efficiency.
- Due to diagonal columns on its periphery, diagrid shows better resistance to lateral loads and due to this, inner columns get relaxed and carry only gravity loads. While in conventional building both inner and outer column are designed for both gravity and lateral loads.
- A significant decrease of bending moment in interior columns of diagrid building is found in comparison to conventional building.
- The use of diagrids significantly decreases the maximum shear force and maximum bending moment in internal and perimeter beams. The sign of maximum bending moment also changes in perimeter beams of diagrid building.
- The diagrid configuration provides a reduction in the span of perimeter beams at alternate floors, hence reducing the beam forces at alternate floors.
- So from results and comparison with conventional building, one can adopt hexagrid structure for better lateral load resistance and this becomes important for seismic zone IV.

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