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Comparative Analysis of Tall Buildings Structure with a Hexagrid System

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***Abstract*: Recently structural designers face new challenges to current design trends in tall buildings which will satisfy strength, stiffness and many more. Ever growing heights and complexity of shape, need for robustness coupled to economy, cognizance of limited material resources and sustainability, are all new worrying inquiries to be tackled with sparkling approaches, novel structural systems and open minds. Structural configurations nice addressing the conventional necessities of strength and stiffness for tall buildings are the ones using the tube concept, whose performance is precisely associated with the concerned shear resisting mechanism, and actually the ancient evolution of the tube concept has been marked by the tries of lowering the incidence of performance loss due to shear deformations. In this dissertation the structural behavior of modern structural solutions for tube structure are mentioned, studying the ordinary behavior of every analyzed geometry, offering new layout techniques and comparing the related structural performance. This study investigated the tall hexagrid buildings, focusing on size and pattern of different the hxagrid modules.**

***Keywords*: Hexagrid (Beehive), Structural systems, Dead load, Live load, Seismic load**

1. Introduction

Bees have an attractive, particular way of establishing their beehives, life which oblige as per their homes, their safety and their source of. 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. Recently various structural engineers studied various structures exist in nature and they see where the principle exist or not and analyze how we can integrate these principles in structures today. However we have also noticed that when we compare natural and manmade structures, natural structural always use live materials while a man uses artificial ones and both of these do not continuously behave in the same manner.

Honeycomb is the beehive's internal structure and it is a densely packed matrix of hexagonal cells. The bees use these cells to store food and to house the “brood”. Also we know that the hexagonal shape seamlessly allocates and disbands the external man-made or environmental forces thus shielding its insides. It also offers 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.

Fig. 1. Natural Forms and Structures

Fig. 2. The beehive’s internal structure

2. Research Methodology

In this study comparison of size and pattern of hexagrid modules under seismic forces is presented. Here 15 storey is taken and same dead load and live load [Han-Ul Lee and Young Chan Kim (2017)] is applied in all the buildings for its behavior and comparison. As we all know that buildings are always subjected to vibrations because of earthquake and therefore seismic analysis is essential for the buildings. So in our work we also conduct vibration analysis of all the buildings along with storey drift in seismic zone IV are analysed by means of Staad. Pro software. The response of all the building frames is studied for useful interpretation of results.

1) Steps for comparison

The foremost performance parameters in this research work are different size of thehexagrid modules and the hexagrid shape. However in this investigation only vertical hexagrids in orientations are used. 15 storey buildings have been designed using Staad Pro. Analysis of results in terms of moments,

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displacements, shear force, axial force and drift has been presented in the last chapter

Following steps are adopted in this study

- *Step-1* Selection of floor plan and Seismic zone. As in previous discussions we have designed our models for Zone IV as per IS code 1893 (Part 1):2002 for which zone factor (Z) taken is 0.24. According to our assumptions we modelled 15 storey building with different module size and pattern of hexagridis taken. Floor to floor height is 3m.
- *Step-2* Modelling of buildings using STADD. Pro software
- *Step-3* Investigation of all the building frames was done under seismic zone IV
- *Step-4* Presentation of results with regard to maximum moments in columns and beams, storey displacement, shear force, axial forceand drift.

2) Structural Models

A square floor plan of 20 m x 20 m is considered for all the models. Storey height taken was 3m. The dead load and live load obtained from the base paper [Han-Ul Lee and Young Chan Kim (2017)] are 4KN/m2 and 2.5KN/m2 correspondingly. All the models are investigated for seismic zone IV only. Seismic parameters definitions are taken from Indian code IS 1893 (Part 1): 2002.

Table 1
Geometry and load consideration

Type of structure	**Residential building**
Plan dimension	20 x 20 m
Total height of building	45 m
Height of each storey	3 m
Diagrid section	Steel section
Seismic load (as per IS code 1893 part-1)	Zone IV
Dead load (4 KN/m^2)	875- part 1
Live load (2.5 KN/m^2)	875- part 2
Thickness of slab	150 mm
Beam size	400 x 400 mm
Column size	400 x 300 mm

Table 2
Material properties considered in the modeling

Description	**Value**
Steel table	Standard section (l100012B50016)
Young's modulus of steel, Es	2.17x104 N/mm^2
Poisson ratio	0.17
Tensile Strength, Ultimate Steel	505 MPa
Tensile Strength, Yeild Steel	215 MPa
Elongation at Break Steel	70 %
Modulus of Elasticity Steel	193-200 GPa

3. Generation of the Structure

The structure may be generated from the input file or mentioning the co-ordinates in the GUI. The figure below shows the GUI generation method.

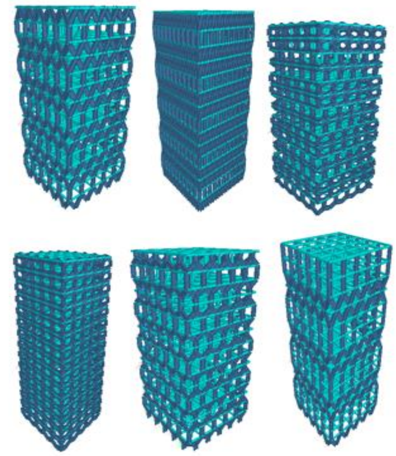

Fig. 3. Models (a) HP1(b) HP2(c) HP3(d) HP 4(e) HP5 (f) HP6

4. Vibration Effect on Different Models

The vibration analysis of a structure suggested a lot of implication in its designing and performance over a period of time. The lowest frequency was in 1st mode. The frequency was increasing with each subsequent mode of vibration and also increases with hexagrid module size.

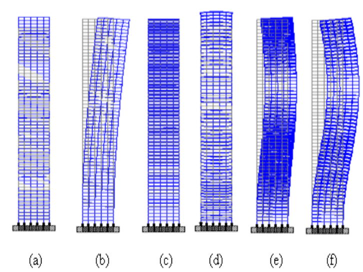

Fig. 4. Mode shape of conventional frame

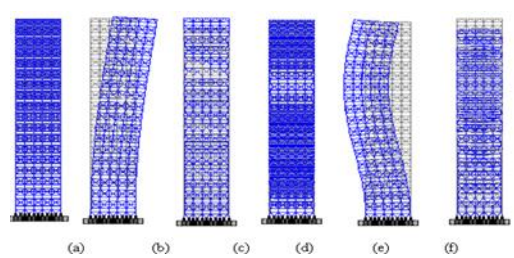

Fig. 5. Mode shape hexagrid pattern 1

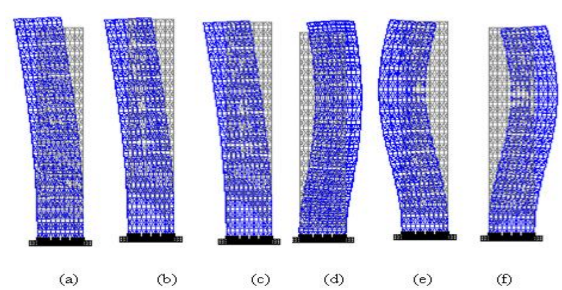

Fig. 6. Mode shape hexagrid pattern 2

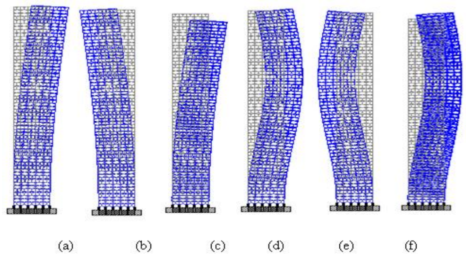

Fig. 7. Mode shape hexagrid pattern 3

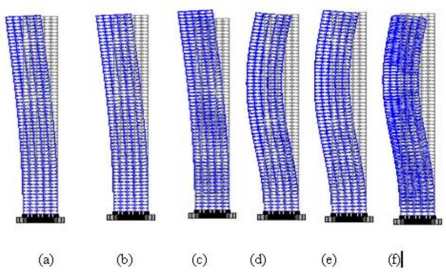

Fig. 8. Mode shape hexagrid pattern 4

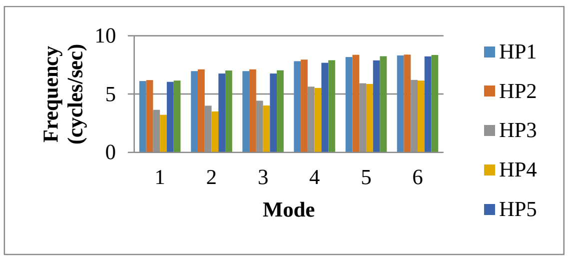

Fig. 9. Variation of frequency with different shape

If you have a Table, simply paste it in the box provided below and adjust the table or the box. If you adjust the box, you can keep the table in single column, if you have long table.

5. Support Reaction

Magnitude of support reaction for various models has been plotted in figure number 9, it is determined that in this comparative study maximum support reaction is in HP4 whereas HP 1shows minimum support reaction value.

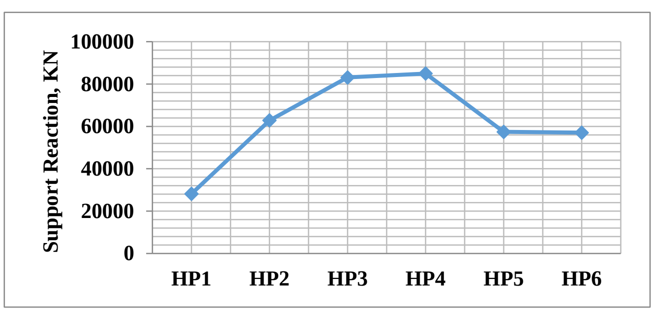

Fig. 10. Support reaction

6. Shear Force

Magnitude of shear force for various models has been plotted in figure number 10, result suggest that maximum shear force is in HP4. HP2 shows minimum shear force value which consequences in balanced structure.

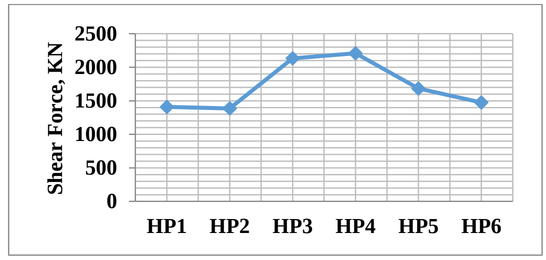

Fig. 11. Maximum shear force

7. Bending Moment

Magnitude of bending moment for various models has been plotted in figure number 11, it is determined that in this comparative study maximum bending moment is in HP4whereas HP2 shows minimum bending moment value which results in balanced section.

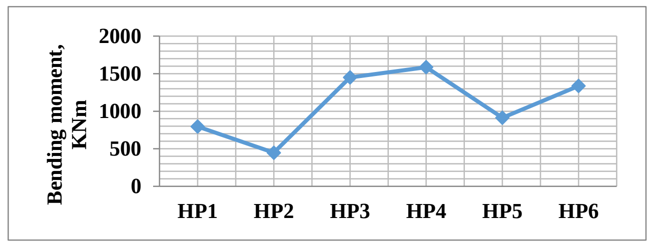

Fig. 12. Maximum bending moment

Here result shows that bending moment is low in HP2 structure which means less reinforcement is required.

8. Displacement

Magnitude of maximum displacement for various models has been plotted in figure number 12, below it is determined that deflection is maximum in HP 3whereas minimum in HP 2 which indicates that HP 3 will require more supports as compared to other cases.

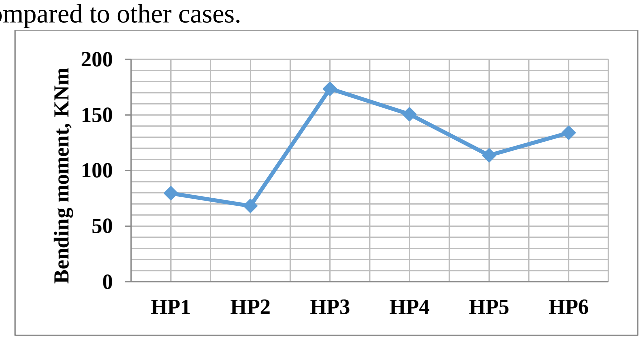

Fig. 13. Displacement comparison

9. Lateral Displacement

It represents the total displacement of the floor w.r.t ground. The lateral forces (wind or seismic) acting on building are the main reason for it. 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 obtained from our analysis for all the models are within the permissible limit.

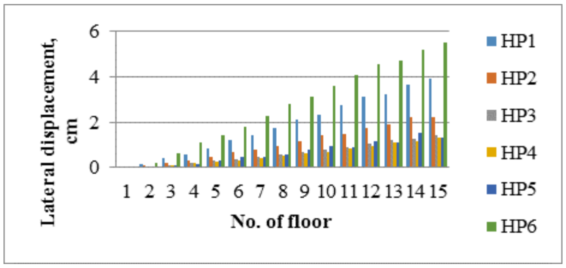

Fig. 14. Lateral displacement of models

In above figure Y axis represent the value of storey displacement and X axis represent number of floor. Structure undergoes maximum displacement at the top storey level in case of HP6. The maximum displacement in HP1, HP2, HP3, HP4, HP5 and HP6 is 3.9372 mm, 2.2436 mm, 1.4372 mm, 1.3140 mm, 1.3429 mm and 5.5382mm respectively. As module size increases displacement of vertical hexagrid increases. Also the hexagrid structure whose module size are small it offers more stiffness to the structural system which reflects the less top storey displacement.

10. Storey Drift

According to IS: 1893-2002, the storey drift in any storey should not exceed 0.004 times storey height. The storey drift values obtained in our analysis is within the permissible limit.

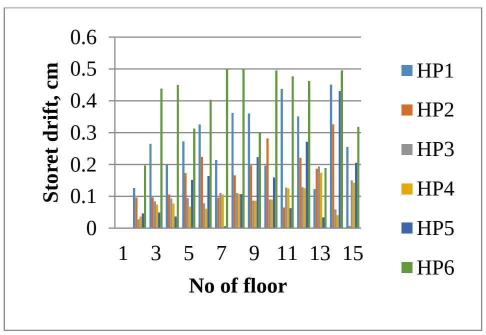

Fig. 15. Storey Drift of different models

Above graph shows the variation of drift in the all structural systems. With reference to lateral load resisting system drift is of interest. Now X axis characterizes number of floor and Y axis signifies Storey drift. We noticed that drift for HP6 is higher compared to HP1, HP2, HP3, HP4 and HP5.We also observed that drift increases with increase in module size. So it is desirable to have vertical hexagrids with greater module size.

11. Time period

By performing the dynamic analysis, time period is found out by considering 6 mode shapes for all models.

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. We observed that the time period is minimum for HP1, hence the stiffness is more when associated to other models. Also in case HP1 as time period is less, lesser is mass of structure and hence more is the stiffness.

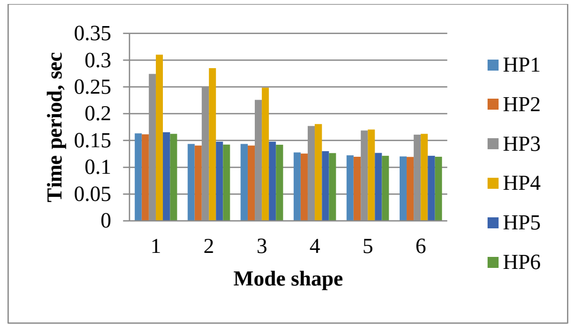

Fig. 16. Time period

The time period for different models is shown in Fig. 5.13. The first mode time period of HP1 is 0.16331 seconds and for HP2 is 0.16137 seconds, HP3 is 0.27432 seconds, HP4 is 0.31036 seconds, HP5 is 0.16539 seconds and for HP6 is 0.16243 seconds respectively. The time period of HP1 structure is the least suggesting that it has higher stiffness compared to other structures.

12. Conclusion

This paper presented an overview of Comparative analysis of tall buildings structure with a hexagrid system.

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