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Structural Behaviour of High Rise Building using Different Hexagrid Sizes for Earthquake Loading

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Abstract: ***In recent years the population is increasing rapidly. Due to this reason the demand for housing is high as every year passes which results in saturation in area consumption. High rise buildings provide an effective and economical explanation for the problem. Tubular system is recent form of high rise building in order to resist lateral load. These are mainly of three types, diagrid, hexagrid and octagrid. Hexagrid system is form of new system for high rise building which were designed on strength and stiffness to withstand wind load and seismic load on a storey height more than 50. The study is mainly going to discuss about the behavior of high rise building using hexagrid system with different hexagrid sizes in module under earthquake loading. The optimum module sizes will be obtained for both equivalent static and non-linear dynamic analysis. A G+59 storey building with symmetric floor plan using equal consumption of steel for the different hexagrid sizes will be modeled in ETABS 2016. The examination and the investigation of conduct of the hexagrid with various module sizes will be examined.***

Keywords: High rise building, Hexagrid building, Hexagrid module size, Equivalent static analysis, Time history analysis.

I. INTRODUCTION

High rise buildings are common types of buildings which are apparently very tall used in recent years after the invention of elevators. These are basically used for many purposes such as residential, office and hotels. The rapid increase in population and urbanization caused a huge hike in land cost thus resulting in big constraint for developers and builders in availability of land. This forms a huge part of vertical growth as natural process. The lateral load resisting method becomes more significant than the structural system that resist gravitational load. The structural design of high rise building is basically for resisting lateral forces such as wind load and earthquake load. The interior structural system and exterior structural system provides the resistivity of the lateral loads. Normally shear wall core, braces frame and their combinations are provided for the lateral load resistivity. Nowadays hexagrid system of tubular behavior is being considered highly efficient and brings out good architectural appearances.

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The introduction of beehive (hexagrid) system helps to improve the efficiency of the tube- type structure as shown in figure1 and the study in this paper focuses on that. The external diagrid perimeter behaves like the major part of elevation of the structure. This forms the aesthetic appearance of the building to a great extent.

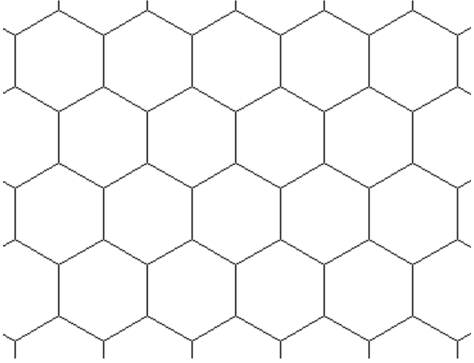


Fig 1 Vertical hexagon pattern

The hexagrid system is special form of trusses combined with tubular system which resist lateral forces which acts in form of compression and tension. The load in hexagrid system is distributed both by gravity load and lateral load in the form of axial stresses.

The paper mainly deals with structural orientation and structural behavior of the hexagrid system. Different module sizes of the hexagrid structure are provided and the top storey displacement, storey drift and base shear are obtained in both static and dynamic analysis. The most efficient model with module size is found.

II. LITERATURE SURVEY

Moon et.al., [1] examined that for the uniform angle diagrid structures, it was found that, as a building becomes taller, the optimal angle also increases because the design of a taller structure with a large height-to-width aspect ratio . For the tall diagrid structures, with aspect ratios ranging from about 4 to 9, the range of the optimal angle is from nearly 60 to 70 degrees.

Connor et.al..[2] presented the detailing procedures provided in the construction of diagrid structures. Vertical columns can resist gravity loads and the diagrid is useful for both gravity and lateral loading.

Jani and Patel [3] have done the analysis and design of a G+ 35 storey steel building. In this paper it is found out that most of the lateral loads are resisted by periphery of the diagonal members. The gravity load is resisted by both the internal columns.

Raghu and Kavya [4] have presented on comparison with the ordinary frame with shear wall; lowest drift ratio is shown by octagrid system. Hexagrid and octagrid structural systems demonstrate very small difference in drift ratios. It was found that frames with hexagrid system showed least displacement. Deepika et.al..[5] have done an analysis study in equivalent static analysis, linear dynamic analysis and nonlinear analysis on a concrete diagrid and a commercial building. The comparison studies on roof displacement, storey displacement and base shear is taken. The optimum angle of 63°for diagrid building shows better performance compared to commercial building. Pooja and Bennet [6] have performed the Equivalent static and dynamic analysis of Diagrid, Hexagrid, Octagrid and exterior braced steel structure. The behavior of diagrid buildings modeled with different diagonal angle is studied.

III. OBJECTIVES AND SCOPE

To model G+59 storey building with different hexagrid patterns using ETABS 2016. The analysis of the G+59 storey models of different hexagrid patterns in equivalent static analysis is to be done. The analysis is only limited to earthquake loading. This study determines the base shear, storey drift and the displacement of the four models. Analysis is to be done in seismic zone 3 and the behavior of the building will be obtained. Then the analysis of the four model will be studied in time history (non-linear dynamic) and the time period, roof displacement and storey drift is found and the behavior is going to be studied. The best performed hexagrid pattern of the four models is to be obtained and the optimum module density of different hexagrid patterns for a fixed volume of steel is found.

IV. BUILDING LAYOUT

A 60 storeyed building of dimension 36 m x 36 m is modeled and analysed with 4 different types of hexagrid patterns with different module sizes. For this study a symmetric floor plan with interior columns are provided the same for all the four models. The pattern of the hexagrid module is kept constant, and the inclination of the diagonal members is maintained at 67.38°. The thicknesses of the hexagrid members are varied such that the total amount of steel used in all the buildings remain the same.

There are basically 4 types of models of vertical hexagrids (VH). . The models were named according to the number of storeys required to form an additional hexagrid layer. They are:

- 2-storey Vertical Hexagrid (VH1)
- 4-storey Vertical Hexagrid (VH2)
- 6-storey Vertical Hexagrid (VH3)
- 8-storey Vertical Hexagrid (VH4)

A. Building models

The study basically consists of four models with constant inclined angle. The total no of hexagrid layers are shown in the table .2

Table 1. Hexagrid Pattern descriptions for the frame

Model name	Module size	Angle of inclination of heagrid	No of Hexagrid layers
VH1	2- Storey module	67.38°	30
VH2	4- Storey module		15
VH3	6- Storey module		10
VH4	8- Storey module		8

B. Specification of the building

The building is a commercial G+59 storey commercial space model with symmetric floor plan of 36 x 36 m with storey height of 3.6 m. the brief details of the building is shown in table 2

Table 2. Input parameters for modeling G+59 storey building

Type of building	Commercial building
No of storey	G+59
Height of base storey	3.6 m
Height of storey	3.6 m
Grade of steel	Fe310
Grade of concrete for slab	M30
Live load	3kN/m²
Floor Finish	1 kN/m²
Size of column	1800X1800
Beam	ISLB600
Hexagrid	Circular hollow section of 750mm outer diameter in 75mm inner diameter
Thickness of slab	150 mm
Seismic zone	III

C. Plan of the model

The plan is symmetric in 36 m x 36 m length to width with eight internal steel columns in the middle [6].

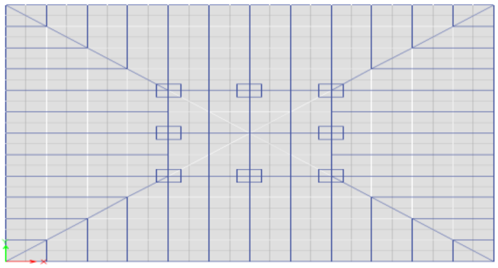
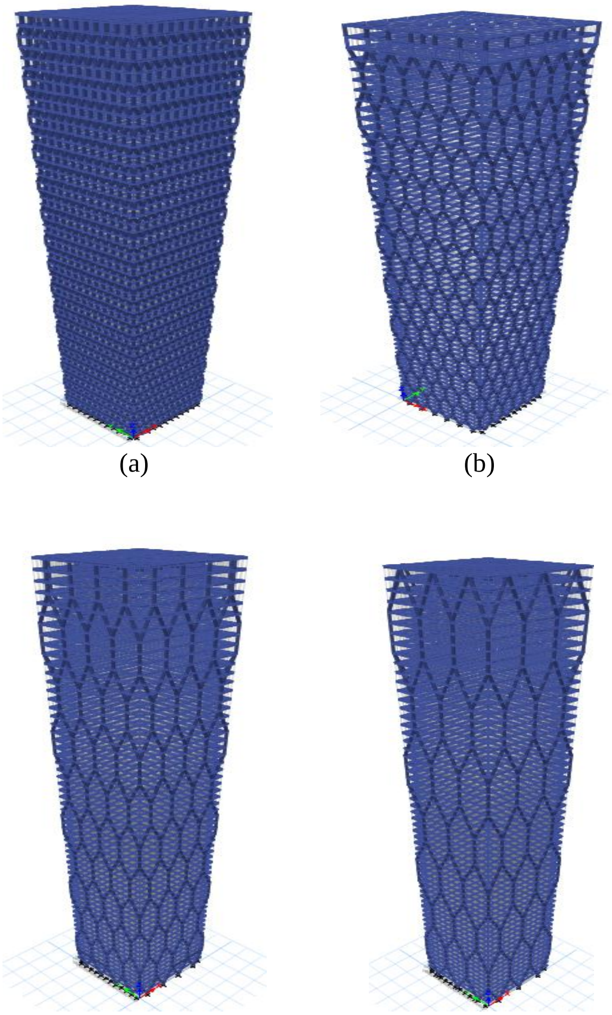


Fig.2. Typical Floor plan

D. 3D rendering view of the model



(a) (b)

(c) (d)

Fig 3. 3d render of the models (a) VH1 model (b) VH2 model ((c(c) VH3 model (d) VH3 model

V. LOADINGS

A. Loadings on the building

1) Dead load
2) Live load
Live load on floor slab = 3 KN/m^2
3) Earthquake load as per IS: 1893 (Part-1), 2016

B. Load combinations

As per IS 800: 2007, the following loads combination are taken under consideration with nine combinations of limit state serviceability and thirteen combinations of limit state of collapse.

VI RESULTS AND DISCUSSIONS

The analysis of the models for the earthquake loadings are done in two methods:
Equivalent static analysis
Non-linear dynamic analysis

A. Equivalent static analysis

The equivalent static analysis is done based on IS:1893 (Part1) 2016

A.1 Maximum roof displacement

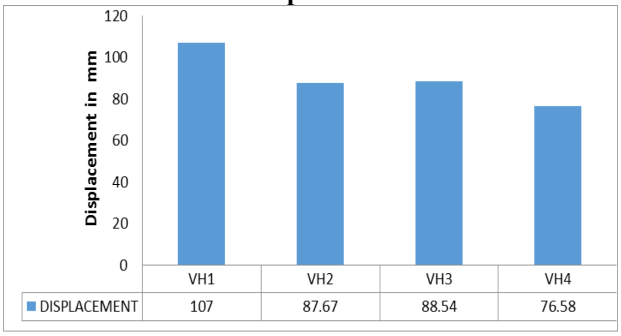


Fig 4. Graph showing maximum displacement in mm

From the figure 4, it shows that the displacement occurred due to lateral force decreases as the size of the module for the hexagrid pattern increases so from the four model 8-storey model (VH4) shows least displacement. As per is 1893 875-111,the maximum allowable displacement H/250 where 'H' is the total height of the building .From the study 216000/500 is 864 mm which is safe.

Table 3: maximum displacement of the four models

Model	Displacement in mm
VH1	107
VH2	87.67
VH3	88.54
VH4	76.58

A.2 Storey drifts

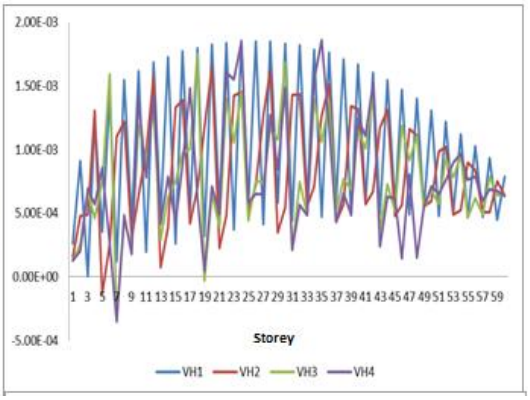


Fig 5. Storey drift of the four models

The figure shows an undulating behavior for the four models. This is because the shear force resisting capacity of each floor largely varies due to the different arrangements of inclined and vertical columns in each storey. The stories with inclined columns can resist more shear forces and undergo less drift than the stories with vertical columns.
The storey drift values decreases as the storey height increases.

A.3 Base shear

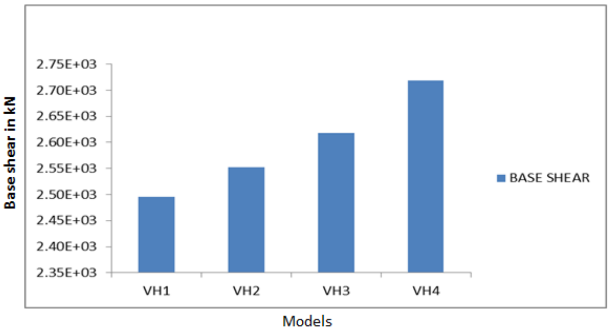
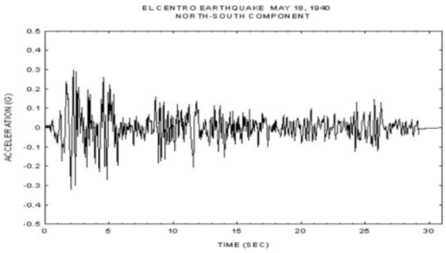


Fig 6. Base shear of the four models

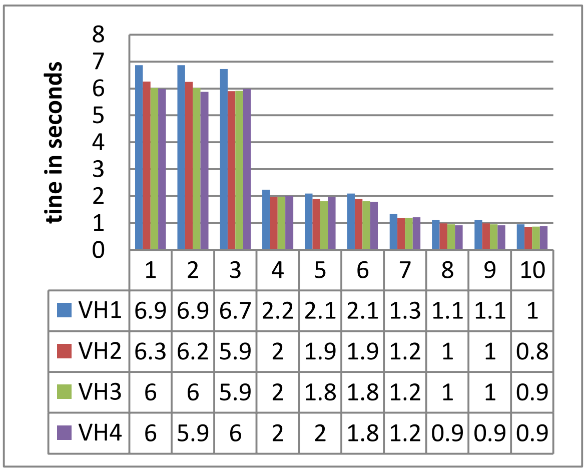
The base shear is maximum for the 4 story model. This shows that stiffness of the 4 story model is maximum among the four models at constant volume.

B. Non-linear dynamic analysis (Time history)

The analysis is done on the data's collected from North-South component El Centro earthquake collected on 1940.



B.1 Time period



	1	2	3	4	5	6	7	8	9	10
VH1	6.9	6.9	6.7	2.2	2.1	2.1	1.3	1.1	1.1	1
VH2	6.3	6.2	5.9	2	1.9	1.9	1.2	1	1	0.8
VH3	6	6	5.9	2	1.8	1.8	1.2	1	1	0.9
VH4	6	5.9	6	2	2	1.8	1.2	0.9	0.9	0.9

Modes of the four models

Fig 7. Time period of the models in various modes

In the non-linear dynamic analysis, the basic and rest of the modes cause the major parts of the response. In this graph it shows that as the size of the module increases, the time period of the building decreases.

B.2 Base shear during dynamic analysis

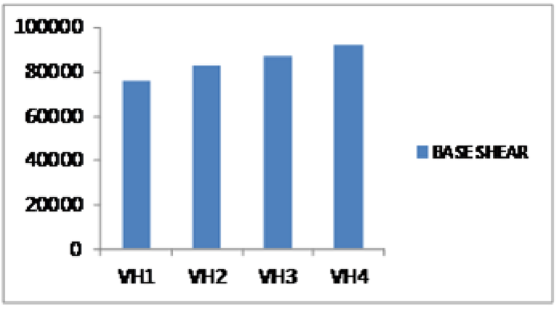


Fig 8. Base shear by weight of the four models

The base shear values increases with increase in size of the module. As acceleration is directly related to base shear, with increase in time period base shear decreases. So we can see that the buildings with higher time period is subjected to less base shear force

B.3 Displacement

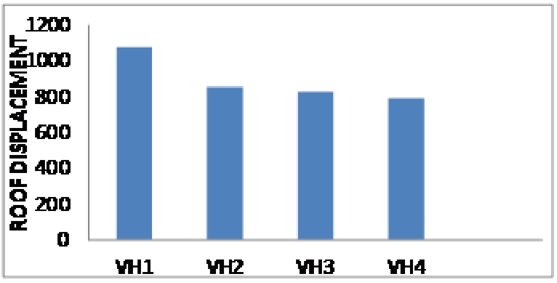


Fig 9. Displacement of the four models in mm

Table 4: Ultimate displacement in time history analysis

Model	Displacement (mm)
VH1	1077
VH2	857.64
VH3	825.23
VH4	790.5

From the figure, it shows that the four models undergo heavy displacement due to El Centro data. 8-storey model shows the least displacement of 790.5 mm among the four models.

VII. CONCLUSION

Based on the results and datas collected from the analysis, the following conclusions can be obtained regarding the performances of the four models.

The G+59 storey building was modeled and analyzed in ETABS 2016 and corresponding behavior was found after equivalent static analysis and time history analysis.

Equivalent static analysis

- As the size of the module increases, the deformation occurred by the vertical hexagrid building is less.
- The storey displacement and storey drift decreases as increase in module size.

Time history analysis

- The displacement values are decreasing with increase in module size. So in both patterns higher module size show better results
- The flexibility is more for 2-storey model (VH1), as the time period increases the building becomes more flexible.
- The time history analysis shows better results and more details on the behaviour. So the non-linear dynamic analysis should be conducted.

So after conducting both the analysis for the models, it is obtained that 8- storey model (VH1) shows the best performance among the four models.

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