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Seismic Behaviour of Hexagrid Type Structural System

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Abstract- **There are a number of high-rise structures constructed all over the world and are being continue to construct. The analysis and design of high-rise structures is quite different from that of low rise structures because of lateral forces due to wind and earthquake. In high-rise structures the resistance to lateral loading becomes dominant criteria that have to be considered in the analysis and design and an efficient lateral load resisting system will define the efficiency of tall structures. In order to improve the efficiency of tube-type structures in tall buildings, a new structural system, called "Hexagrid", is introduced in this study. It consists of multiple hexagonal grids on the facade of the building. In hexagrid structural system almost all the conventional columns are eliminated. The hexagrid resist both gravity & lateral load by the axial action of the diagonal members so, they simply act in tension or compression with no bending, depending upon the direction of the loading. A regular floor plan 36m x 36m and irregular floor plans shaped in the form of C, L and T are considered, all structural members are designed as per IS 456:2000. G+30, G+40 and G+50 storeys models are considered to compare the performance in accordance with height. Earthquake parameters are considered from 1893-2002. Dead & live loads are considered as per Indian Standards. Here, analysis of hexagrid system will be conducted by using analysis & design software, ETABS.**

I. INTRODUCTION

Tall buildings have great potential of creating sustain- able built environments by their own nature. Compared with the cities with low-rise buildings, those with tall buildings use land more efficiently. Early designs of tall buildings recognized the effectiveness of diagonal bracing members in resisting lateral forces. Most of the structural systems deployed for early tall buildings were steel frames with diagonal bracings of various configurations such as X, K, and chevron.

A major point of this design approach is to introduce a new structural system for Tall building. The hexagonal and diamonds were located along the entire exterior perimeter surfaces of the building in order to maximize their structural effectiveness and capitalize on the aesthetic innovation. This strategy is much more effective than confining diagonals to narrower building cores. In the hexagrid structure system, almost all the conventional vertical columns are eliminated. Our approach is to define a unique structural system for Tall building in order to minimize additional system for lateral loads (lateral system). In this system (Beehive), members in hexagrid structural systems can carry gravity loads as well as lateral forces due to their hexagonized configuration in a distributive and uniform manner. Compared with other systems in Tall buildings, hexagrid structures are much more effective in minimizing shear deformation because they carry shear by axial action of the diagonal members, while other structures carry shear by the bending of the vertical columns and horizontal spandrels.

Fig 1. Example of hexagrid structure

II. METHODOLOGY

- Conduct literature review on seismic behaviour of hexagrid structures.
- Modelling of G+30, G+40 and G+50 RC structures with plan irregularities.
- Analysis to be done using ETABS software.
- Time period, top storey displacement, storey drift and base shear parameters are compared.

III. MODELLING OF BUILDINGS

An ideal symmetric structures having the distribution of loads is uniform along each storey and three asymmetric structures were chosen for the study. Asymmetric structures includes C shape, L shape and T shape floor. The buildings under consideration are high rise buildings. All the structure had got the same perimeter for the plot they are compared for their irregular plan. The seismic analysis were carried out as per the code IS 1893: 2002. Zone V and medium soil type are considered for analysis. The analysis of the structural model is done in ETABS 2016.

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G+30, G+40 and G+50 storied RC structures which are symmetric and asymmetric in plan have been considered for the study. The RC design is based on IS-456 (2000). The building is assumed to be situated in Zone V as per IS 1893 (2000). The concrete floors are modelled as rigid. The details of the model is given in the table 1. The structures are assumed to be constructed on medium soil as per IS 1893.

Table 1: Structural details

Plan Dimensions	36m x 36m
Floor to floor height	3m
Depth of slab	120mm
Number of stories	G+30, G+40 and G+50
Floor finish	$1kN/m^2$
Live load	$2kN/m^2$
Characteristics strength of concrete	$30N/mm^2$
Characteristics strength of steel	$415\ N/mm^2$
B1	400mm x 600mm
C1	1650mm x 1650mm
D1	800mm x 800mm
Angle of inclination	45°
Zone factor	0.36
Importance factor	1
Type of soil	Medium
Response reduction factor	5
Damping ratio	5%

a. Variation of height

It contains structures with variation in height. ie, G+30, G+40 and G+50 structures. Fig 2 shows the typical elevations for these structures.

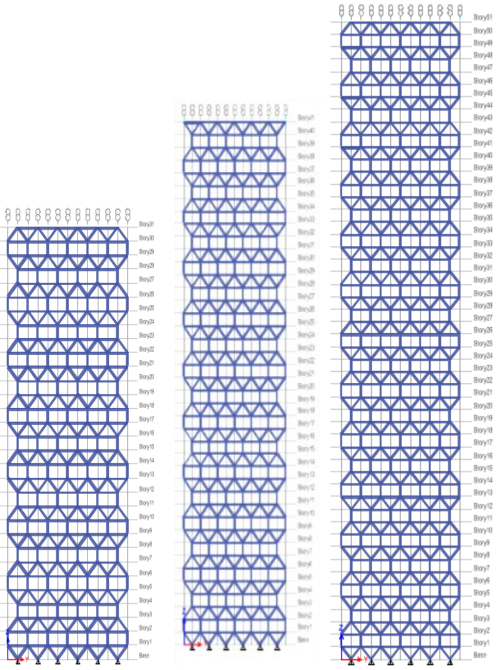


Fig 2. Elevation of building

b. Variation in plan shape

It contains G+30, G+40 and G+50 structures with variation in plan shapes. Different plan shapes are C shape, L shape and T shape. Fig 3 shows the different plan irregularities used for the thesis work.

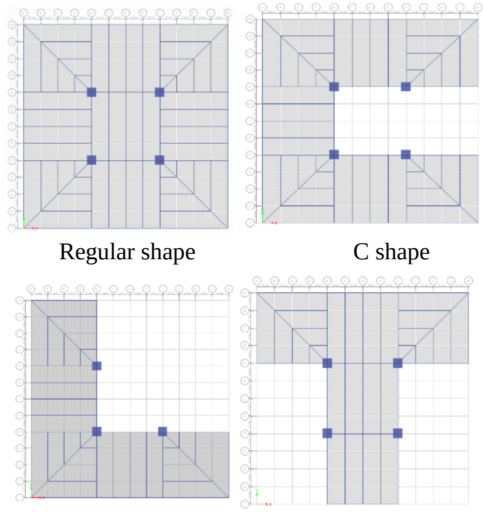


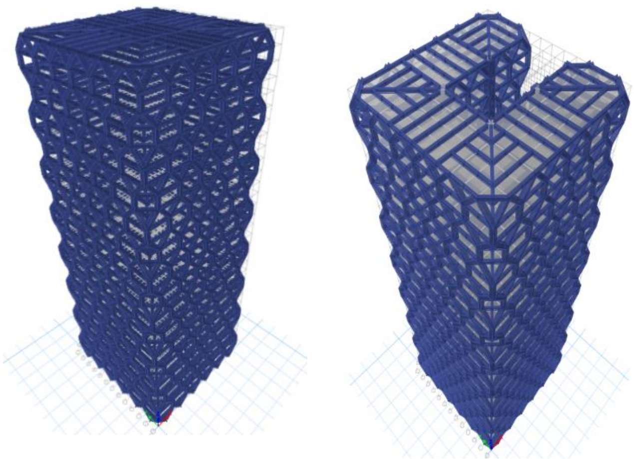
Fig 3. Plan irregularity

a. Model Geometry

In order to differentiate models from each other various abbreviations are used. For example, C30: Model with 30 storey C shaped plan irregularity. Table 3 given below shows the model details of the thesis work. Fig 4 to 6 shows the three dimensional view of models used for the study.

Table 2: Model details

Designation	Details
R30	30 storey regular structure
C30	30 storey C shaped plan irregular structure
L30	30 storey L shaped plan irregular structure
T30	30 storey T shaped plan irregular structure
R40	40 storey regular structure
C40	40 storey C shaped plan irregular structure
L40	40 storey L shaped plan irregular structure
T40	40 storey T shaped plan irregular structure
R50	50 storey regular structure
C50	50 storey C shaped plan irregular structure
L50	50 storey L shaped plan irregular structure
T50	50 storey T shaped plan irregular structure



(a) R30 (b) C30

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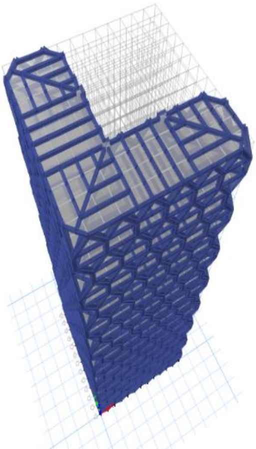
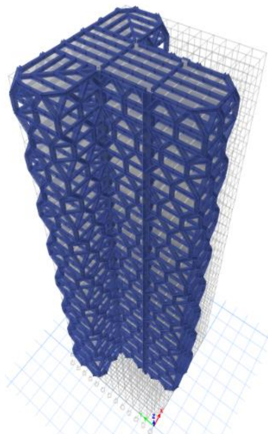


(c) L30



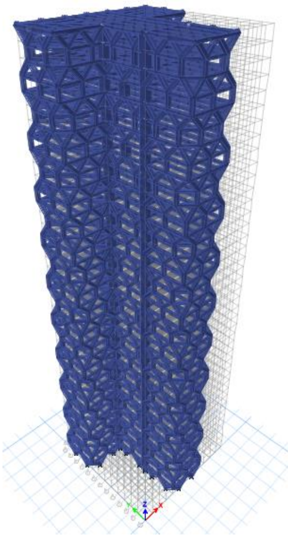
(d) T30

Fig 4. Three dimensional view of 30 storey building

(a) R40

(b) C40

(c) L40



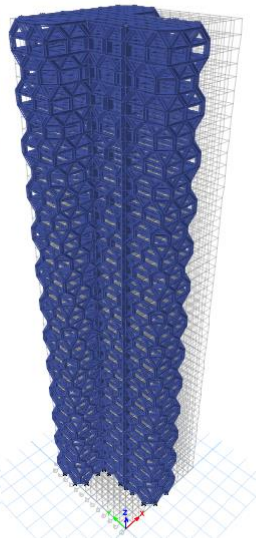
(d) T40

Fig 5. Three dimensional view of 40 storey building

(a) R50

(b) C50

(c) L50



(d) T50

Fig 6. Three dimensional view of 50 storey building

IV. ANALYSIS

In the present study, static and dynamic analysis of the models created are carried out using modeling and analysis software ETABS. Hexagrid structural system consists of Hexagrid perimeter which is made up of a network of multi-story tall hex-angulated truss system. Hexagrid is formed by intersecting the diagonal and horizontal components. This innovation transfers both gravity loads and lateral loads by redirecting member forces, and eliminates the need for vertical columns on the exterior of the building. Architecturally the absence of columns in the corners of the building provides great panoramic views from the interior. Structurally, the degree of an angle between diagonal members consisting of Hexagird nodes is a significant design variable to determine stress distribution resisting internal forces into Hexagrid as well as a building system. In addition, the stress distribution changes depending on the height and span of a given building and the member size like thickness of Diagrid.

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Most of all, connectivity among the hexagrid members linked to member angles is the first considerable element for hexagrid analysis, since investigation of connectivity, i.e., topology provides us with global systematical mechanism. In order to measure hexagrid member analysis and compare the results, in the comparison presented here, diverse pined supports for boundary condition are deposited into a given initial design space. Pined support positions are modeled by initial domain distributions of density which is referred to as design variables. The column-shape, and beam-shape, which depend on initial topologies into design space, i.e., angles of Pined supports. Positions where relatively large stress acts are structurally weak, and therefore material supplement needs to be properly stiffened there. The optimal density assignments are equal to stress distributions.

Stress at the centre node position which is produced by a horizontal load is larger than that by a vertical load. It means that material reinforcement for resisting a horizontal load is more necessary than one for a vertical load. The largest stress acts to the node part in all the angle models, and therefore a node part or a connection of diagonal members is the most significant reinforcement component with respect to structural safety in Hexagrid systems. The Hexagrids are redundant and load path following. It combines the benefits of a hollow tube with those of a truss and its chords. The angled setting of the columnar elements allows for a natural flow of forces through the structure. In this manner, both gravity loads and lateral loads are transferred through the Hexagrid to the ground below. Loads are able to follow the hexagons through the structure as it naturally resists vectors of forces through its hexagonal shapes. Load paths are continuous and uninterrupted. Vertical gravity loads follow the structure of the tube from top to base along the hexagonal members of said tube. The same vertical gravity loads are able to transfer from one columnar element to another in the rare or designed case of an interruption.

V. RESULTS AND DISCUSSIONS

Analysis of a structure provides a comprehensive idea about the overall response history of structure. Here we have done the linear static and dynamic analysis. Maximum story displacement, story shear, drift and time period for modes are obtained. Tables 3, 4 and 5 shows the analysis results of G+30, G+40 and G+50 storey models with plan irregularities.

Displacement comparison of G+30, G+40 and G+50 are shown in Fig 7, 9 and 11. Time Period comparison is shown in Fig 8, 10 and 12.

Table 3: Analysis results of G+30 models

Model	Displacement (mm)	Time-period (sec)	Drift (%)	Base Shear (kN)
R30	59.33	2.289	0.04	8812
C30	47.6	2.333	0.04	10357
L30	58.46	2.237	0.08	5867
T30	64.13	2.209	0.06	5995

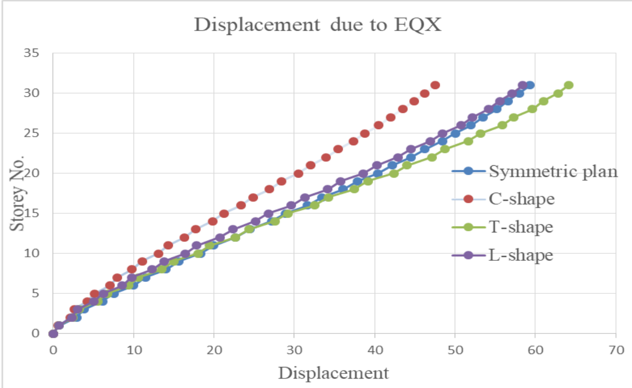

Fig 7. Displacement comparison of G+30

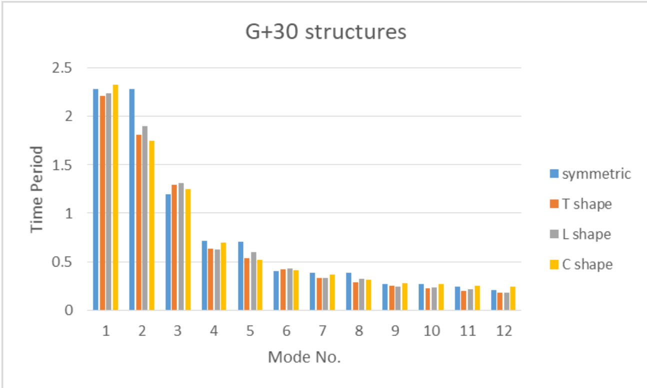

Fig 8. Time Period comparison of G+30

Table 4: Analysis results of G+40 models

Model	Displacement (mm)	Time-period (sec)	Drift (%)	Base Shear (kN)
R40	90.7	3.356	0.06	7965
C40	75.8	3.401	0.06	9001
L40	86.5	3.424	0.1	5076
T40	98.4	3.34	0.08	5265

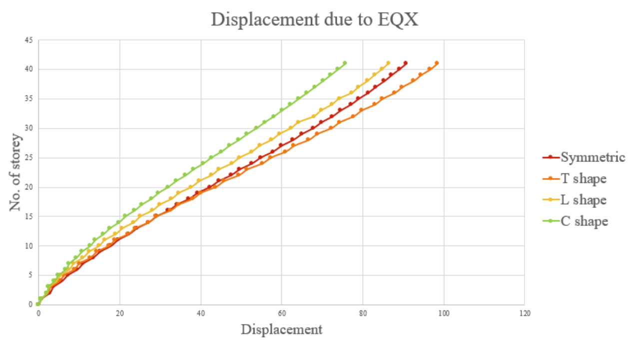

Fig 9. Displacement comparison of G+40

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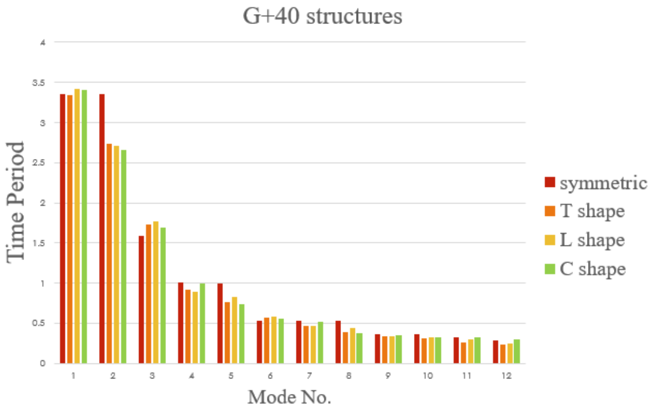

Fig 10. Time Period comparison of G+40

Table 4: Analysis results of G+50 models

Model	Displacement (mm)	Time-period (sec)	Drift (%)	Base Shear (kN)
R40	149	4.63	0.08	8333
C40	111.1	4.635	0.08	7878
L40	161.7	4.93	0.16	5839
T40	163.7	4.69	0.1	5490

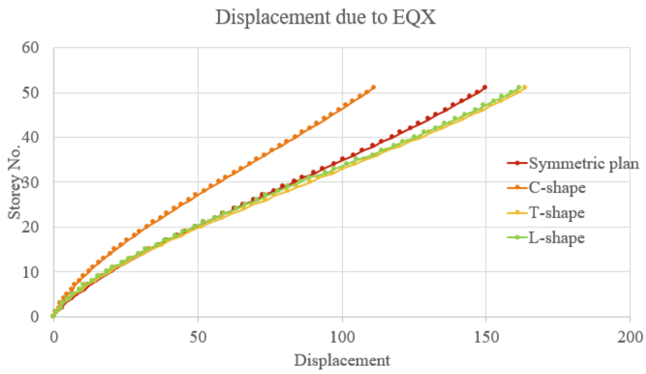

Fig 11. Displacement comparison of G+50

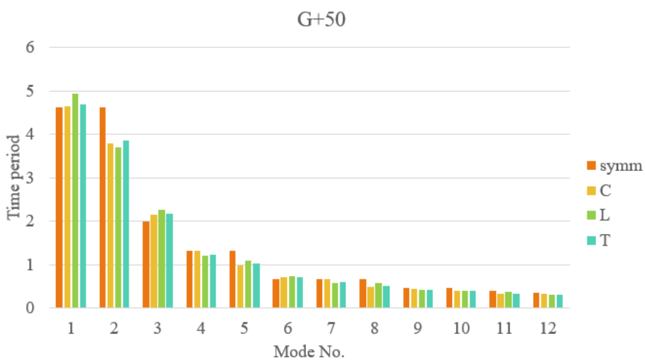

Fig 12. Time Period comparison of G+50

VI. CONCLUSIONS

In the above structural models the linear static and dynamic analysis is performed to investigate the performance point of the building frame in terms of displacement, Time period, Drift ration and Base shear. From the above study following conclusions were drawn.

- Based on plan irregularity, minimum displacement is in the order C < L < Symmetric < T (X-direction) in G+30, G+40 and G+50.
- As the height of building increases displacement also increases (maximum in G+50 model).
- The performance point of T shape and L shape plan irregularity is almost nearer to each other. It maybe due to same plan area.
- Time period increases with increase in height of the building.
- Base shear is minimum for G+40 models except for C shaped model.

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