Comparative Study of Response on Hexagrid and Conventional Structure with Vertical and Stiffness Irregularity

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Abstract— structures are never perfectly irregular and hence the designers and engineers need to evaluate the effect of irregularity on a structure during an earthquake. Structural irregularity may due to non-uniform distribution of mass, stiffness, strength or due to their structural form. This paper quantify and compare the effect of vertical stiffness irregularity of hexagrid and conventional structural system with irregular plan. Hexagrid is an innovative structural system for effective lateral load resistance. The understanding of response of these structural systems is a matter of concern when they are in earthquake prone areas. The comparison is made in terms of storey displacement, storey drift, storey shear and time period.

Key words: Structural Irregularity, Hexagrid Structure, Storey Displacement, Storey Drift, Storey Shear, Time Period

I. Introduction

It is impossible to avoid irregularity in a structure. Non uniform distribution of mass, stiffness, strength or loading leads to structural irregularity. The structural irregularity may also due to their structural form. The presence of irregular frame subject to earthquake and other lateral loads is a matter of concern. A significant difference in storey stiffness, strength, or mass with irregular plan my produce unsafe structures. Vertical stiffness irregularity exists when the lateral stiffness of the seismic force resisting system in a storey is less than 70% of the stiffness of any adjacent storey or less than 80% of the average stiffness of the three stories above or below. In many cases, change in storey stiffness results in a change in strength at the same storey. Modification of member properties, member sizes, material at a storey and vertical discontinuities of structural members cause stiffness and strength irregularities in a structure. It also occurs due to difference in interstorey height. In framed structures, hexagrid structure is a new type of structure which take lateral loads effectively. They are the extension to the diagrid structural system. Hexagrid eliminates outer peripheral columns and the diagonal members carry lateral loads by axial action.

This paper address the effect of vertical stiffness irregularities on hexagrid and conventional structural system due to difference in storey height. The results are compared in terms of storey displacement, drift shear and time period.

II. Structural Modelling

A 48 storey vertically irregular steel frame is considered for hexagrid and conventional structural system with stiffness irregularity. To investigate the effect of structural irregularity, each frame was modelled in two ways- Structure without and with vertical stiffness irregularity. Plan dimensions are 42 m x 42 m up to 24 stories, 30m x 30 m for next 12 stories and 18 m x 18 m for the last 12 stories. Height of each storey is 3.5 m. The height of 10th, 20th, 30th and 40th stories of building frames is chosen as 4 m for getting stiffness irregularity. The slab thickness of all frames is 120 mm. Column is selected as wide steel flange ISWB550. Column spacing is 6 m. Primary beams are ISWB400 and secondary beams are ISLB600. The diagonal member in hexgrid structure is also ISWB550. Angular orientation of diagonal column is in such a way that each hexagrid is connected one storey. The design dead load and live load on floor slab are 3.75 kN/m^2 and 2.5 kN/m^2 respectively.

Interior frame of structures is designed for only the gravity load. The design wind load is computed based on location Thiruvananthapuram, Wind speed 39 m/s, Terrain category 3, Class C, Risk co-efficient 1.06, Topography factor 1 as per IS: 875 (III)-1987. The design earthquake load is computed based on Zone factor 0.16, Soil type I, Importance factor 1, Response reduction factor 5 as per IS 1893-2002. Support condition is chosen as fixed.

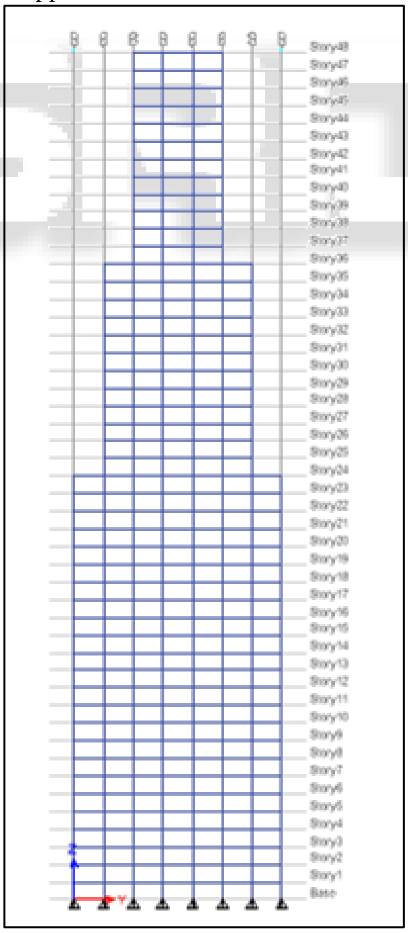

Fig. 1: Elevation of Conventional Building Frame

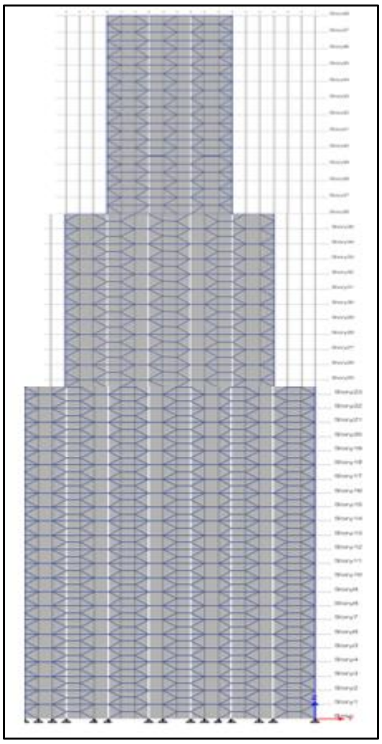

Fig. 2: Elevation of Hexagrid Building Frame

Fig. 1 and Fig. 2 show elevation of conventional and hexagrid building frame respectively.

III. ANALYSIS RESULTS

The analysis results in terms of storey displacement, storey drift, shear and modal time period are shown below.

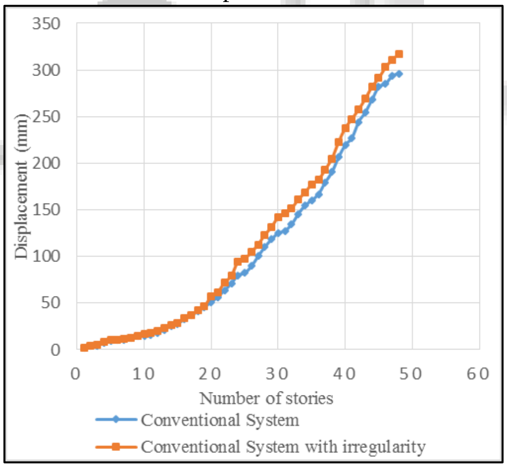

Fig. 3: Comparative displacement for conventional system

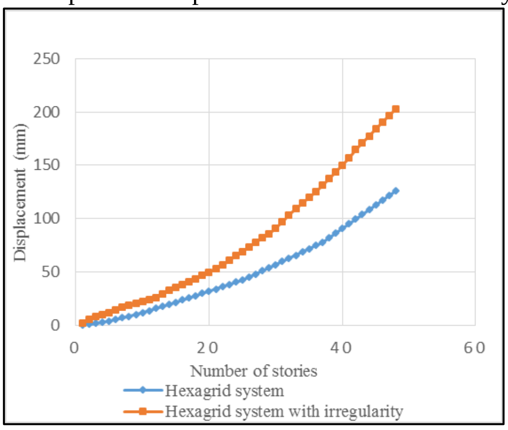

Fig. 4: Comparative displacement for hexagrid system

In Fig. 3 and Fig. 4, the value of storey displacement represent on Y axis and number of stories on X axis. Top storey displacement on conventional structural system without and with stiffness irregularity are 296.31 mm and 317.13 mm respectively. The same for hexagrid structural systems are 126.04 mm and 202.64 mm respectively. It is clear that the change in top storey displacement due to stiffness irregularity is more for hexagrid structure than conventional system.

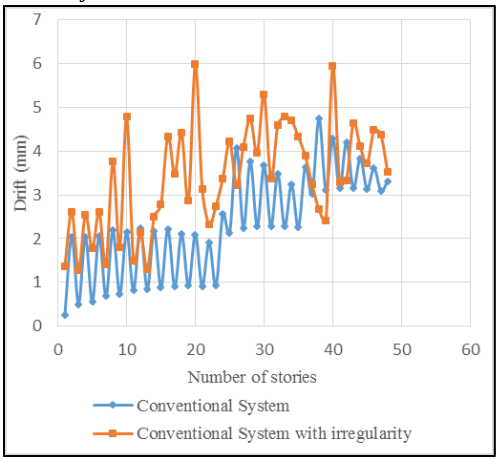

Fig. 5: Storey drift for conventional system

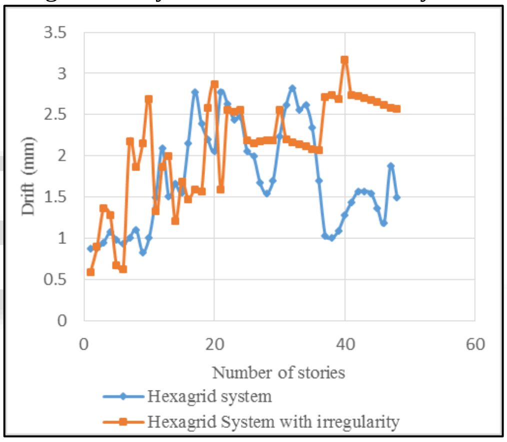

Fig. 6: Storey drift for hexagrid system

Fig. 5 and Fig. 6 show comparative result of drift in conventional and hexagrid system respectively. It is observed that the change in drift due to lateral load in hexagrid and conventional structural system are about same manner. The graphs show a high drift demand in both structure due to irregularity. Thus vertical stiffness and geometrical irregularity is a matter of concern in earthquake prone areas.

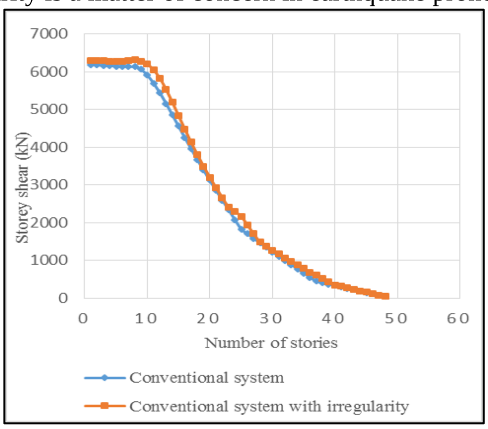

Fig. 7: Storey shear for conventional system

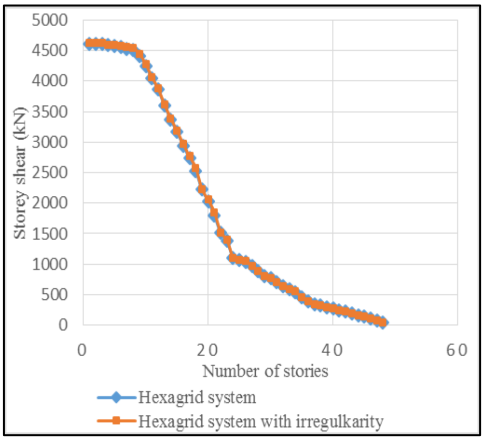

Fig. 8: Storey shear for hexagrid system

In Fig. 7 and Fig. 8, a comparative result of storey shear is presented. Maximum shear force in conventional system and hexagrid structural system does not affected adversely by the stiffness irregularity since there is not much difference in shear force.

Fig. 9 and Fig. 10 Shows comparative modal time period of conventional and diagrid structural system with and without structural irregularity. Number of mode is represented in X axis and Time period is represented in Y axis. From the results, we can observe that both hexagrid and conventional system shows response change due to vertical structural irregularity under lateral loads.

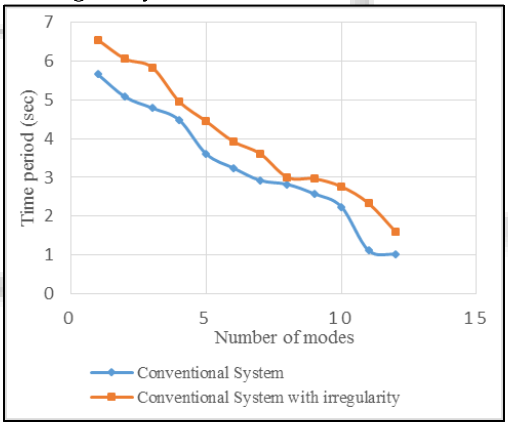

Fig. 9: Modal time period for conventional system

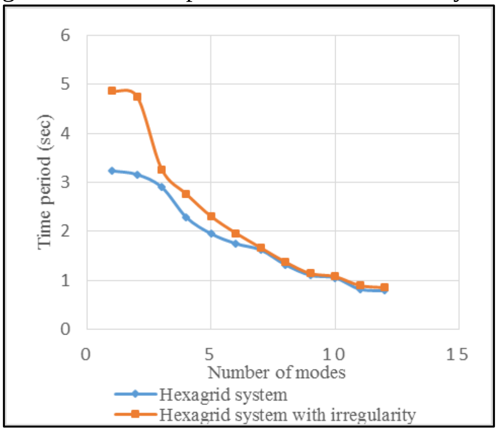

Fig. 10: Modal time period for hexagrid system

IV. Conclusion

The results prove that vertically irregular structures are harmful and the effect of stiffness irregularity on the vertical irregular structure is dangerous in seismic zone. Therefore irregularities in a building must be avoided as far as possible. Complex shaped buildings are getting trend today but they carry a risk of sustaining damages during earthquake. Even though hexagrid structures are efficient in lateral load resistance, they should be free from vertical irregularities while constructing in earthquake prone areas. Such buildings should be designed properly taking care of their dynamic behavior.

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