Effect of Vertical Irregularity on Diagrid Structures Analyzed with Composite Columns and Conventional Columns

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EFFECT OF VERTICAL IRREGULARITY ON DIAGRID STRUCTURES ANALYZED WITH COMPOSITE COLUMNS AND CONVENTIONAL COLUMNS

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Abstract: *An earthquake is a sudden movement of the earth caused by the abrupt release of long-accumulated strain. Plate tectonic forces have shaped the earth for millions of years. Conceptual frameworks and innovative combinations are therefore required to reduce the effect of earthquakes on high-rise structures. Diagrid structural system is a recent advancement in the construction industry that has been widely used for tall buildings due to their structural efficiency and aesthetic potential provided by the system's unique geometric configuration. The diagrid structure employs triangulated grids in place of vertical columns in the periphery. As a result, systems that are more efficient at achieving stiffness against lateral loads are considered better options for tall building design.*

The primary goal of this thesis is to determine the optimum vertical irregular diagrid structure for different vertical irregular ratios according to IS 1893-2016 in terms of storey displacement and then analyze it with composite and conventional columns for seismic and wind conditions for zone 3 using ETABS 2019.1v software according to Indian codes. The seismic behavior of vertical irregular diagrid structures with conventional and composite columns is compared in this paper. A comparative study is conducted based on the results to determine the best performing vertical irregular diagrid structure in terms of seismic and wind activity. It was found that vertical irregular diagrid building with the composite column shows better performance. The parameters compared to determine the best performing vertical diagrid structure are storey displacement, storey drift, and storey shear.

Keywords: *vertical irregularity; diagrid structure; seismic response; storey displacement; storey drift.*

1. INTRODUCTION

An earthquake is a natural occurrence that stimulates a brief shaking or trembling of the earth. It arises as a result of a deep crustal disruption or internal crustal disturbances. Some of the earthquakes that occurred in India had magnitudes ranging from 4.0 to 8.6, resulting in structural destruction, human casualties and injuries. Buildings frequently collapse often during earthquakes due to irregularities in geometry, mass, and stiffness. As a result, vertical irregular tall structures are more vulnerable to earthquakes (Mithulraj M,2019). The structure must be able to withstand all lateral forces resulting from wind and seismic activity. To mitigate the effects of earthquakes on high-rise structures, conceptual frameworks and innovative combinations are required.

The Diagrid structural system is a new significant development in the construction industry that has been often used for tall buildings due to its system's geometrical configuration and structural efficiency and aesthetic potential. In the periphery of the diagrid structure, triangulated grids substitute vertical columns (Lucky Patidar and Lavina Talawale,2020). As a result, technologies that provide stiffness against lateral loads more effectively are regarded preferable solutions for tall structure design.

R.Umamaheshwari. et.al [1]have studied the performance of a conventional structure with diagrid structure under seismic loadings. Diagrid structure performed so well, despite eliminating all the vertical columns in the periphery of the structure and concluded that the diagrid structure is evidently more efficient than conventional structure. Patil Mohana Keshav et.al [2]Have studied the load distribution on columns in diagrid structures. From the study it is observed that most of the lateral load is resisted by diagrid columns on the periphery, while gravity load is resisted by both the internal columns and peripheral diagonal columns. They have concluded that due to increase in lever arm of peripheral diagonal columns, diagrid structural system is more effective in lateral load resistance.

From the literature review it was concluded that

(i) The diagrid structure is evidently more efficient than conventional structure.

(ii) Diagrid structural system provides more flexibility in planning interior space and facade of the building and withstands lateral forces comparatively. (iii)Internal columns need to be designed for vertical load only.

2. METHODOLOGY

According to IS 1893-2016, four tall, vertically irregular diagrid constructions with a total of 22 stories with various vertical irregular ratios have been modelled in Etabs V19.1.0. In all four of the models, the height of each storey is 3 meters. Model 1 has a plan dimension of 25m x 25m from the base to the 12th storey, 21m x 21m from the 13th to the 18th level, and 14m x 14m from the 19th to the 22nd storey. It has an A/L ratio of A >0.25 L. Model 2 has a plan that is 25 m x 25 m from the base to the 12th storey and 14 m x 14 m from the 13th to the 22nd level, with L2 > 0.25 L1. Model 3 has an A > 0.1 L, a plan dimension of 22.5 m x 22.5 m for the 13th to 18th storey, and 21 m x 21 m for the base to 12th storey, 22.5m *22.5m for 13^{th} to 18^{th} storey, 24m * 24m for 19^{th} to 22^{nd} storey.

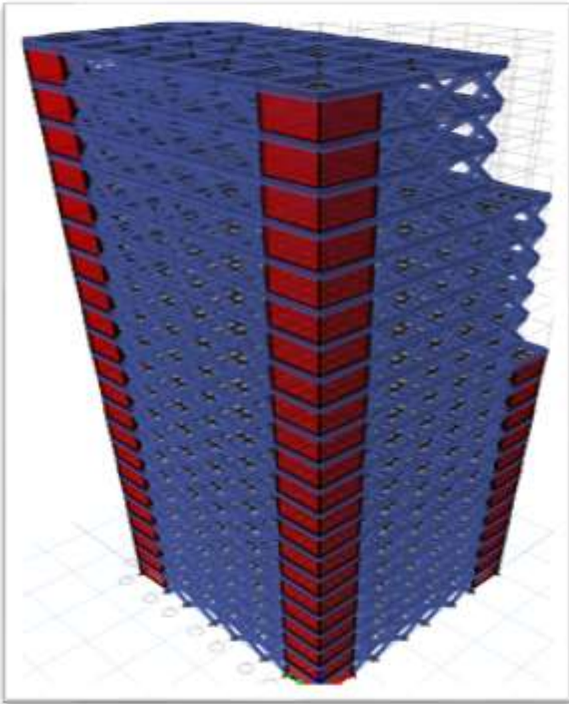

Fig 2.1 **3 d view of the model 1: A >0.25 L**

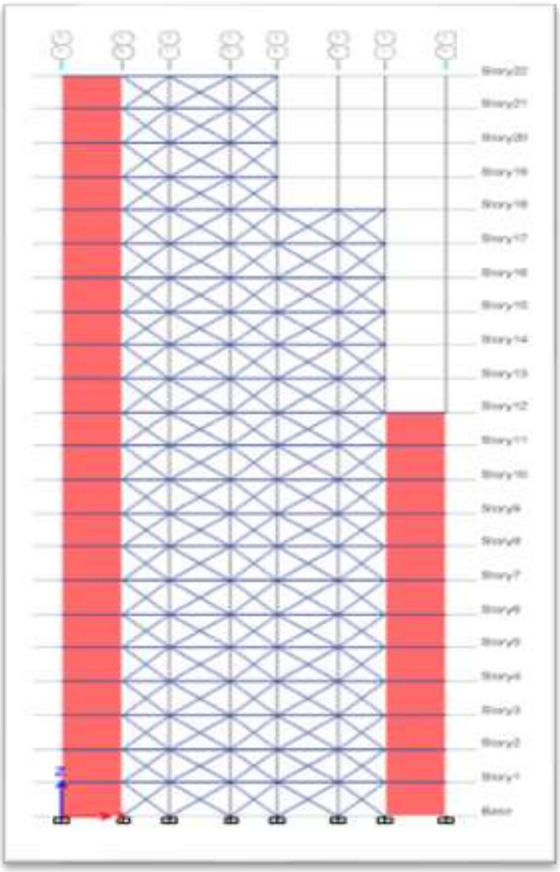

Fig 2.2**: Elevation of the model 1: A >0.25 L**

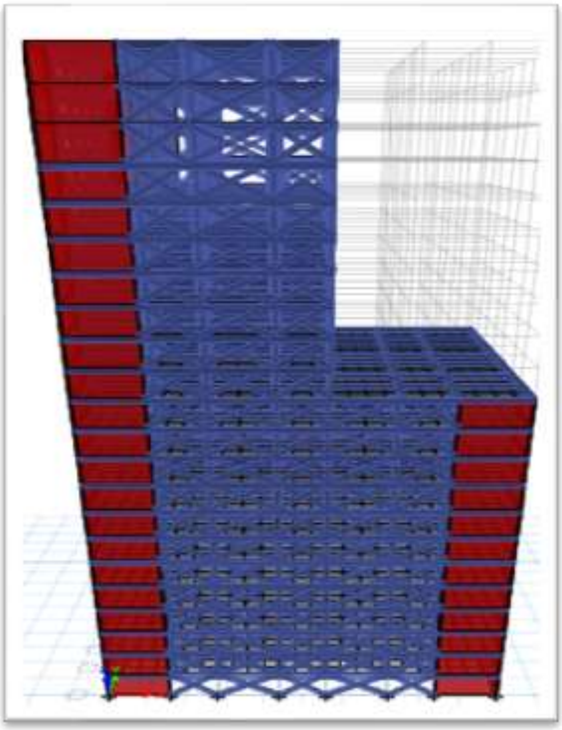

Fig 2.3 **3d view of the model 2: L2 > 0.25 L1**

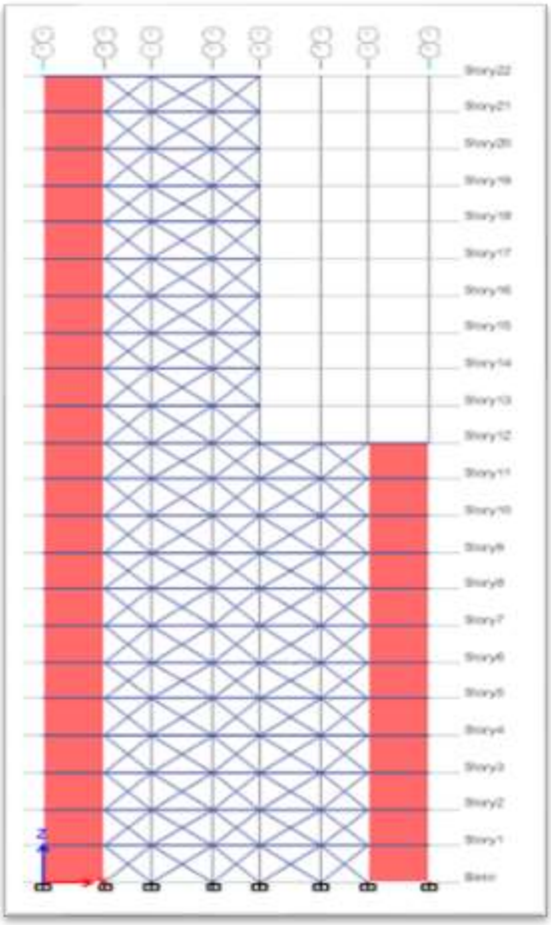

Fig 2.4 **Elevation of the model 2**

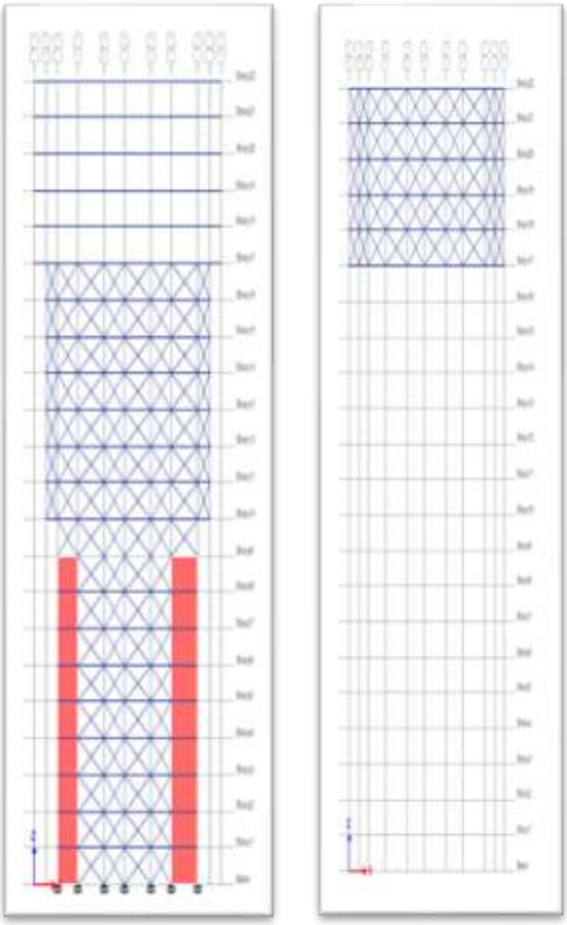

Fig 2.6 **Elevation of model 3**

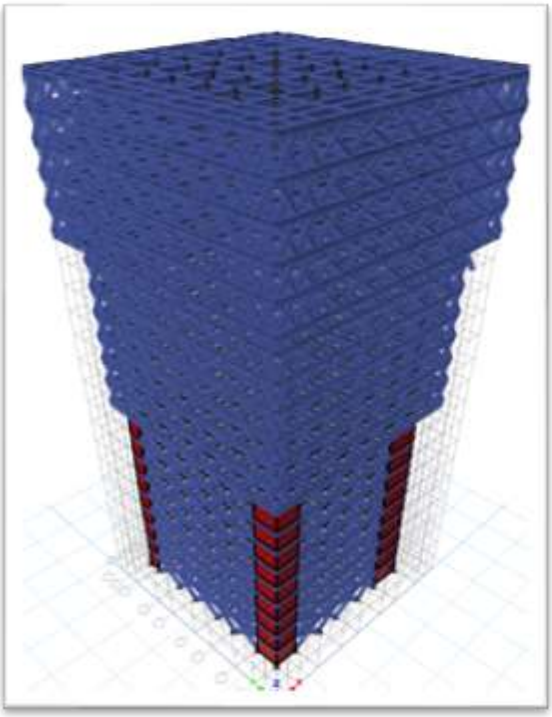

Fig 2.5 **3d view of the model 3: A >0.1 L**

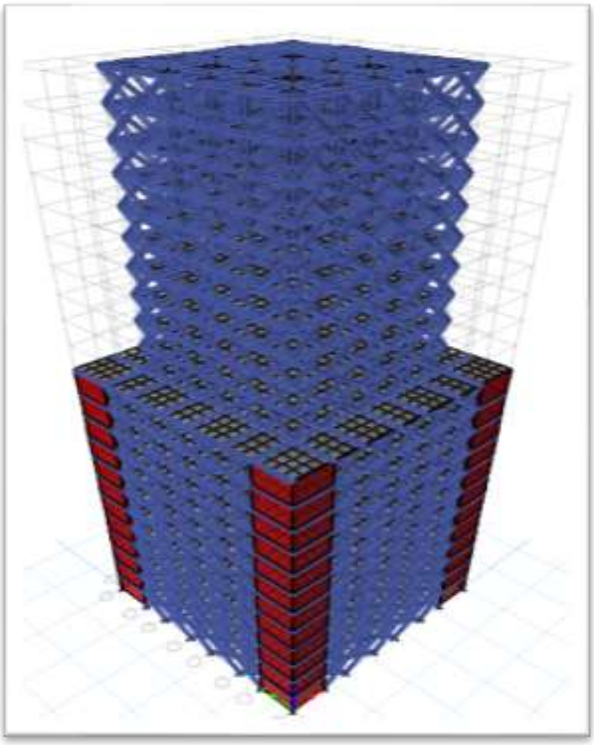

Fig 2.7 **3d view of the model 4: A >0.125L**

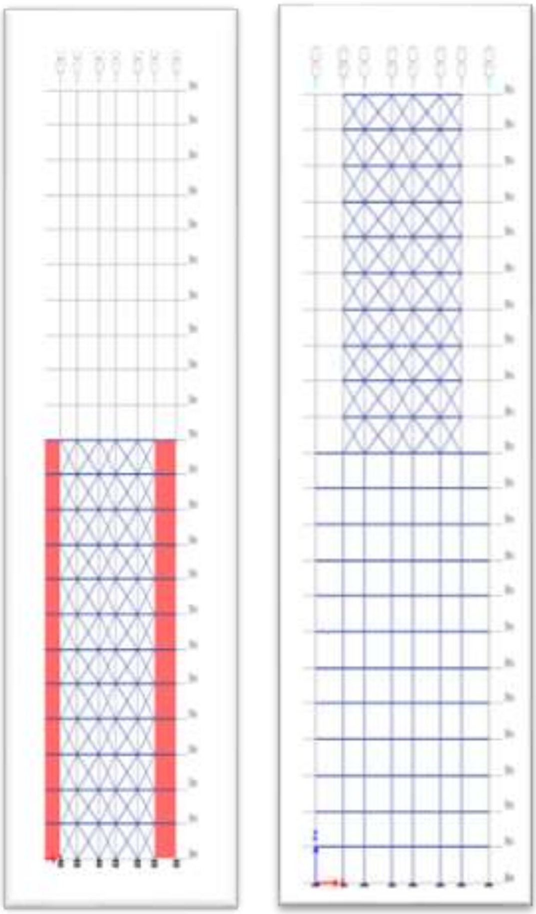

Fig 2.8 **Elevations for model 4**

In order to analyse the model, response spectrum analysis is used, and wind characteristics are taken into account because the building is taller than 10 metres. For analysis, seismic zone III is taken into consideration, and a 39 m/s wind speed is used. For the examination of all the model's medium soil with a damping ratio of 0.05 and importance factor 1 and response reduction factor of 5 are taken into consideration. Based on the findings, comparison research is done to determine which vertical irregular diagrid construction performs the best in terms of seismic behaviour. To identify the best performing vertical diagrid system, three metrics are looked at: storey displacement, storey drift, and storey shear.

2.1 Parametric study of vertical irregular diagrid structure with different vertical irregular ratio

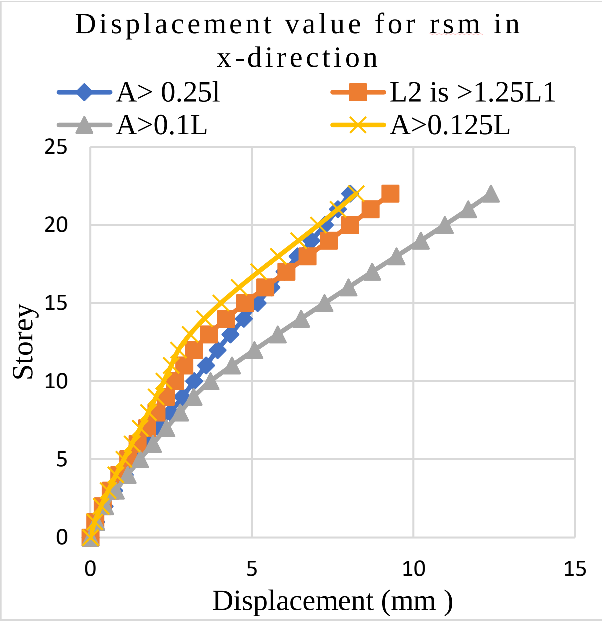

Fig 2.1.1 **Storey displacement value for rsm in x-direction**

The above graph 2.1.1 briefs the storey displacement for response spectrum method in x direction for different vertical irregular diagrid building.

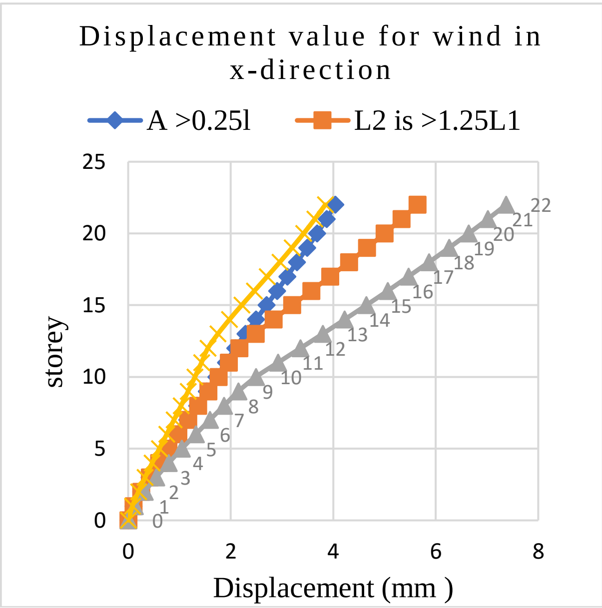

Fig 2.1.2 **Storey displacement value for wind in x-direction**

The above graph 2.1.2 briefs the Storey displacement for wind in x direction for different vertical irregular diagrid building.

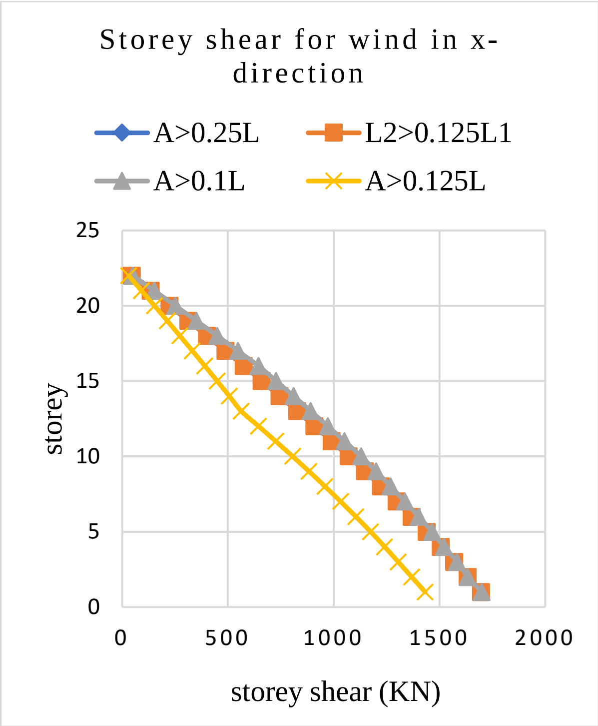

Fig 2.1.3 **Storey shear for wind in x-direction**

The above graph 2.1.3 briefs the Storey shear for wind in x direction for different vertical irregular diagrid building

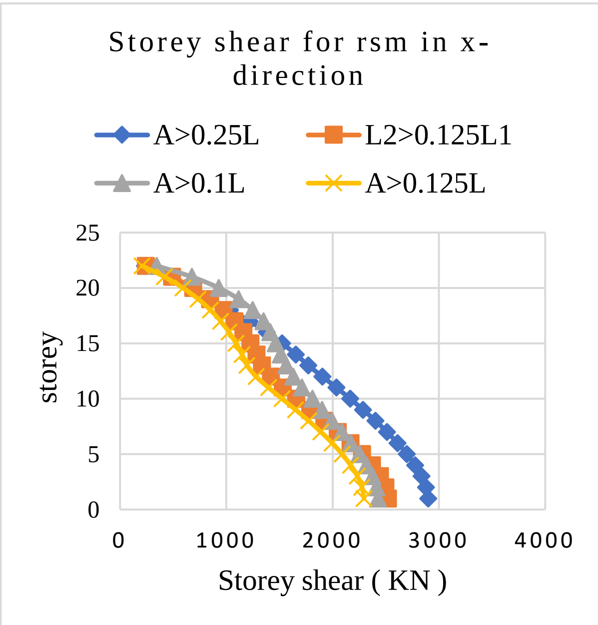

Fig 2.1.4 **Storey shear for rsm in x-direction**

The above graph 2.1.4 briefs the storey shear for rsm in x direction for different vertical irregular diagrid building.

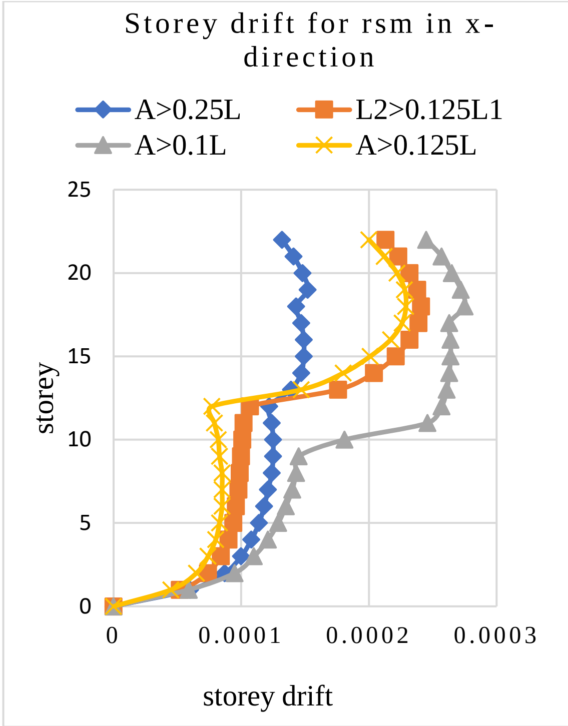

Fig 2.1.5 **Storey drift for rsm in x-direction**

The above graph 2.1.5 briefs the storey drift for rsm in x direction for different vertical irregular diagrid building

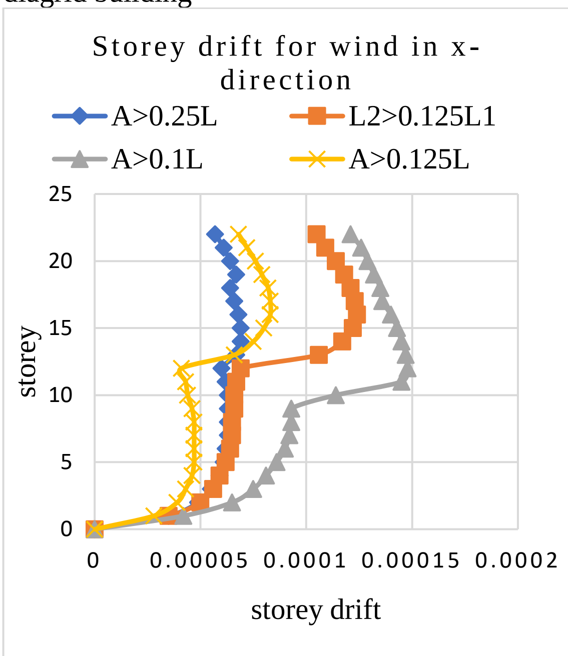

Fig 2.1.6 **Storey drift for wind in x-direction**

The above graph 2.1.6 briefs the storey drift for wind in x direction for different vertical irregular diagrid building. From the graph of different vertical irregular ratios of diagrid buildings having composite columns are being compared for wind in x direction.

- A >0.25 L is having lesser storey drift at the top storey.
- Vertical irregular building having ratio of A >0.125 L is found to be having lesser displacement comparatively.
- A > 0.25 L is having lesser displacement at the top storey.
- Maximum displacement at top storey is found at A >0.1L.
- Vertical irregular building having ratio of A >0.125 L is found to be having lesser storey shear comparatively.
- A >0.125 L is having lesser storey shear at the bottom storey.
- Maximum storey shear at bottom storey is found at A > 0.25L
- Considering all the results, A >0.125L is the optimum vertical irregular ratio for vertical irregular diagrid building.

2.2 Parametric study of the vertical irregular diagrid structure analysed with composite columns and conventional column

Table 1: Details of the building

Structure	OMRF
Number of stories	G+21
Type of building	Regular and Asymmetrical in plan
Height of the building	66 m
Storey height	Bottom Story: 3 m Typical story: 3 m
Support	Fixed
Seismic zones	3
Importance factor	1
Reduction factor	5
Soil type	medium
Damping ratio	0.05
Live load	3KN
Floor load	1.5KN
Parapet load	1KN

Composite column size 600mm * 600mm, conventional column size 600mm * 600mm, steel I section width of flange 250mm, thickness of flange 25mm, depth 450mm, depth of web 13mm, thickness of slab 125mm, thickness of shear wall 200mm, size of diagrid 300 mm * 300 mm, size of beam 300 mm * 600 mm, grade of concrete M30, grade of steel Fe 345, spacing of grids in x direction 4m, 3m alternatively.

Model 1 Vertical irregular diagrid structure with composite column

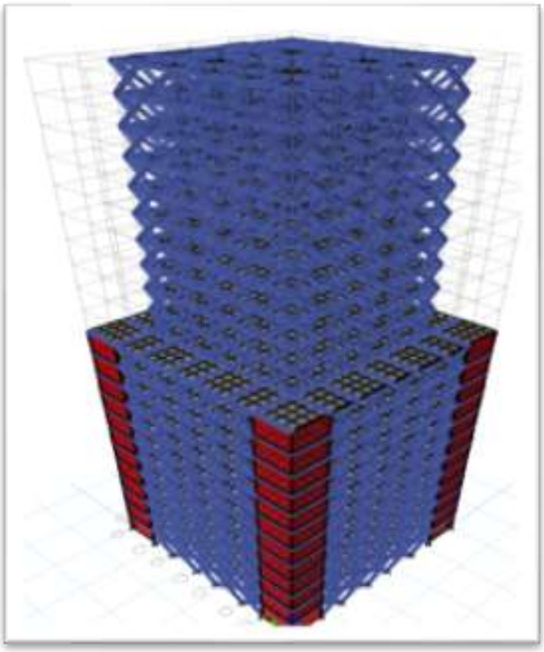

Fig 2.2.1 **Model 1 Vertical irregular diagrid structure with composite column.**

Model 2 Vertical irregular diagrid structure with conventional column.

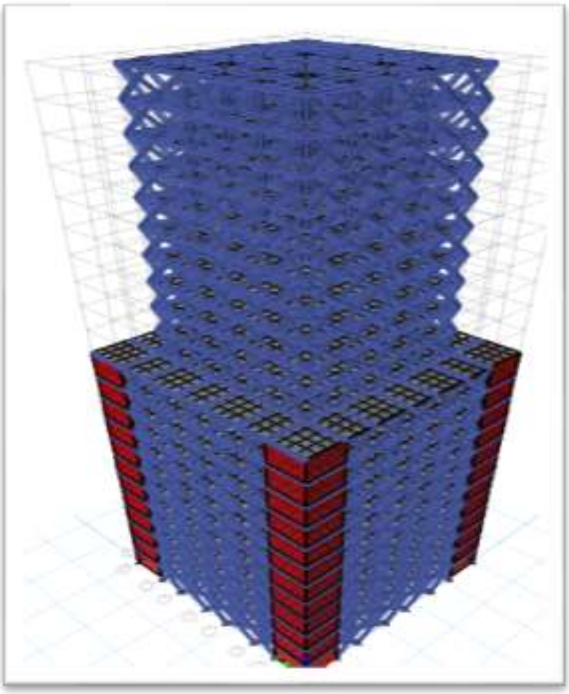

Fig 2.2.2 **Model 2 Vertical irregular diagrid structure with conventional column**

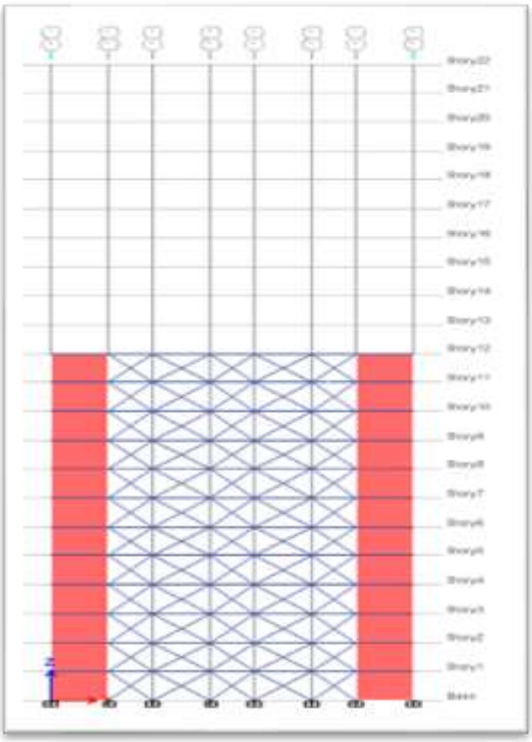

Fig 2.2.3 **Elevation -G**

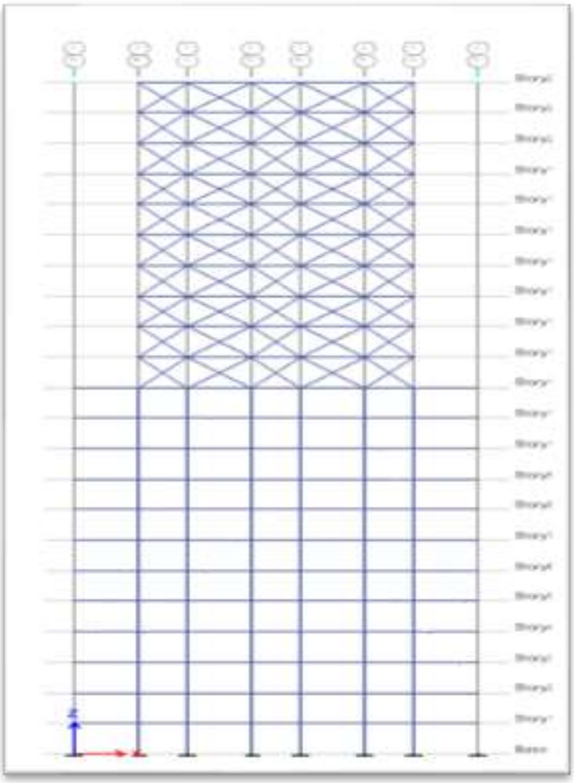

Fig 2.2.4 **Elevation -2**

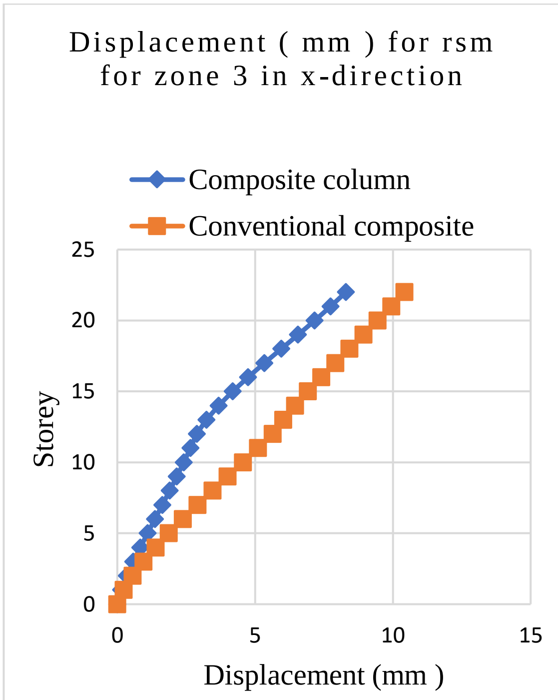

Fig 2.2.4 **Vertical irregular diagrid structure with composite column**

The above graphs 2.2.4 brief the Storey displacement for response spectrum method in x direction for different vertical irregular diagrid building

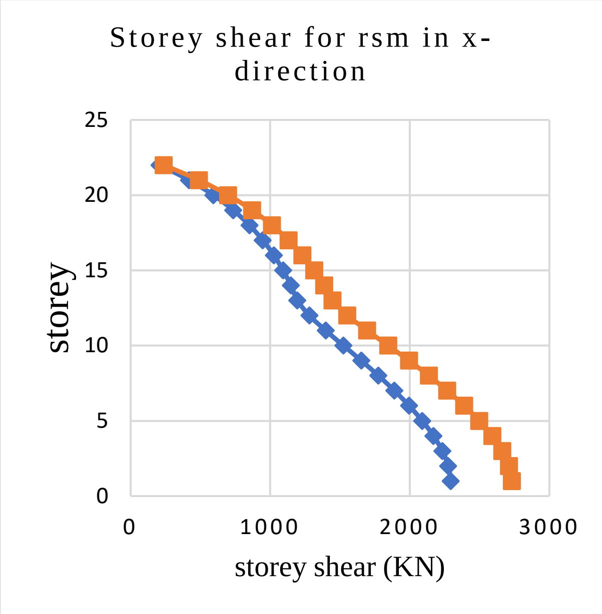

Fig 2.2.5 **Storey shear for rsm in x-direction**

The above graph 2.2.5 briefs the Storey shear for rsm in x direction for different vertical irregular diagrid building having composite and conventional column.

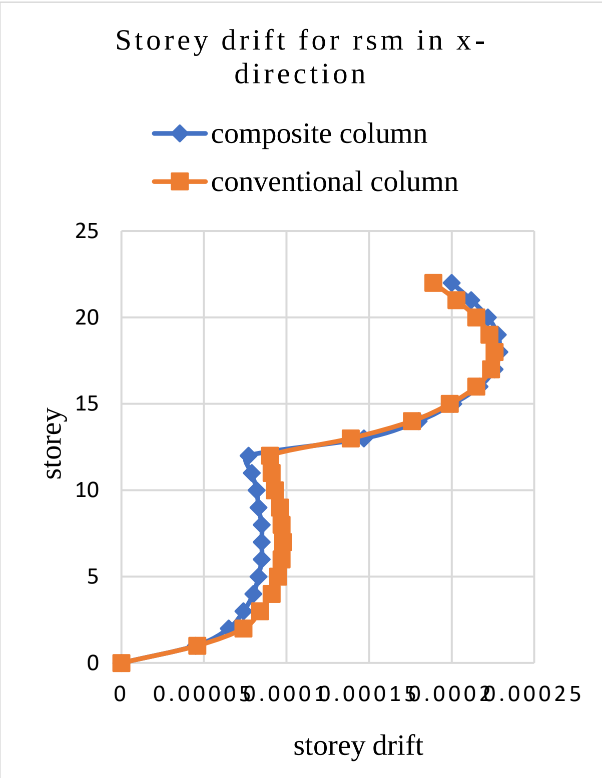

Fig 2.2.6 **Storey drift for rsm in x-direction**

The above graphs 2.2.6 brief the Storey drift for response spectrum method in x direction for different vertical irregular diagrid building having composite and conventional column.

3. Results and Discussions.

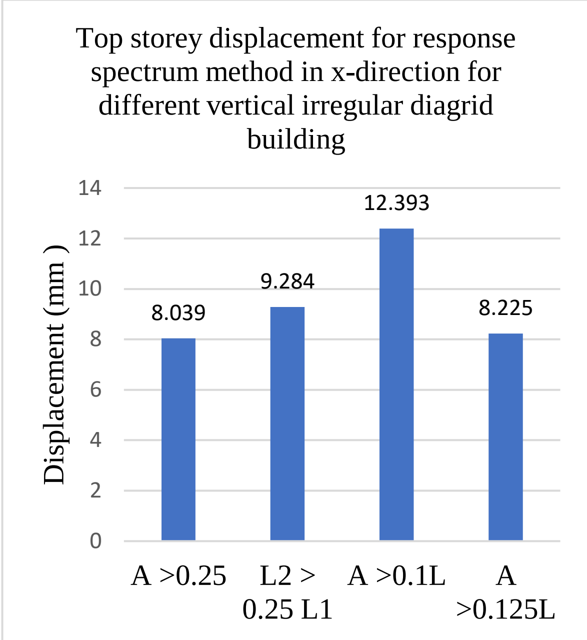

Fig 3.1 **Storey displacement value for rsm in x- direction**

Above fig 3.1 briefs top storey displacement for response spectrum method in x direction for different vertical irregular diagrid building.

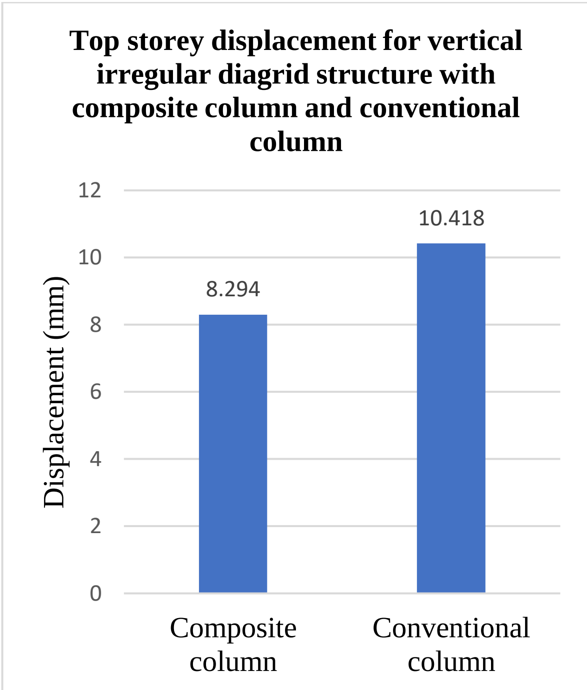

Fig 3.2 **Storey displacement value for wind in x -direction**

Above fig 3.2 briefs top storey displacement for vertical irregular diagrid structure with composite column and conventional column for rsm in x direction.

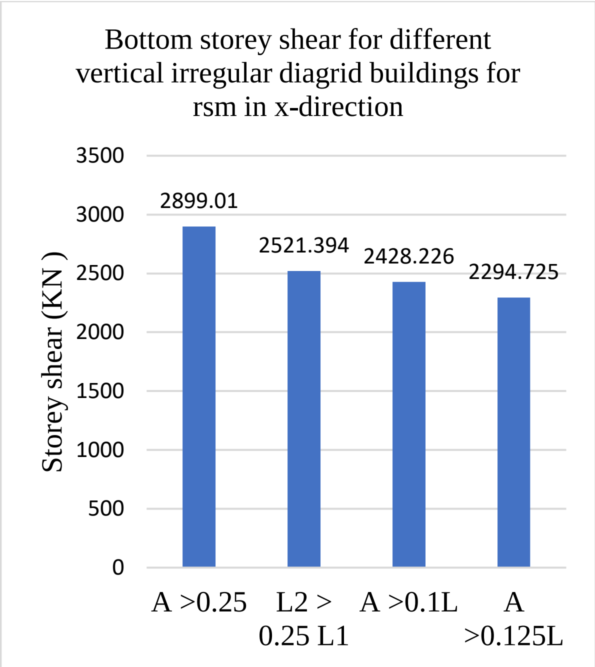

Fig 3.3 **Storey shear for rsm in x-direction**

Above fig 3.3 briefs storey shear for different vertical irregular diagrid buildings for rsm in x direction

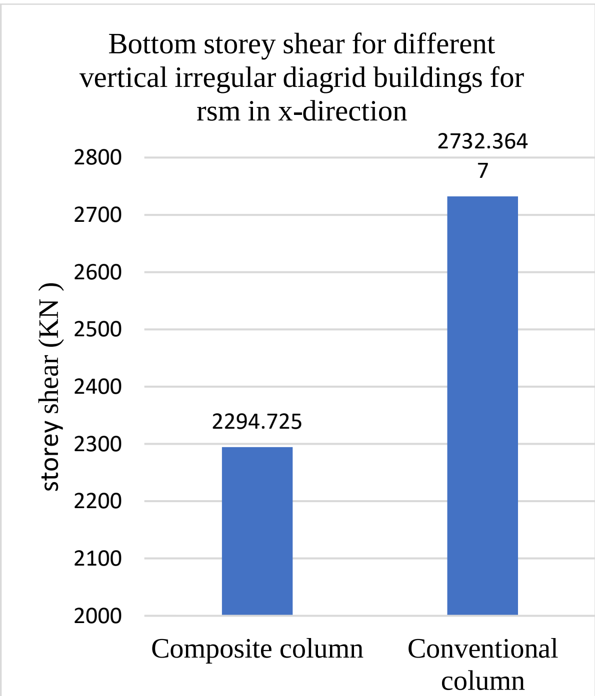

Fig 3.4 **Storey shear for rsm in x-direction**

Above fig 3.4 briefs storey shear for different vertical irregular diagrid buildings having composite column and conventional column.

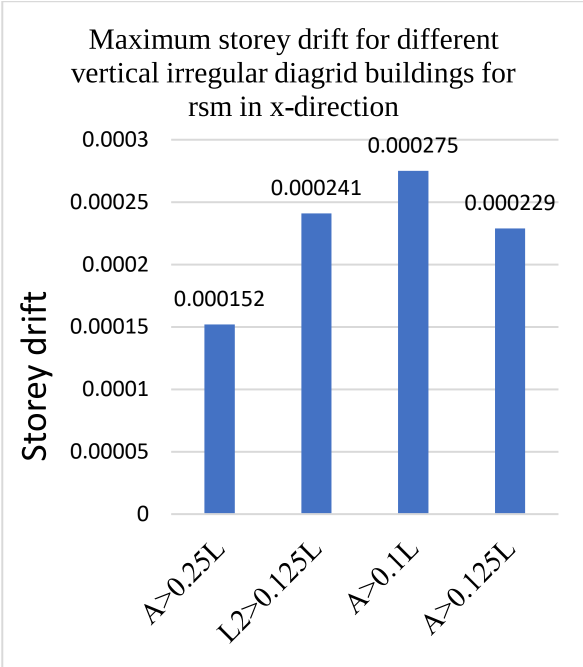

Fig 3.5 **Storey drift for rsm in x-direction**

Above fig 3.5 storey drift for different vertical irregular diagrid buildings for rsm in x direction

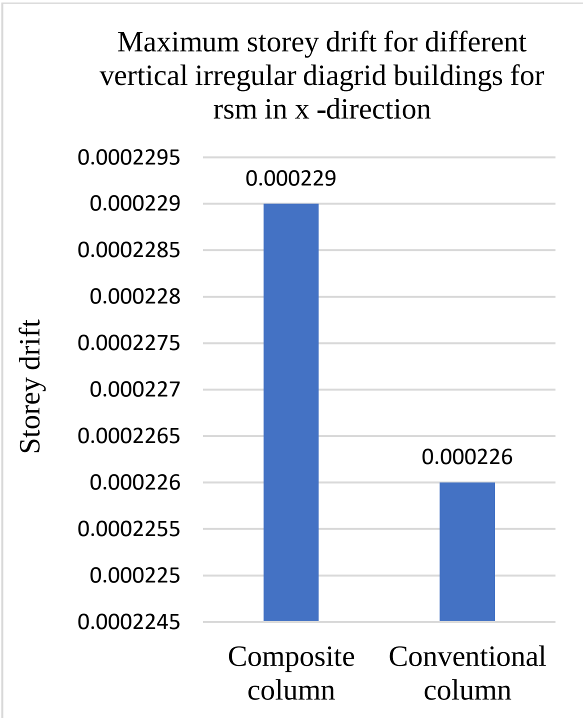

Fig 3.6 **Storey drift for rsm in x-direction**

Above fig 3.6 briefs storey shear for different vertical irregular diagrid buildings having composite column and conventional column.

- Comparing all the parameters from the result obtained from the analysis, it is found that A >0.25 L vertical irregular ratio is found to be the optimum ratio for vertical irregular diagrid structure among all the different ratios considered for the study.
- Vertical irregular diagrid structure with composite column is having lesser displacement and storey shear compared to the vertical irregular structure with conventional column.

4. Conclusion

- A >0.25L is found to be the optimum vertical irregular ratio for the modelled structure.
- Vertical irregular diagrid structure with composite column is having lesser displacement and storey shear compared to the vertical irregular structure with conventional column.
- Maximum allowable storey displacement is L/250.
- Vertical irregular diagrid structure with composite column is having lesser displacement comparatively.
- The percentage of variation between minimum and maximum displacement at the top storey is 20.38%.
- Vertical irregular diagrid building with the composite column is having maximum storey drift.
- The percentage of variation between maximum drift for the composite and conventional column is 1.31%.
- Vertical irregular diagrid building with composite column is having lesser storey shear.
- The percentage of variation between maximum and minimum displacement at the bottom storey is 16.01%.
- Vertical irregular building having ratio of A >0.125 L is found to be having lesser displacement comparatively.
- A >0.125 L is having lesser displacement at the top storey.
- Maximum displacement at top storey is found at A >0.1L.
- The percentage of variation between maximum and minimum displacement for different vertical irregular diagrid building is 47.84%.

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