

Dynamic Analysis of Tall Buildings Using Diagrid Structural Systems for Seismic and Wind Resistance

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Abstract- Rapid urbanization and increasing land scarcity have led to the development of high-rise structures, where lateral load resistance becomes a governing design criterion. The diagrid structural system has emerged as an efficient alternative due to its superior stiffness, reduced material usage, and architectural flexibility. This study investigates the structural behaviour of 48-storey steel diagrid buildings with three plan configurations plus (+), rectangular, and L-shape located in Seismic Zone III. The analysis includes linear static, response spectrum, and wind load analysis using ETABS software. Parameters such as storey displacement, storey drift, and storey shear are evaluated for different diagrid module configurations (2, 4, 6, and 8 storeys). The study aims to determine the optimum diagrid angle for improved structural performance. Results indicate that diagrid systems significantly reduce displacement and drift compared to conventional systems, with optimal performance observed within a specific range of diagrid angles.

Key Words: - Diagrid Structure, High-Rise Buildings, Seismic Analysis, Storey Drift, ETABS, Structural Optimization

I. INTRODUCTION

The rapid increase in population and land cost has necessitated vertical construction. As building height increases, lateral loads such as wind and seismic forces dominate structural design. Conventional systems like rigid frames and shear walls are increasingly being supplemented by advanced systems such as diagrids.

A diagrid system consists of a network of diagonal members forming a triangulated configuration. Unlike conventional framed structures, diagrids eliminate vertical perimeter columns and transfer

both gravity and lateral loads through axial forces in diagonal members. This results in improved structural efficiency, reduced material consumption, and enhanced architectural aesthetics.

II. OBJECTIVE OF THE STUDY: -

- To evaluate the response of high rise building with diagrid system.
- To understand the behavior of rectangular, plus (+) and L- shape of diagrid structure by locating same height of building in seismic zone III.
- To carry out static analysis, response spectrum analysis and wind analysis in term of story displacement and story drift.
- To analyze the structure by keeping constant height and changing the diagrid angle
- To find optimum diagrid angle of diagrid system in seismic zone III by considering all aspects.

III. Review of previous studies:

H. U. Lee and Y. C. Kim (2019) introduced the hexagrid system and proposed stiffness-based preliminary design methods for tall buildings.

Sawan Rathore and Sumit Pahwa (2019) carried out comparative studies and identified optimum diagrid inclination based on performance criteria.

Akshat and Gurpreet Singh (2018) used response spectrum analysis and observed reduced storey displacement and drift in diagrid structures.

Trupti A. Kinjawadekar and Amit C. Kinjawadekar (2018) performed dynamic analysis and confirmed

improved seismic performance of diagrid systems over conventional frames.

Dr. Gopisiddappa et al. (2017) concluded that diagrid angles between 63° and 75° provide optimal stiffness and reduced displacement.

T. Bhuiyan (2016) optimized member sizes considering both wind and seismic loads, highlighting the importance of stiffness-based design criteria.

Manthan I. Shah et al. (2016) compared conventional and diagrid systems, concluding that diagrid structures provide better performance with relatively lower steel consumption.

Femy Mariya Thomas et al. (2015) focused on determining the optimal diagrid angle and found that different module configurations significantly affect displacement and drift behavior.

Giulia Milana et al. (2014) conducted nonlinear finite element analysis and evaluated the effect of diagrid inclination angles on structural weight and performance.

K. Jani and P. V. Patel (2013) analyzed high-rise steel diagrid buildings using ETABS and observed that lateral loads are primarily resisted by perimeter diagrid members, while gravity loads are shared with internal columns.

K. S. Moon (2011) further investigated diagrid systems in complex geometries and concluded that geometric configuration significantly influences structural efficiency and design optimization.

Barry Charnish (2008) studied the structural design of the 69-storey Bow Tower, demonstrating the effectiveness of perimeter diagrid systems in reducing energy consumption and enhancing structural performance.

M. M. Ali and K. Moon (2007) highlighted the structural efficiency and constructability challenges of diagrid systems in complex-shaped tall buildings such as twisted and freeform towers. Their work

emphasized the need for multidisciplinary approaches for advanced structural forms.

IV. MODELING & ANALYSIS: -

The present study investigates the structural behavior of 48-storey high-rise buildings with diagrid systems for plus (+), rectangular, and L-shaped configurations. The analysis compares parameters such as storey shear, storey displacement, and storey drift under seismic loading in Zone III. The study also aims to determine the optimum diagrid angle for 2-storey, 4-storey, 6-storey, and 8-storey module configurations.

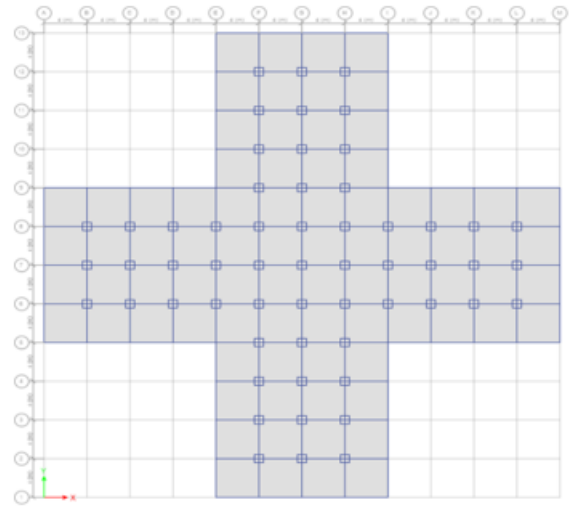


Figure: Plan of Plus (+) shape building model Above Figure shows the typical plan of Plus (+) shape building models which are considered for the study Number of bays in X and Y directions are 12 as shown in figure and spacing between each bay is 4 meters.

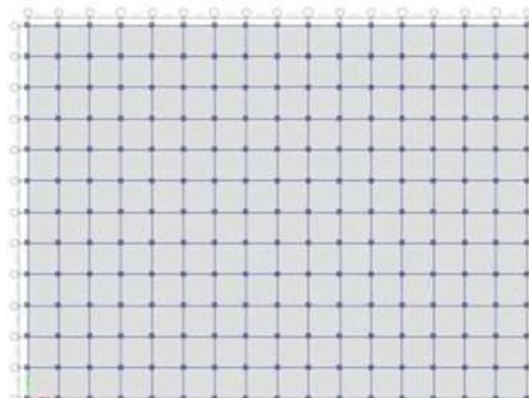


Figure: Plan of rectangular shape building model the typical plan of rectangular shape building models which are considered for the study as shown in figure and spacing between each bay is 4 meters.

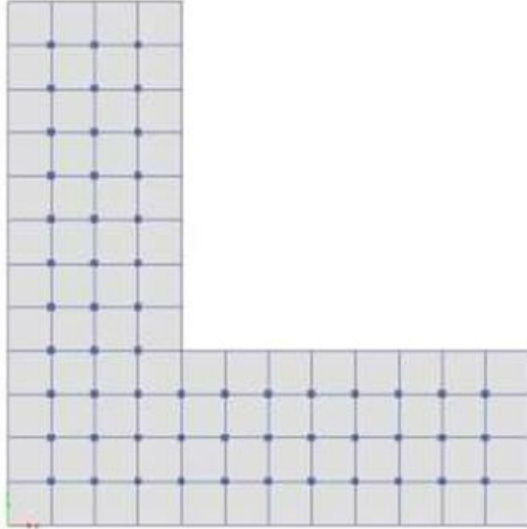


Figure: Plan of L shape building model the typical plan of L shape building models which are considered for the study as shown in figure and spacing between each bay is 4 meters. building is subjected to following Loads as per IS 875 (part 1 and 2)-2015: Dead load: 2 kN/m², Live Load: 3 kN/m²

The following table shows that basic design consideration in seismic zone III.

Zone	Zone factor	Location of building	Basic wind speed of city in m/s	Soil type
III	0.16	Pune	39	Hard(site type 1)

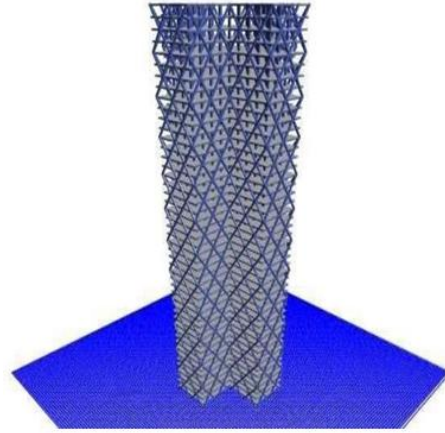


Figure: - 3D rendered view of plus (+) shape structure

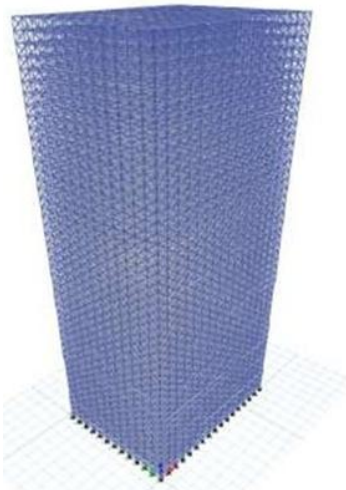
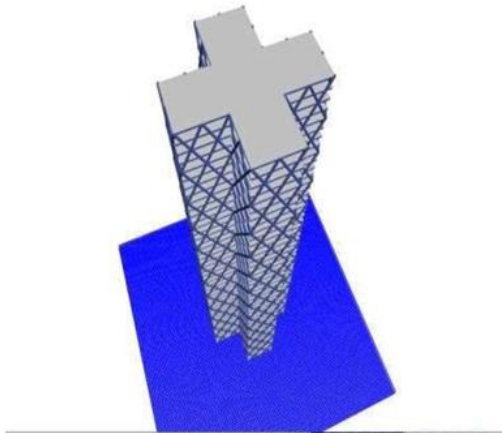


Figure: - Top View of Plus (+) Shape

Figure: - 3D rendered view of rectangular shape structure

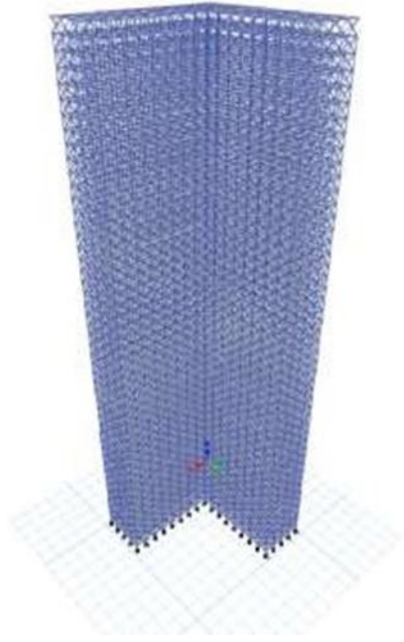


Figure: -3D rendered view of L- shape structure

4. Section properties for plus(+), rectangular shape of building in zone III:-

All sections properties have been same in each shape of building in zone III. For beams the Indian standard wide flange beam sections are used and for columns steel tubes are used. For diagrid members steel pipes are used.

Below Table shows the section properties for all storey module of building model with diagrid systems.

Story	Beam	column [tube section]	diagrid [pipe section]
1-16	ISMB 550	750 X 750 X 50	750 X 25
17-32	ISMB 500	700 X 700 X 45	750X 25
33-48	ISMB 500	600 X 600 X 35	750 X25

Table: Section properties for Plus (+), rectangular shape of building in zone III

Below Table shows the values of diagrid angles for the respective storey modules of plus (+) shape of structure. As the storey module increases the angle of diagrid increases. Diagrid angles taken for the study are varies from 410 to 740

story's per module	Angle
2	41.18 ⁰
4	60.25 ⁰
6	69.14 ⁰
8	74.05 ⁰

Table: Diagrid angle for plus (+) shape of building

5. Load Combinations: -

There are different types of load combinations are considered which are given below in table.

Load case No.	Load case details
1	1.5(D.L+L.L)
2	1.2(D.L+L.L+ EQ-X)
3	1.2(D.L+L.L- EQ-X)
4	1.2(D.L+L.L+ EQ-Y)
5	1.2(D.L+L.L- EQ-Y)
6	1.5(D.L+ EQ-X)
7	1.5(D.L- EQ-X)
8	1.5(D.L+ EQ-Y)
9	1.5(D.L- EQ-X)
10	0.9D.L+ 1.5EQ-X
11	0.9D.L- 1.5EQ-X
12	0.9D.L+ 1.5EQ-Y
13	0.9D.L- 1.5EQ-Y
14	1.2(D.L+L.L+ WL-X)
15	1.2(D.L+L.L- WL-X)
16	1.2(D.L+L.L+ WL-Y)

17	1.2(D.L+L.L- WL-Y)
18	1.5(D.L+ WL-X)
19	1.5(D.L- WL-X)
20	1.5(D.L+ WL-Y)
21	1.5(D.L- WL-Y)
22	0.9D.L+ 1.5WL-X
23	0.9D.L-1.5WL-X
24	0.9D.L+ 1.5WL-Y
25	0.9D.L- 1.5WL-Y
26	1.2(D.L+L.L+ RS-X)
27	1.2(D.L+L.L- RS-X)
28	1.2(D.L+L.L+ RS-Y)
29	1.2(D.L+L.L- RS-Y)
30	1.5(D.L+ RS-X)
31	1.5(D.L- RS-X)
32	1.5(D.L+ RS-Y)
33	1.5(D.L- RS-Y)
34	0.9D.L+ 1.5RS-X
35	0.9D.L- 1.5RS-X
36	0.9D.L+ 1.5RS-Y
37	0.9D.L- 1.5RS-Y

All load combinations are selected during analysis of story modules in seismic zone III. The load combinations mentioned in table are selected in ETABS using default steel structure combination

6. Result Analysis: -

Tabular Representation of Story Displacement & Story Drift

Table 6.4 shows that tabular representation of story displacement & story drift for rectangular, plus(+) and L-shape of building in seismic zone III.

Shape of building	Zone	Module	Max. story displacement (mm)			Max. story drift (m)		
			W.L	E.Q	R.S	W.L	E.Q	R.S
Rectangular shape	III	2	184.85	47.59	26.17	0.001307	0.000347	0.000199
		4	166.76	43.39	26.48	0.001176	0.000338	0.000231
		6	186.12	45.57	28.48	0.001388	0.000332	0.000218
		8	193.49	45.90	29.93	0.001445	0.000341	0.000231
		Combination	189.80	44.08	29.53	0.001532	0.000326	0.000234
Plus(+) shape	III	2	216.93	71.34	39.52	0.001581	0.000522	0.0003
		4	187.20	64.13	40.27	0.001317	0.000465	0.000303
		6	209.06	66.05	42	0.001548	0.000481	0.000361
		8	245.48	70.42	45.93	0.001839	0.000522	0.000354
		Combination	213.65	63.324	43.51	0.001734	0.000477	0.000344
L-shape	III	2	247.36	163.63	98.89	0.001728	0.001213	0.000729
		4	194.35	138.89	87.18	0.001360	0.001011	0.000559
		6	213.62	141.21	95.41	0.001558	0.001023	0.000709
		8	252.65	150.57	103.55	0.001885	0.001109	0.000781
		Combination	218.45	136.97	97.56	0.001783	0.001023	0.000744

In rectangular, plus (+) and L- shape of building wind load is having maximum of value of story displacement & story drift as compare to the earthquake load and also 8-storey diagrid module is having maximum of value of story displacement & story drift in rectangular, plus (+) and L- shape of building. Combination of all module in rectangular building gives less value of maximum storey displacement and maximum storey drift than plus (+) and L-shape of building.

The maximum storey displacement and maximum storey drift reduce in the region of 60 degree to 70 degree. Out of all storey modules 4 storey module in each shape of building gives less value of maximum storey displacement and maximum storey drift as compare to 2-storey, 6-storey and 8-storey modules.

V. CONCLUSION: -

- Diagrid angle in the region of 60° to 70° provides more stiffness to the diagrid structural system which reflects the less top storey displacement.
- The storey drifts minimum in the region of diagrid angle 60° to 70° in rectangular building as compare to plus (+) and L- shape of building. Both the maximum story displacement and maximum story drift values are within the permissible limit.
- The effect of lateral force on stories is less in rectangular structure with diagrid angle 60° to 70° so the optimum angle of diagrid is observed in the region of 60° to 70°.

- Static analysis, dynamic analysis and wind load analysis are performed on diagrid structure and it observed that, maximum story displacement and maximum story drift are maximum in case of wind load analysis as compare to earthquake analysis and response spectrum analysis in rectangular, plus(+) and L- shape of building.
- Last diagrid module in each shape of building which is made up of combination of two story, four story, six story and eight story diagrid module having maximum story displacement and maximum story drift values as compare to each storey module.
- It has been also concluded that for the high-rise buildings, the diagrid system is used for the better performance of lateral load and gravity load resistance in the recent year. Diagrid columns on the perimeter of the building resist the lateral loads as well as gravity loads so the internal columns are designed for vertical loads only.
- The diagrid structure performs well in all the parameters such as performance, expression and stability and due to a smaller number of columns, effective and efficient planning of the facade of building is possible.

VI. SCOPE FOR THE FUTURE WORK: -

- In this study we performed linear static analysis, linear dynamic analysis (Response spectrum method) and wind load analysis, whereas in further study non-linear static analysis (pushover analysis) and non-linear dynamic analysis (Time history analysis) can be performed for diagrid building.
- In this project we considered regular plan for modeling. In further work we can consider irregular plan for modeling of the structure.
- In the present work, combination storey module is made of two, four, six, eight storey module, whereas in further study different combination storey modules can be made so that we can reduce storey displacement and storey drift.

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