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ANALYSIS AND DESIGN OF HIGH-RISE DIAGRID STRUCTURES

Swagat Dattatraya Aher[1], Prof.Vishwajit Kadlag[2]

[1]PG Scholar,Department of Civil Engineering,Dr.D.Y.Patil School of Engineering and Technolgy, Charholi Bk, Via Lohegaon, Pune, Maharastra, India
[2]Associate Professor, Department of Civil Engineering, Dr.D.Y.Patil School of Engineering and Technolgy, Charholi Bk, Via Lohegaon, Pune, Maharastra, India

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Abstract - *As the world's population grows, so does the cost of accessible land. The lateral loads become more important than the gravitational loads as the building's height rises. Wind load and earthquake load are two forms of lateral loads that can be applied to high-rise buildings. Different forms of lateral load resisting structures used in high-rise buildings include shear walls, rigid framed structures, brace tubes, wall frames, outrigger systems, and diagrid systems.*

For lateral load resistance, the diagrid structural system is an efficient and effective structural system. Diagrid structure is a type of exterior structural system in which all external columns are replaced by a sequence of triangular shaped diagonal grids, and inside columns are solely meant to support gravity loads.

Two forms of 48 story structures in seismic zone III are studied in this study: rectangular &L-shape. The total height of all the structures is 168 meters. There are four diagrid modules in the seismic zone. In the diagrid construction, two, four, six, and eight modules have been employed. E-TABS is used to analyses and simulate diagrid structure. IS 800:007 is used to design all structural members. For earthquake analysis, IS 1893 part1- 2016 is utilized, and for wind load analysis, IS 875 part3- 2015 is employed. For dynamic analysis, the response spectrum approach is used. The maximum storey displacement and maximum storey drift of all the study findings are compared, and the ideal diagrid angle for all modules is calculated.

Key Words: **Diagrid structure, Storey displacement, Storey drift, Optimum diagrid angle**

1. INTRODUCTION

Rapid population expansion and high land costs have a significant influence on the construction sector, which leads to an upward trend in building construction. However, when building heights rise, lateral load resisting systems become more critical than gravity load resisting structural systems. To withstand the lateral stresses. Rigid frame, shear wall, wall-frame, utilised braced tube system, outrigger system, and tubular system are some of the most prevalent systems. Because of the structural efficiency and aesthetic possibilities given by the system's distinctive geometric design, the diagonal grid structural system has recently become popular for tall structures. Rapid population expansion and high land costs have a significant influence on the construction sector, which leads to an upward trend in building construction. However, when building heights rise, lateral load resisting systems become more critical than gravity load resisting structural systems. To be able to tolerate lateral strains. Some of the most common systems include rigid frame, shear wall, wall-frame, employed braced tube system, outrigger system, and tubular system. The diagonal grid structural system has lately become popular for tall structures due to its structural efficiency and aesthetic possibilities provided by the system's distinctive geometric form. Because of the layout and efficiency of a diagrid system, the number of structural elements required on the outside side of buildings is reduced, resulting in less blockage to the outside view. The structural efficiency of the diagrid system also aids in the avoidance of interior and corner columns, allowing for great floor design freedom. The most recent high-rise building system, which has now become the most popular The "Diagonal Grid System," also known as the "Diagrid system," is popular among today's designers. The Diagrid system is made up of multiple diagonal components that join to produce a triangulated or grid-shaped design. The name "diagrid" is derived from the phrases "diagonal" and "grid." A diagrid structure is a sort of structural system that consists of diagonal grids connected by horizontal rings to provide a beautiful and redundant structure that is particularly useful for high-rise structures. Due to its triangulated configuration, diagrid structures differ from braced frame systems in that diagonals as key structural components contribute in supporting gravity load as well as lateral load, obviating the requirement for vertical columns. A diagrid system's column-free structure has various advantages, including great architectural freedom, elegance, and huge day illumination due to its small outside surface. Because of its structural efficiency, the diagrid system has recently been used on numerous tall steel structures.

2. Objective of Study

I. To assess the performance of a high-rise building equipped with a diagrid system.

II. To do static analysis, response spectrum analysis, and wind analysis in terms of story displacement and drift

III. Determine the diagrid system's optimal diagrid angle.

3. Geometric parameters of the building models

Structural parameter	Steel structure
Shapes of building	rectangular and L-shape
Number of stories	48
Size of plan	
a). for rectangular shape	48m x 64m
b). for L-shape shape	48m x 48m
Spacing between bays	4m
Spacing between diagrid along perimeter	8m
Height of each storey	3.5m
Number storey per module	2, 4, 6, & 8 storey
Grade of structural steel (Fy)	Fe 500
Grade of concrete (Fck)	M40

3.1 Comparative analysis

Case-I : Comparison between each module for rectangular and L-shape shape of structure.

2-storey module

4-storey module

6-storey module

8-storey module

Case-II: Combination all storey modules rectangular and L-shape of structure.

2-storey, 4-storey, 6-storey and 8 storey

4. Research Methodology

The analysis of a 48-story diagrid structure with rectangular and L-shaped building is offered in this work. As per Indian Standard, lateral forces owing to earthquakes and wind effects are taken into account. The structure was analyzed using IS 1893:2016 and IS 800:2007. The ETABS programme is used for modeling and analysis of diagrid systems. Earthquake loads are subjected to response spectrum analysis. The beams and columns are treated as flexural components for linear static and dynamic analysis. The major goal of this study is to investigate the behavior of high-rise buildings with Diagrid systems of various angles for rectangular and L-shape structures in seismic zone III, as well as to determine the best diagrid angle using static, dynamic, and wind analysis. In first phase, modeling of 48 storey high rise buildings with Diagrid systems by defining material and section properties & having same height with different diagrid angles which is done by using ETABS software.

In second phase, define several sorts of loads and their combinations on the rectangular shape of the structure in the second phase. Define the functions necessary for the response spectrum in dynamic analysis. Finally, using the findings of the study, verify the behavior of a rectangular shape structure with Diagrid systems of the same height and different angle in seismic zone III.

In third phase, define several sorts of loads and their combinations on additional L-shape structures for dynamic analysis in the third phase. Define the functions that will be used to create the response spectrum. Finally, using the findings of the study, examine the behavior of the L-shape of structure with Diagrid systems with the same height and different angle in seismic zone III.

In fourth phase, The collecting and analyzing data on two forms of structures in the form of several parameters such as Storey shear and Storey Drift is the fourth phase.

In the fifth step, evaluate all seismic zone-III factors to determine the best angle for rectangular and L-shaped structures, as well as combinations of 2, 4, 6, and 8-story modules.

5. Modeling and Analysis

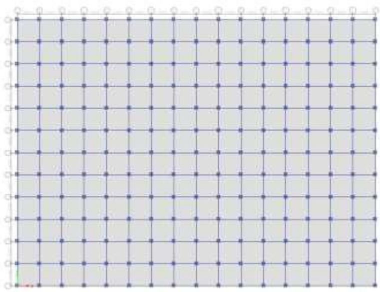

Fig -1: Plan of rectangular shape building model

Figure 1 shows 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.

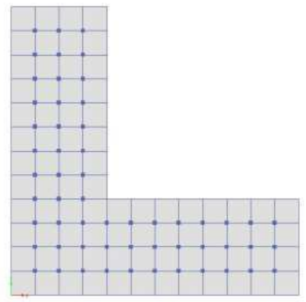

Fig -2: Plan of L- shape building model

The 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)

Table -1: Basic design consideration

Fig -3: 3D rendered view of rectangular shape structure

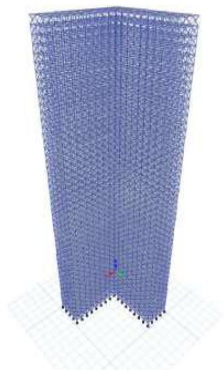

Fig -4: 3D rendered view of L- shape structure

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 -2: Section properties for rectangular & L-shape of building

Number storeys per module	Angle (Degree)
2	41.18
4	60.25
6	69.14
8	74.05

Table -3: Diagrid angle for rectangular & L- shape of building

During the seismic zone III narrative module analysis, all load combinations are chosen as per IS 800. In ETABS, the load combinations shown in the table are selected using the default steel structure combination.

Wind parameter details: (AS PER IS 875-2015) in zone III.

Terrain category – 3

Structure class – C

Risk coefficient – 1.06

Topography factor – 1

Importance factor- 1.30

6. Result and Discussion

1. Analysis Result and its Discussion for **Rectangular shape of** building in Seismic Zone III.

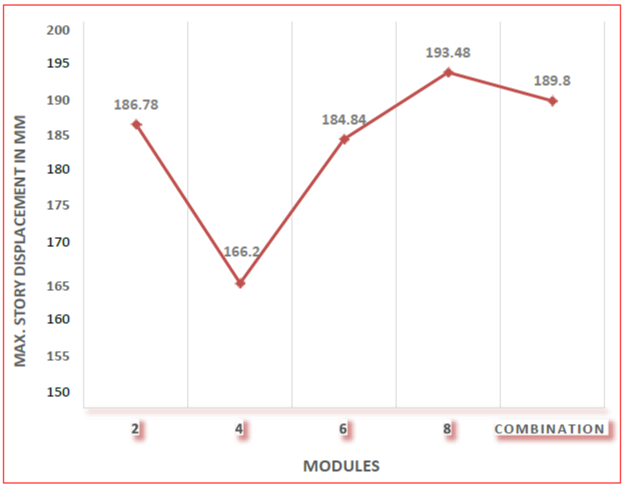

Fig -5: Maximum storey displacement for all modules modules in rectangular shape structure

The graphical representation of maximum storey displacement of 48 story rectangular building modules in zone III is shown in Figure: 5. In the 8 module diagrid, the maximum storey displacement is 193.48 mm. The greatest storey displacement with the least value is 166.2 mm, which is recorded for a four-story module. The minimum value of maximum story displacement is found to be between 60 degree and 70 degree. The maximum allowable storey displacement is 336 mm, When comparing eight module diagrid to four module and six module diagrid, the maximum story displacement for four module and six module diagrid is reduced by 14.09 % and 4.46 % respectively.

The maximum storey drift of 48 story rectangular building modules in zone III is depicted graphically in Figure:6. This is the graphical representation for wind load analysis because, when compared to seismic and response spectrum analysis, wind load analysis offers the highest values of tale drift in zone III. The maximum storey drift in the combo module is 0.001532m, which is greater. The smallest maximum storey drift value is 0.001176 m, which may be found in the four-story module diagrid. The maximum allowable storey drift is 0.014 m. Maximum story drift for all modules in zone III is observed to be within this limit. Maximum story drift for four module and six module diagrid is reduced by 23.24% and 15.68% when we compare with combination module diagrid which gives maximum value of drift in zone III.

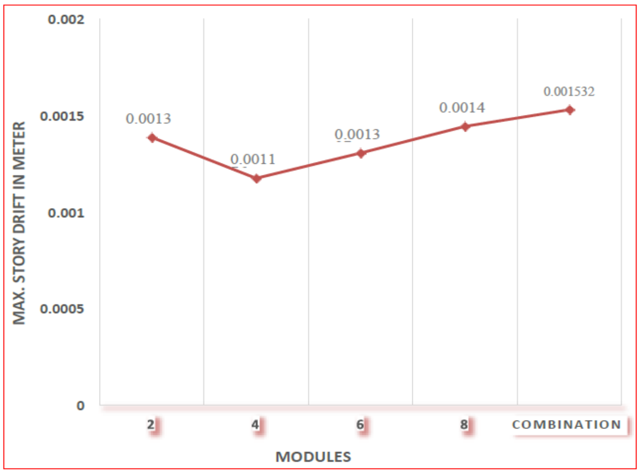

Fig -6: Maximum storey drift for all modules in rectangular shape structure

2. Analysis Result and its Discussion for **L-shape of building** in Seismic Zone III.

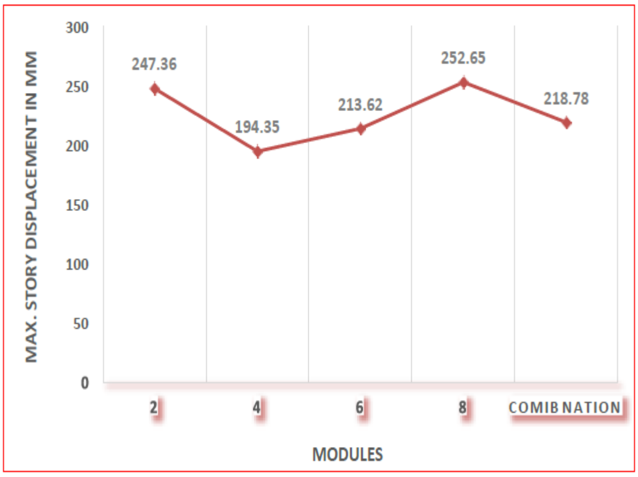

Fig -7: Maximum storey displacement for all modules in L-shape structure

The maximum storey displacement of 48 storey L-shaped building modules in zone III is depicted graphically in Figure 7. In 8 modules, the maximum storey displacement is 252.65mm. 194.35 is the smallest figure of maximum storey displacement mm, which may be seen in a four-story module. It has been discovered that the minimum value of maximum storey displacement ranges from 60 to 70 degree. The highest allowable storey displacement is 336 mm, and all modules in zone III have maximum story displacements that are within the allowable limit. When we compare the maximum story displacement of eight module diagrid to four and six module diagrid, the maximum story displacement of four and six module diagrid is lowered by 23.07 % and 15.44 % respectively.

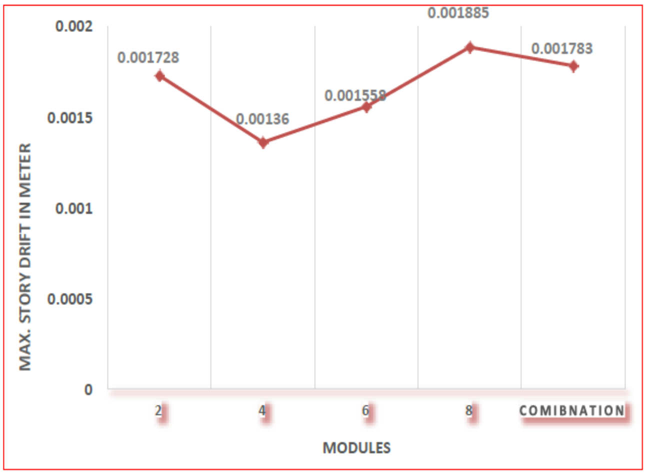

Fig -8: Maximum storey drift for all modules in L-shape structure

The maximum storey drift of 48 storey L-shaped building modules in zone III is depicted graphically in Fig 8.In the 8 module diagrid, the maximum storey drift is 0.001885 m. The smallest maximum storey drift value is 0.001360 m, which may be found in The diagrid is a four-story module. The maximum allowable storey drift is 0.014 m, and maximum story drift for all modules in zone III is observed to be within this limit. When eight module diagrid is compared to four and six module diagrid, the maximum narrative drift for four and six module diagrid is lowered by 27.85 % and 17.34 % respectively.

7. Conclusion

i).Wind load has the maximum story displacement and story drift in rectangular and L-shaped buildings as compared to earthquake load.

ii).8-storey diagrid module has the maximum story displacement and story drift in rectangular and L-shaped buildings.

iii).Combination of all modules in rectangular building produces minimum value of maximum storey displacement and maximum storey drift than L-shape of structure. In the 60-70 degree range, maximum storey displacement and maximum storey drift decrease.

iv). In comparison to 2-storey, 6-storey, and 8-storey modules, the 4 storey module in any form of building delivers less value of maximum storey displacement and maximum storey drift.

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