Parametric Study of Concrete Diagrid Structures Having Diagrid Connection At Different Storeys And Their Comparison

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Abstract- *One of the evocative structural design solutions for tall buildings is recently embraced by the diagrid (diagonal grid) structural system. Diagrid with a perimeter structural configuration characterized by a narrow grid of diagonal members involved both in gravity and in lateral load resistance, requires less structural steel than a conventional frame and has emerged as a new design trend for tall-shaped complex structure due to aesthetics and structural performance. In this study four G+ 36 storey models of concrete diagrid structures are considered, each model having diagrid connection at different storeys. These models would be analysed and compared for various parameters such as storey displacement, storey drift and axial forces in the diagrid members using ETABS 2016 software.*

Keywords- Diagrid Structure, Storey displacement, Storey drift, Axial forces, Seismic Analysis, Wind Analysis.

I. INTRODUCTION

The rapid growth of urban population and limitation of available land, the taller structures are preferable nowadays. So, when the height of structure increases then the consideration of lateral load is very much important. For that the lateral load resisting system becomes more important than the structural system that resists the gravitational loads. The lateral load resisting systems that are widely used are: rigid frame, shear wall, wall-frame, braced tube system, outrigger system and tubular system. Recently, the diagrid (Diagonal-Grid) structural system is widely used for tall steel buildings due to its structural efficiency and aesthetic potential provided by the unique geometric configuration of the system. Diagrid structure has good appearance and it is easily recognized. Hence the diagrid structural system has renewed the interests of architectural and structural designers to achieve structural effectiveness and aesthetics in case of high-rise buildings.

1.1 CONCEPT OF DIAGRID STRUCTURAL SYSTEM

Diagrids can be described as the perimeter structural frames characterized by a narrow grid of diagonal members which resist both gravity and in lateral loads. The diagrid structural system is an evolution of the braced steel tube structures. Diagrid members are diffusely spread over the facade, giving rise to closely spaced diagonal elements and allowing for the complete elimination of the conventional vertical columns. Therefore, the diagonal members in diagrid structures act both as inclined columns and as bracing elements, and carry gravity loads as well as lateral forces; due to their triangulated configuration, mainly internal axial forces arise in the members, thus minimizing shear racking effects.

1.2 OBJECTIVE OF THE STUDY

- To understand the concept of diagrid structural system and various components of a diagrid.
- The main objective is to study the performance of diagrid structure under seismic and wind load conditions, for four different diagrid models.
- The four diagrid models are modelled as the Diagrid members connecting one, two, three and four stories.
- The parameters like storey drift, story displacement and axial force are to be studied.
- Analysing the performance of the Diagrid structures and finding out the best diagrid structural configuration amongst the four models.

II. LITERATURE REVIEW

1. **Diagrid structural system for tall buildings: state of the art review - Premdas.S and M. Sirajuddin.**

This paper provides a systematic summary of the existing research achievements of the diagrid structural system for tall buildings. The paper also includes important topics such as sustainability of diagrid structures and a detailed conclusion about the mechanism of load transfer system.

2. Optimal diagrid angle of high-rise buildings subjected to lateral loads - Jayesh Venkolath.

The above study is carried out by considering the different angles for a 24 storied circular diagrid building. The circular plan of 30.7 diameter is considered with five different types of angles of diagrid that is 36.8°, 56.3°, 66°, 77.5° and 83.6° A comparative study is carried out using the parameters lateral displacement, storey drift, storey shear, time period.

3. Comparative study of diagrid structures over braced tube structures - Arpitha L.

In this paper multiple models were compared for different plans of the structure, such as square and hexagonal, the maximum storey displacement, storey drift, base shear, and time period, the structures were analysed for seismic zone III and zone V as per IS 1893:2002.

III. BUILDING CONFIGURATION

3.1 DESCRIPTION OF THE MODELS

For the analysis and comparison of diagrid concrete structures 4 different models are to be considered, they are as follows:

- MODEL 1: A concrete diagrid frame structure of G + 36 is to be considered, taking diagrid in between single storey.
- MODEL 2: A concrete diagrid frame structure of G + 36 is to be considered, taking diagrid in between two storeys.
- MODEL 3: A concrete diagrid frame structure of G + 36 is to be considered, taking diagrid in between three storeys.
- MODEL 4: A concrete diagrid frame structure of G + 36 is to be considered, taking diagrid in between four storeys.

3.2 GEOMETRIC PARAMETERS OF THE DIAGRID MODELS

SR.NO	PARAMETER	DETAILS
1	Structure Type	Reinforced concrete structure
2	Number of storeys	G + 36
3	Number of Bays along X & Y	15
4	Size of Plan	75m x 75m
5	Length of each Bay	5m
6	Height of each storey	3.5m
7	Grade of Concrete (Fck)	M30
8	Grade of Steel (Fy)	Fe500
9	Seismic Zone	V
10	Type of Soil	Medium
11	Wind speed	50m/s

3.3 DETAILS OF THE STRUCTURAL MEMBERS

- Column details = 900 MM X 1100 MM
- Beam details = 450 MM X 600 MM
- Diagrid beam = 450 MM X 600 MM
- R.C.C. slab = 200 MM thick
- Shear wall = 250 MM thick
- Live load = 4 KN/M²
- Floor finish load = 1 KN/M²
- Floor wall loads = 15 KN/M²
- Shear wall = 250 MM

3.4 DETAILS OF DIAGRID STRUCTURAL MODEL

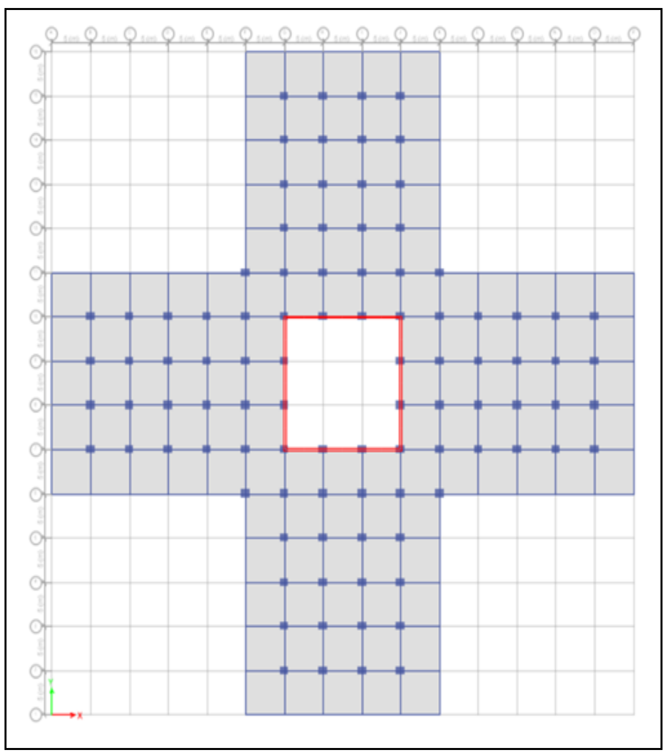

Fig No :1 Plan of model.

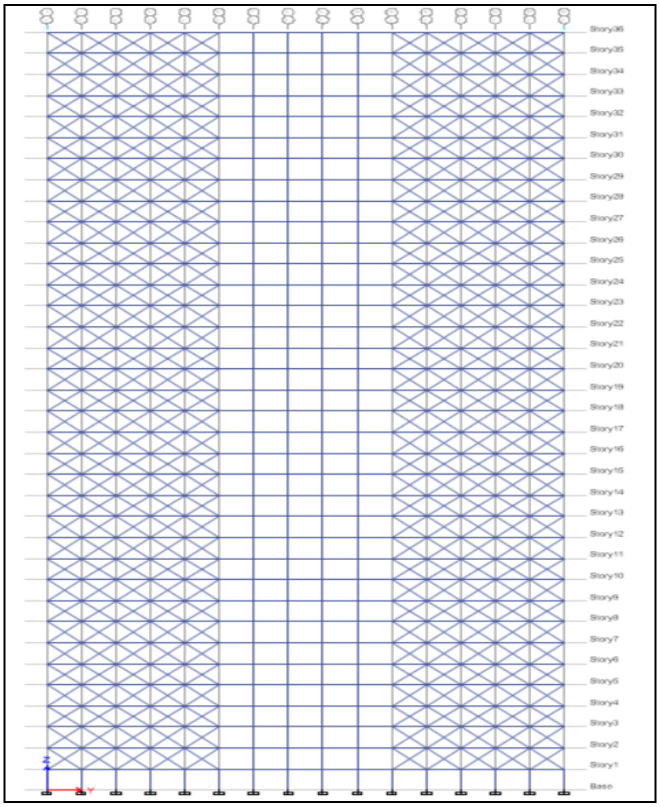

Fig No: 2 Elevation of model-1, with Diagrids connecting single storey.

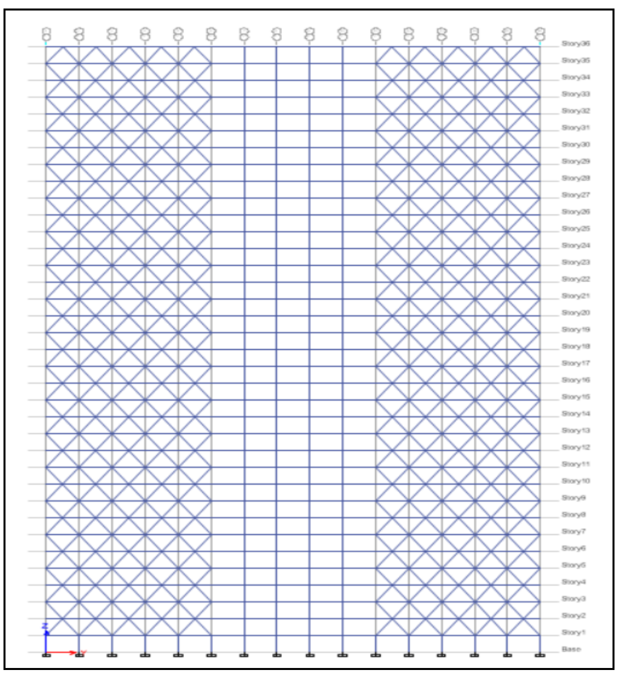

Fig No:3 Elevation of model-2, with Diagrid connection between two stories.

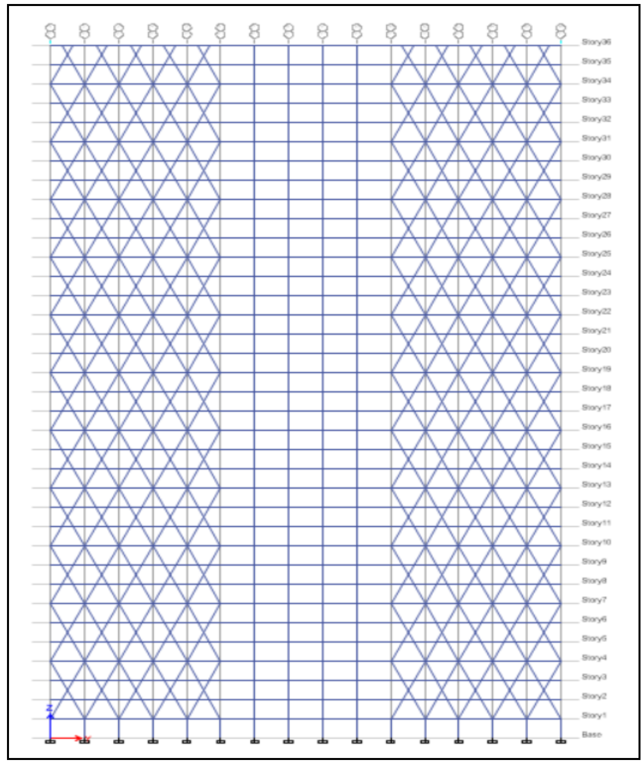

Fig No :4 Elevation of model-3, with Diagrid connecting three stories.

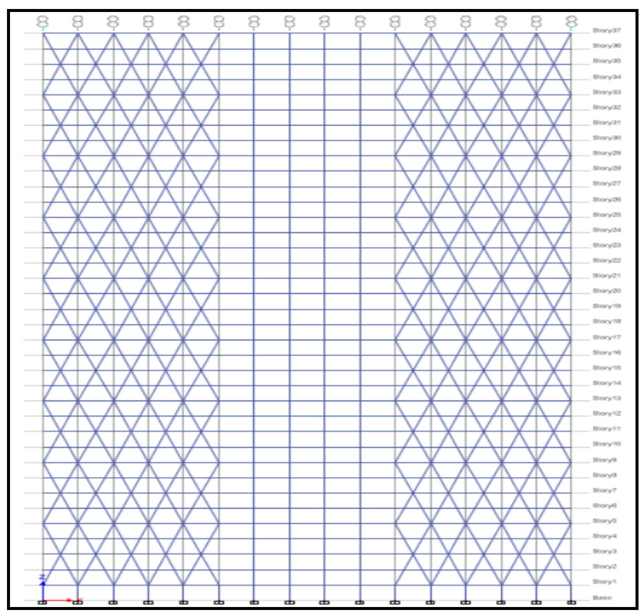

Fig No:5 Elevation of model-4, with Diagrid connecting four stories.

IV. RESULTS COMPARISON AND DISCUSSION

All the four diagrid structural models are modelled using ETABS software. All the models were subjected to earthquake and wind forces. Following are the parameters of comparison for all the four diagrid modules:

- Maximum storey displacement

- Maximum storey drift
- Axial forces in the diagrid members.

4.1 MAXIMUM STOREY DISPLACEMENT

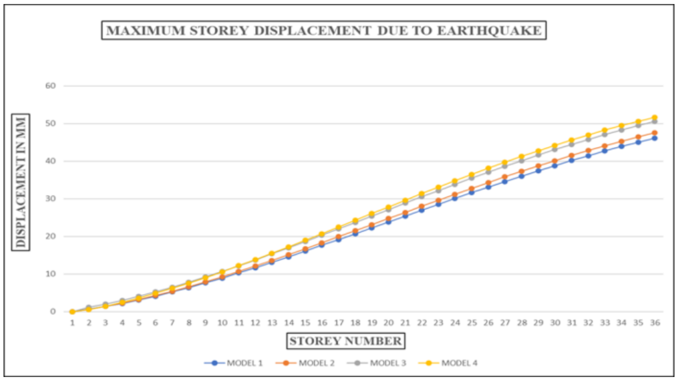

Fig No :6 Graph representing maximum storey displacement due to earthquake.

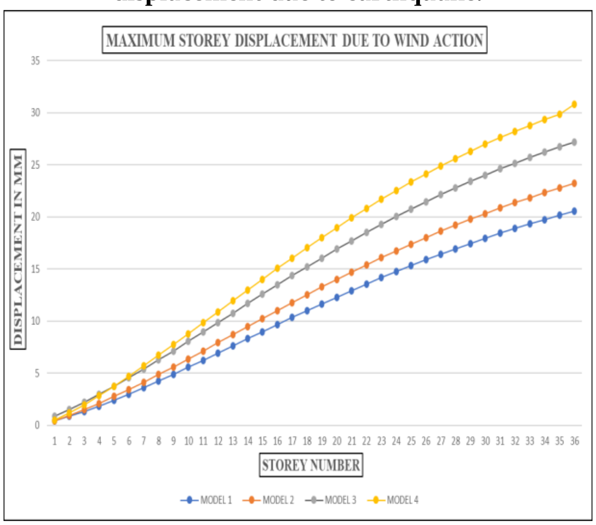

Fig No :7 Graph representing maximum storey displacement due to wind action.

4.2 MAXIMUM STOREY DRFT

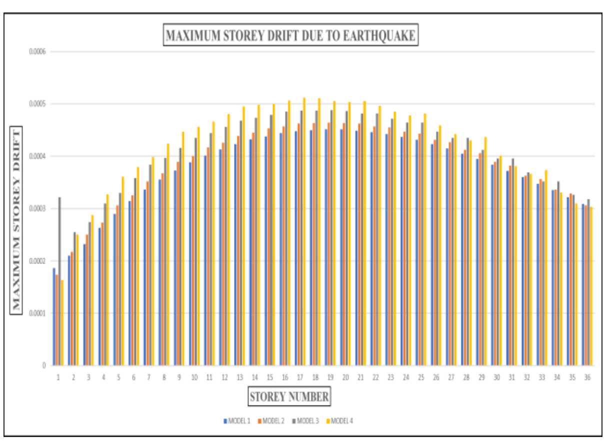

Fig No: 8 Bar chart representing maximum storey drift due to earthquake.

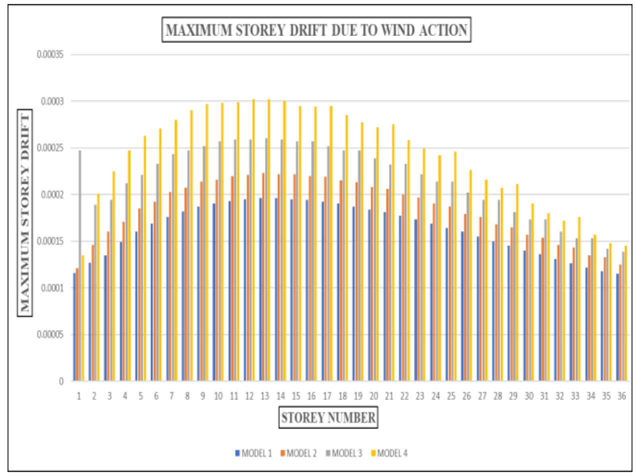

Fig. No. 9 Bar chart representing maximum storey drift due to wind action.

4.3 AXIAL FORCES IN THE DIAGRID MEMBERS

In this case the values of the axial forces in the diagrid members due to earthquake and wind action were observed vertically over a specific bay, for all the four models.

The values of the axial forces in the diagrid member D33 of the second model are mentioned below.

DIAGRID CONNECTION BETWEEN STOREY	MAXIMUM AXIAL FORCE IN THE DIAGRID MEMBER – D33 (MODEL 2)	
	EARTHQUAKE	WIND
1^{ST} – 3^{RD}	3343.675 KN	3699.061 KN
3^{RD} – 5^{TH}	2877.138 KN	3303.260 KN
5^{TH} – 7^{TH}	2510.356 KN	2982.684 KN
7^{TH} – 9^{TH}	2210.075 KN	2710.759 KN
9^{TH} – 11^{TH}	1951.080 KN	2469.423 KN
11^{TH} – 13^{TH}	1722.567 KN	2250.012 KN
13^{TH} – 15^{TH}	1517.9261 KN	2046.749 KN
15^{ND} – 17^{TH}	1332.630 KN	1855.448 KN
17^{TH} – 19^{TH}	1163.3595 KN	1672.942 KN
19^{TH} – 21^{ST}	1007.435 KN	1496.747 KN
21^{ST} – 23^{RD}	862.508 KN	1324.826 KN
23^{RD} – 25^{TH}	726.236 KN	1155.419 KN
25^{TH} – 27^{TH}	595.980 KN	986.896 KN
27^{TH} – 29^{TH}	468.422 KN	817.619 KN
29^{TH} – 31^{ST}	339.015 KN	645.792 KN
31^{ST} – 33^{RD}	201.147 KN	469.2394 KN
33^{RD} – 35^{TH}	166.896 KN	285.051 KN
35^{TH} – 36^{TH}	67.850 KN	91.760 KN

The axial forces in the diagrid members tend to vary from higher values at the lower storeys to lesser values at the top storeys.

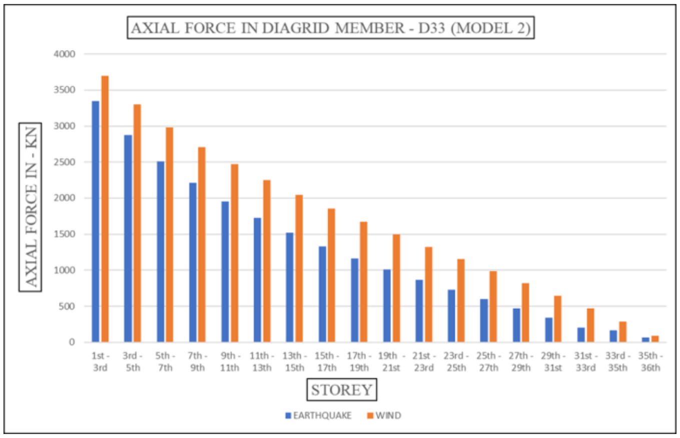

Fig No: 10 Axial force in diagrid member D33 (model 2) when the structure is subjected to earthquake and wind action.

V. OBSERVATION

5.1 OBSERVATION ON SEISMIC ANALYSIS

Storey displacement in X-direction for diagrid structure in case of model number 1 is 47.229 mm, whereas storey displacement of diagrid structure in case of model number 4 is 53.686mm that is diagrid structure with diagrid connection at single storey gives less storey displacement. In Diagrid structure the Storey displacement is less for diagrids connecting lesser number of stories.

Maximum storey displacement is noticed at the top most storey of the diagrid structure in case of model four. Also, maximum storey drift experienced by the diagrid structure in model four with respect to seismic analysis, is between storey 15 and storey 19.

5.2 OBSERVATION OF WIND ANALYSIS

All four models are modelled in ETABS, the geometric parameters and load patterns are taken same as seismic analysis. These models are analysed for wind loads also. The wind parameters are selected as per IS 875-1987(part-3) Code Book. The diagrid structure having diagrid connection between 4 stories has the maximum drift when compared with the other models.

The maximum storey drift when the structure is subjected to the wind action model 4 gives the maximum drift values and is noticed between storey 11 and storey 15, whereas the maximum storey displacement is noticed at the top storey of the diagrid structure.

5.3 OBSERVATION OF THE MAXIMUM AXIAL FORCES IN THE DIAGRID MEMBERS

The maximum axial forces in the diagrid members of a specific bay connecting at different storey levels were observed and it can be clearly seen that the values of the axial force in the diagrid members are maximum at the lower storey levels and these values decrease as we move up to higher storey levels. Same pattern can be observed in the readings of axial forces for all the four models.

VI. CONCLUSION

- From the study it is concluded the Diagrid structure with diagrid connecting single storey gives better results in seismic and wind analysis.
- Diagrid structure with diagrid connecting single storey gives the better results, for storey displacement when the structure is subjected to earthquake.
- Diagrid structure with diagrid connecting single storey gives better results for storey displacement when the structure is subjected to wind action.
- The first diagrid model has less storey drift as compared to the remaining three diagrid models, when the structure is subjected to earthquake and wind action.
- While considering the axial forces in the diagrid members at varying storey intervals for all four models, the values of the axial force in the diagrid members are maximum at the lower storey levels and these values decrease as we move up to higher storey levels.
- Construction of diagrids is a complicated task but if executed properly it results in a safer structural system.

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