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Parametric study of Diagrid, Pentagrid and Hexagrid structural systems

Shankar C. Sharma[1], Dr. A. A. Bage[2]

[1]*Civil Engineering Department, Sardar Patel College of Engineering, shankarcsharma@yahoo.in*
[2]*Civil Engineering Department, Sardar Patel College of Engineering, a_bage@spce.ac.in*

Abstract*—Diagrid structure is one of the most unique structural systems that have been developed in recent years. For designing tall buildings there are various structural systems such as moment resisting frame, shear wall systems, bracing systems, space trusses, tubular structures etc. Diagrid is one of the new structural systems which is adopted for designing tall buildings. In the present paper a comparative parametric study of Diagrid, Pentagrid and Hexagrid structural system has been done. A 13, 37, and 46 storey building with shear wall have been modelled and analysed for Diagrid, Pentagrid and Hexagrid structural systems. The shear wall of thickness 230 mm has been used. A total of 24 buildings have been modelled and analysed. The modelling and analysis has been performed using ETABS. The dynamic analysis is performed for earthquake by response spectrum method and for wind by wind dynamic analysis (Gust factor method). From the analysis maximum storey displacement, maximum storey drift, base shear and fundamental time period parameters have been compared for all models.

***Keywords*— Parametric study, Diagrid structural system, Pentagrid structural system, Hexagrid structural system, Etabs**

I. INTRODUCTION

The structural systems of a high-rise building are designed to take care the vertical gravity loads and lateral loads which are induced due to wind or seismic activity. In structural system, the members which are designed to carry the loads are termed as structural members and remaining members are termed as non- structural members. The term 'structural system' or 'structural frame' is load-resisting sub-system of a structure. The structural system transfers the loads to the interconnected structural components or members. Tall building or high rise structures construction are more in this period; because of increase in population, economic prosperity and also due to the scarcity of lands. Hence high-rise structures are preferred. Height is main factor in this kind of buildings. Demand for tall buildings has increased due to increase in demand for business and residential space, high strength structural elements, materials and also various software like Etabs, Staad pro etc. these are analysis and design software's have provided the solution for growth of high rise structures.

Diagrid is a particular form of space truss. Diagrid system is made by series of triangulated truss system which are at the perimeter of the structure. Diagrid is formed by intersecting the diagonal and horizontal components. Diagrid has good aesthetic appearance and it is easily noticed. The arrangement and efficiency of a Diagrid system reduce the number of structural element required on the façade of the buildings, hence there is less obstruction to the outside view. The major use of diagrid structural system is in avoiding the interior and corner columns due to which major flexibility in floor plan is available. The gravity loads and lateral forces are taken by the triangulated members in diagrid structural system. Diagrid structure is more effective in minimizing the shear deformation, because they carry lateral shear by axial action of diagonal elements.

The pentagrid structural systems are created by arranging the technically developed irregular pentagons alternatively inverted both in horizontal and vertical directions. Pentagrid structural systems are established by using multi angle concept in which all the elements share both gravity and lateral loads partially.

The hexagrid structural system, eliminates almost all the regular vertical columns. Hexagrid structural system consists of hexagonal perimeter which is made up of a network of multi-storey tall hex-angulated truss system. Hexagonal grid is made by intersecting the diagonal and horizontal elements.

II. AIM AND OBJECTIVE

The objectives of the project are as follow:

- To analyze and compare the structural performance in terms of maximum storey displacement, maximum storey drift, base shear and fundamental time period of diagrid, pentagrid and hexagrid structural systems for different storey heights i.e. 13 storey, 37 storey and 46 storey.
- To investigate the effect of storey module i.e. 2 storey module (2SM) and 3 storey module (3SM) on above mentioned parameters for diagrid, pentagrid and hexagrid structural system.
- Maximum storey displacement, maximum storey drift, base shear and fundamental time period parameters are compared for above mentioned structural systems for earthquake by Response spectrum method and for wind by wind dynamic analysis.

III. METHODOLOGY

In this study comparison of Diagrid, pentagrid and hexagrid system is compared with conventional system in terms of storey displacement, storey drift, base shear and fundamental time period.

Following steps are adopted in this study.

Step 1: Selection of site condition and seismic zone.

Step 2: Selection of building geometry and modelling of Diagrid, pentagrid, hexagrid and conventional structural system using ETABS 2016 software for the same plan.

Step 3: Application of loads and load combination to the structural model according to the standard codes.

Step 4: Analysis of each building frame models.

Step 5: Comparative study of results in terms of maximum storey displacement, maximum storey drift, base shear and fundamental time period. By considering different storeys i. e. 13 storey, 37 storey, and 47 storeys.

Step 6: Effect of 2 storey module (2SM) and 3 storey module (3SM) on above mentioned parameters.

Step 7: Above structures are analysed by dynamic method for earthquake and for wind by response spectrum method and gust factor method, the results have to be compared with regular bare frame models.

IV. MODELLING DATA

TABLE I

Table showing modelling data

Plan dimension	(36 X 36) m
Number of storey	13, 37, 46
Floor to floor height	3.5m
Structure utility	Commercial
Seismic zone	3
Seismic coefficient	0.16
Response reduction factor	5
Importance factor	1
Wind speed	44 m/s
Structure type	C
Analysis method	• Response spectrum method • Wind dynamic analysis
Codes used	• IS 456-2000, • IS 800-2007. • IS 875-2015. • IS 1893 Part 1-2016

The design data as follow:

1. For all the types of buildings 450x900 mm concrete sections have been used as beam sections.
2. For all the four types of buildings 900x900 mm concrete section have been used as column sections for interior as well as exterior.
3. For Diagrid, pentagrid hexagrid structural systems the grids are provided as pipe section of 400 mm diameter and 10 mm thickness.
4. For all four types of structural systems shear wall of size 230 mm thickness is used.
5. Floor finish of 1.5 kN/m2 is applied on all the storeys.
6. Live load of 3 kN/m2 and 2kN/m2 is applied on all storeys except terrace level and terrace level respectively.
7. Wall load of 12kN/m and 7kN/m as parapet wall load is applied on the storeys.

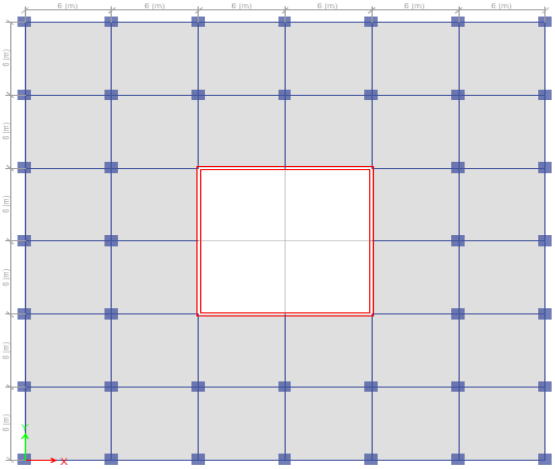

Fig. 1 Floor plan of regular building

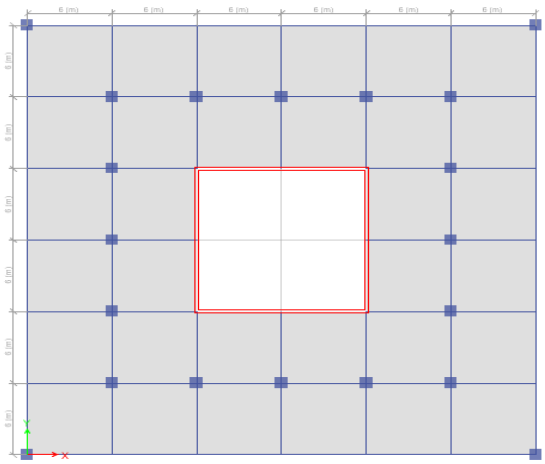

Fig. 2 Floor plan of diagrid, pentagrid and hexagrid structural system building

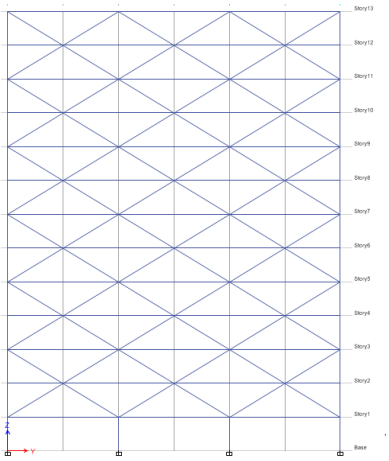

Fig. 3 Elevation of diagrid building (2 SM)

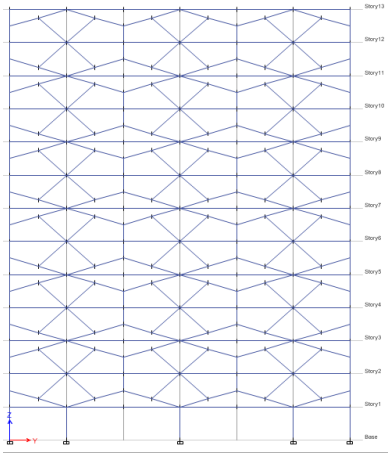

Fig. 4 Elevation of pentagrid building (2 SM)

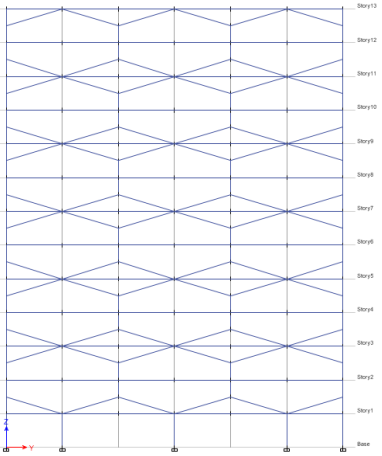

Fig. 5 Elevation of hexagrid building (2 SM)

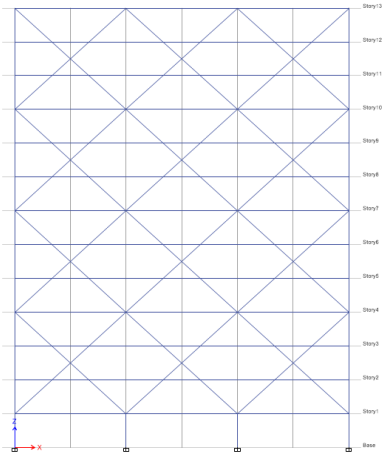

Fig. 6 Elevation of diagrid building (3 SM)

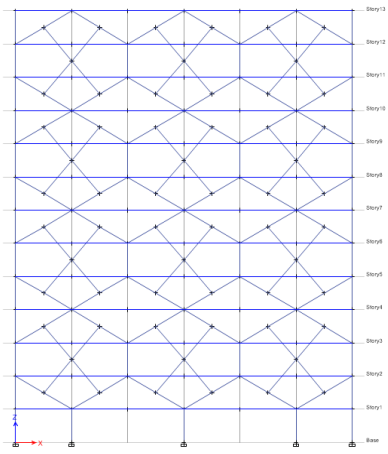

Fig. 7 Elevation of pentagrid building (3 SM)

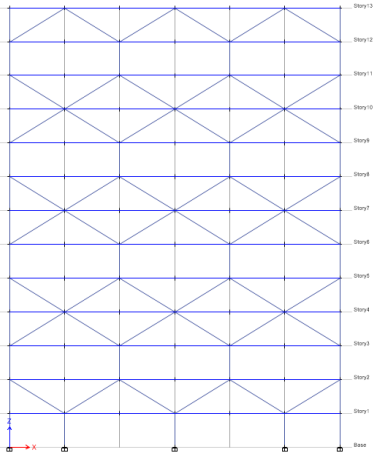

Fig. 8 Elevation of hexagrid building (3 SM)

V. RESULTS

- From the above given data the building had been modelled in Etabs.
- The method of analysis are earthquake and wind are Response spectrum method and Wind dynamic analysis (Gust factor method) respectively.
- Maximum Storey displacement, maximum storey drift, base shear and fundamental time period parameters are compared for diagrid, pentagrid and hexagrid structural systems for 13 storey, 37 storey and 46 storey buildings for both 2SM and 3SM.

TABLE II
Percentage reduction in maximum storey displacement in RSM

STOREY LEVEL	13		37		46	
MODULE	2SM	3SM	2SM	3SM	2SM	3SM
DIAGRID	27.83%	28.61%	20.75%	23.97%	1.58%	4.46%
PENTAGRID	19.02%	24.11%	14.41%	18.93%	-3.94%	-5.31%
HEXAGRID	14.18%	20.74%	12.60%	14.55%	-28.79%	-7.65%

TABLE III
Percentage reduction in maximum storey displacement in WIND

STOREY LEVEL	37		46	
MODULE	2SM	3SM	2SM	3SM
DIAGRID	9.96%	12.24%	1.83%	4.58%
PENTAGRID	5.56%	7.58%	-8.00%	-1.96%
HEXAGRID	2.36%	3.68%	-14.43%	-3.38%

TABLE IV
Percentage reduction in maximum storey drift in RSM

STOREY LEVEL	13		37		46	
MODULE	2SM	3SM	2SM	3SM	2SM	3SM
DIAGRID	28.73%	41.44%	3.91%	5.47%	1.89%	4.72%
PENTAGRID	18.23%	20.99%	2.73%	3.52%	-12.89%	-2.83%
HEXAGRID	6.08%	19.89%	1.17%	0.78%	-13.52%	-4.40%

TABLE V

Percentage reduction in maximum storey drift in WIND

STOREY LEVEL	37		46	
MODULE	2SM	3SM	2SM	3SM
DIAGRID	16.67%	18.86%	3.70%	9.41%
PENTAGRID	6.36%	15.79%	-27.06%	-19.66%
HEXAGRID	4.61%	9.43%	-27.39%	-22.52%

TABLE VI

Percentage reduction in base shear in RSM

STOREY LEVEL	13		37		46	
MODULE	2SM	3SM	2SM	3SM	2SM	3SM
DIAGRID	5.93%	6.24%	5.74%	6.03%	5.50%	5.80%
PENTAGRID	5.92%	5.71%	5.76%	6.10%	4.79%	5.73%
HEXAGRID	5.91%	2.82%	5.77%	6.12%	3.43%	5.89%

TABLE VII

Percentage reduction in fundamental time period in RSM

STOREY LEVEL	13		37		46	
MODULE	2SM	3SM	2SM	3SM	2SM	3SM
DIAGRID	14.55%	15.10%	2.82%	4.12%	-2.69%	-1.17%
PENTAGRID	8.39%	10.77%	-7.81%	-6.26%	-8.61%	-4.83%
HEXAGRID	-5.87%	2.82%	-19.00%	-0.68%	-18.69%	-5.56%

*+ve values= % reduction and –ve values= % increase

VI. CONCLUSIONS

- For 13 storey, 37 storey, & 46 storey building diagrid structural system is better than pentagrid and hexagrid structural systems.
- 3SM gives better results than 2SM for maximum storey displacement, maximum storey drift, base shear and fundamental time period parameters.
- While studying the maximum storey displacement and maximum storey drift it was found that earthquake is governing in 13 storey building and wind is governing in 37 storey and 46 storey buildings
- Results are compared with regular bare frame models
- Maximum storey displacement is reduced by 28.61% in 13 storey, 12.24% in 3SM37 storey and 4.58% in 46 storey for 3SM for diagrid models.
- Maximum storey displacement is reduced by 24.11% in 13 storey, 7.58% in 37 storey and increased by 1.96% in 46 storey for 3SM for pentagrid models.
- Maximum storey displacement is reduced by 20.74% in 13 storey, 3.68% in 37 storey and increased by 3.38% in 46 storey for 3SM for hexagrid models.
- Maximum storey drift is reduced by 41.44% in 13 storey, 18.86% in 37 storey and 9.41% in 46 storey for 3SM for diagrid models.

- Maximum storey drift is reduced by 20.99% in 13 storey, 15.79% in 37 storey and increased by 19.66% in 46 storey for 3SM for pentagrid models.
- Maximum storey drift is reduced by 19.89% in 13 storey, 9.43% in 37 storey and increased by 22.52% in 46 storey for 3SM for hexagrid models.
- Base shear is reduced by 6.24% in 13 storey, 6.03% in 37 storey and 5.80% in 46 storey for 3SM in diagrid models.
- Base shear is reduced by 5.71% in 13 storey, 6.10% in 37 storey and 5.73% in 46 storey for 3SM in pentagrid models.
- Base shear is reduced by 2.82% in 13 storey, 6.12% in 37 storey and 5.89% in 46 storey for 3SM in hexagrid models.
- Time period is reduced by 15.10% in 13 storey, 4.12% in 37 storey and increased by 1.17% in 46 storey for 3SM in diagrid models.
- Time period is reduced by 10.77% in 13 storey and increased by 6.26% in 37 storey and 4.83% in 46 storey for 3SM in pentagrid models.
- Time period is reduced by 2.82% in 13 storey and increased by 0.68% in 37 storey and 5.56% in 46 storey for 3SM in hexagrid models.

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