Parametric Study of Conventional, Diagrid and Hexagrid Structural Systems

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Abstract

Moment resisting frames, shear wall systems, bracing systems, space trusses, tubular structures, and other structural systems are used to design tall buildings. Diagrid is a modern structural technology that is being used to develop tall buildings. A parametric comparison of simple frame construction, diagrid, and hexagrid structural systems is conducted in this project. For simple frame buildings, diagrid and hexagrid structural systems, the 13, 37, and 46-storey structure with shear wall was modelled and analyzed. A shear wall with a thickness of 230 mm is used. A total of 18 structures are modelled and analyzed. The modelling and analysis are done using ETABS. The response spectrum method is used for earthquake dynamic analysis, and the wind dynamic analysis is used for wind dynamic analysis. Maximum storey displacement, maximum storey drift, base shear, and fundamental time period parameters for all models are compared in the analysis. The diagrid construction is found to be better than the bare structure, in terms of stiffness, rigidity and responses.

Keywords
Diagrid, Hexagrid, shear wall, storey displacement, base shear, fundamental time-period and story drift and structural systems.

1. Introduction
A high-rise building's structural system is designed to withstand vertical gravity loads as well as lateral loads caused by wind or seismic activity. All other members are referred to as non-structural members because they do not form part of the structural system. In structural engineering, the term 'structural system' or 'structural frame' refers to a structure's load resisting subsystem. Loads are transferred through the structural system by interconnected structural components or members. Due to rapid urbanization and population growth, the cost of land is rapidly increasing, and land availability has become a constraint for developers and builders. As a result, vertical growth appears to be a natural process. Controlling lateral responses while keeping constructability and cost in mind has become the order of the day for structural engineers. The increased wind pressure caused by the building's large, exposed area, the high intensity of the wind at higher elevations, and the earthquake loads all contribute to the bulk of structural forces. Recent developments in tall building design bring new challenges to structural designers, in addition to the classic needs for strength, stiffness, ductility, and system efficiency. The tube concept is used in structural configurations that best satisfy the typical demand of strength and stiffness for tall buildings.

2. Literature Review
Moona (2011), The performance of diagrid systems used for complex-shaped tall buildings such as twisted, tilted, and freeform towers is investigated in this paper. Diagrid structures are widely used for tall buildings today because of their structural efficiency and architectural potential. This study made use of metric structural models. Kani et al (2013) studied plan of 36 story diagrid steel building. A normal floor plan of 36 m × 36 m size is thought of. ETABS programming is utilized for demonstrating and investigation of structure. All underlying individuals are planned utilizing IS 800:2007 thinking about all heap blends. Burden dispersion in diagrid framework is likewise read for 36 story building. Likewise, the investigation and configuration consequences of 50, 60, 70 and 80 story diagrid structures are introduced. From the review it is seen that a large portion of the parallel burden is opposed by diagrid segments on the outskirts, while gravity load is opposed by both the inner segments and peripherial inclining segments. In this way, inner sections should be intended for vertical burden as it were. Because of expansion in switch arm of peripherial a skew sections, diagrid primary framework is more powerful in horizontal burden obstruction. Horizontal and gravity load are opposed by hub power in corner to corner individuals on outskirts of structure, which make framework more powerful. Diagrid primary framework gives greater adaptability in arranging inside space and exterior (Deepika et al. 2016) Tall buildings' load action differs

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significantly from that of low-rise buildings. Many lateral load resisting systems are classified as either interior or exterior structures. Diagrid and hexagrid systems are classified as external structures because they are installed on the outside of buildings Mashhadiali et al. (2014) This research was carried out in order to design two types of 28-story and 48-story building models that could withstand wind loads for both structural systems. According to the analytical results, the hexagrid has sufficient potential for force redistribution due to its unique configuration.

Mele et al. (2021), This study gives a preliminary understanding of tube layouts for tall buildings based on unconventional structural pattern geometries. Sorathiya et ai. (2017), A stiffness-based design methodology for determining preliminary member sizes of r.c.c diagrid structures for tall buildings is presented in this paper. A G+24, G+36, G+48, G+60 storey RCC building with a plan size of 18 m 18 m located in Surat is being considered for wind and seismic analysis. STAAD. Pro software is used for structural member modelling and analysis (Rahimian, 2016, Cascone et al. 2021, Giovanni et al. 2014).

3. Methodology

In this comparative study has been carried out by modelling the building in ETABS such as simple frame building, diagrid structural system building and hexagrid structural system building.

3.1 Modelling data

Table 1. Modeling Data

Plan dimension	(36 X 36) m
Number of storey	13, 37, 46
C-C Spacing between column	6 m
Floor to floor height	3.5m
Location of building	Mumbai
Structure utility	Commercial
Seismic zone	3
Seismic coefficient	0.16
Response reduction factor	5
Importance factor	1.2
Wind speed	44 m/s
Structure type	C
Analysis method	• Dynamic analysis(RSM) • Wind dynamic analysis
Codes used	• IS 456-2000, • IS 800-2007. • IS 875-2015. • IS1893 Part 1-2016

3.2. Design data

For all the types of buildings 450*450 mm concrete sections have been used as beam sections. For all the three types of buildings 450*600 mm concrete section have been used as column sections for exterior. For all three types of building 450*450 mm concrete section have been used as column section for interior. For diagrid and hexagrid structural systems the grids are provided as pipe section of 400 mm diameter and 10 mm thickness. For all three types of structural systems shear wall of size 230 mm thickness is used. Floor finish of 1.5 kN/m^2 is applied on all the story.

Live load of 3 kN/m^2 and 2kN/m^2 is applied on all story except terrace level and terrace level respectively.
Wall load of 12kN/m and 7kN/m as parapet wall load is applied on the story (Figure 1-8).

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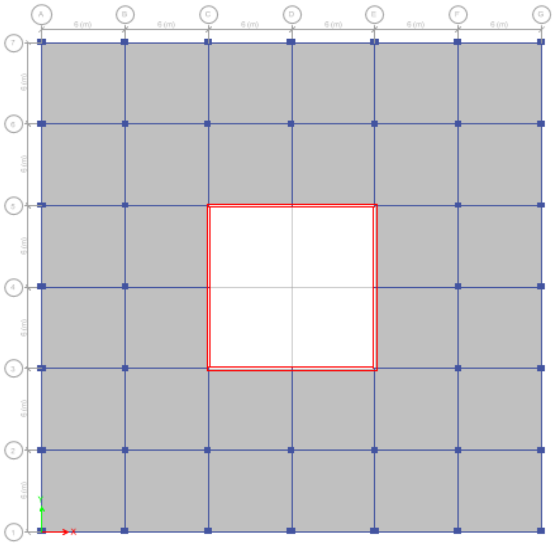

Figure 1. Floor plan of bare structure

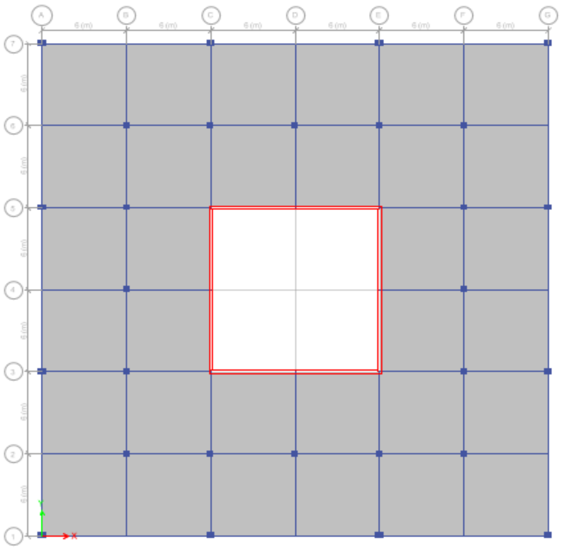

Figure 2. floor plan of diagrid and hexagrid Structural system

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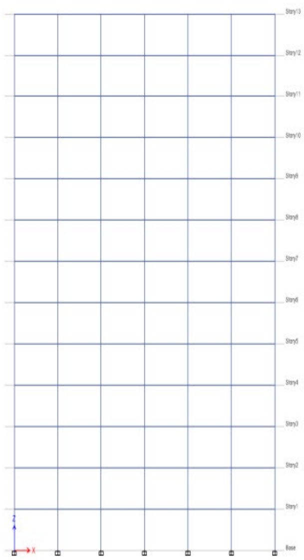

Figure 3. Elevation of bare Structure

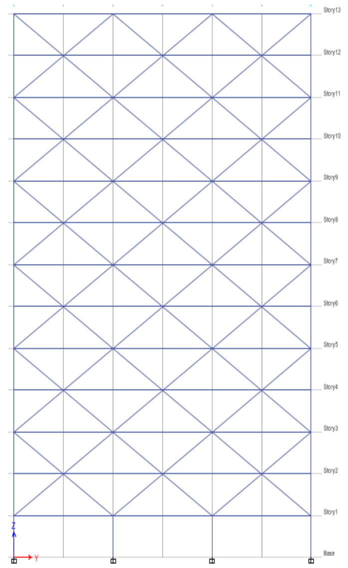

Figure 4. Elevation of 2 storey module (2SM) diagrid

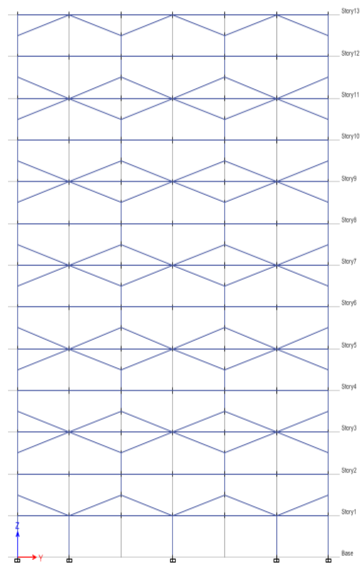

Figure 5. Elevation of 2 storey module (2SM) hexagrid

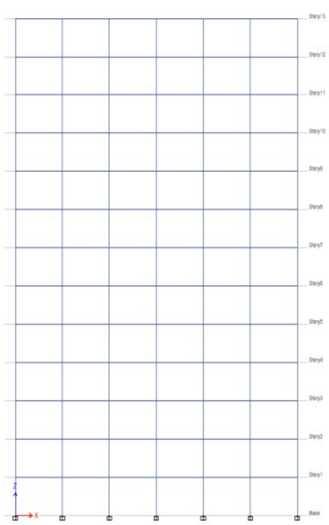

Figure 6. elevation of bare Structure

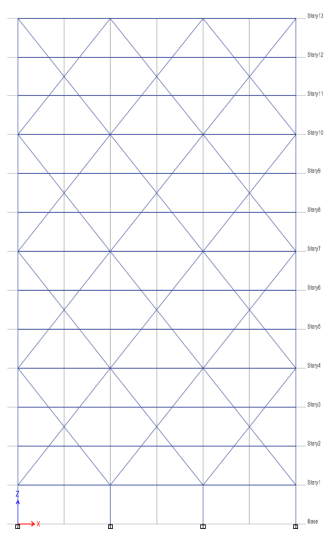

Figure 7. elevations of 3 storey's module (3SM) diagrid

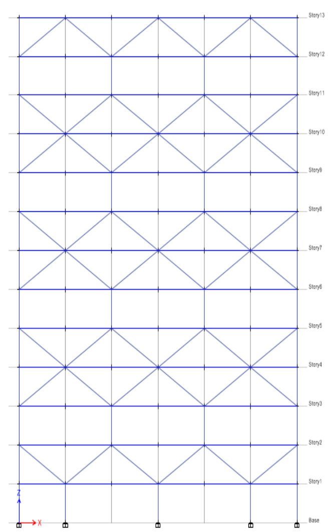

Figure 8. elevation of 3 storey module (3SM) hexagrid

4. Results and Discussion

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 bare, diagrid and hexagrid structural systems for 13 storey, 37 storey and 46 storey buildings for both 2SM and 3SM (Table 2-7).

Table 2. Percentage reduction in maximum storey displacement in RSM

Storey level	13		37		46	
Module	2SM	3SM	2SM	3SM	2SM	3SM
Diagrid	28.83	29.61	21.75	23.63	2.20	4.10
Hexagrid	18.23	23.22	14.30	17.19	1.80	3.80

Table 3. Percentage reduction in maximum storey displacement in WIND

Storey level	37		46	
Module	2SM	3SM	2SM	3SM
Diagrid	10.10	13.16	2.28	4.47
Hexagrid	2.20	3.70	1.30	2.39

Table 4. Percentage reduction in maximum storey drift in RSM

Storey level	13		37		46	
Module	2SM	3SM	2SM	3SM	2SM	3SM
Diagrid	27.78	36.59	4.89	6.68	3.71	5.49
Hexagrid	9.90	13.56	3.58	5.10	1.82	3.97

Table 5. Percentage reduction in maximum storey drift in WIND

Storey level	37		46		
Module	2SM	3SM	2SM	3SM	
Diagrid	18.56	20.40	6.60	9.89	
Hexagrid	8.39	10.23	1.96	3.01	

Table 6. Percentage reduction base shear in RSM

Storey level	13		37		46	
Module	2SM	3SM	2SM	3SM	2SM	3SM
Diagrid	5.90	6.78	5.39	6.23	5.09	5.87
Hexagrid	5.30	6.30	5.03	5.85	4.89	5.13

Table 7. Percentage reduction in fundamental time period in RSM

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Storey level	13		37		46	
Module	2SM	3SM	2SM	3SM	2SM	3SM
Diagrid	16.84	17.48	7.49	11.27	4.64	6.81
Hexagrid	9.36	11.37	5.78	7.29	1.49	2.39

1. for 13 storey, 37 storey, & 46 storey building diagrid structural system is better than bare and hexagrid structural systems, 3SM gives better results than 2SM for maximum storey displacement, maximum storey drift, base shear and fundamental time period parameters.
2. 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.
3. Results are compared with regular bare frame models
4. Maximum storey displacement is reduced by 29.61% in 13 storey, 13.16% in 3SM37 storey and 4.47% in 46 storey for 3SM for diagrid models.
5. Maximum storey displacement is reduced by 23.22% in 13 storey, 3.70% in 3SM37 storey and 2.39% in 46 storey for 3SM for hexagrid models.
6. Maximum storey drift is reduced by 36.59% in 13 storey, 20.40% in 37 storey and 9.89% in 46 storey for 3SM for diagrid models.
7. Maximum storey drift is reduced by 13.56% in 13 storey, 10.23% in 37 storey and 3.01% in 46 storey for 3SM for hexagrid models.
8. Base shear is reduced by 6.78% in 13 storey, 6.23% in 37 storey and 5.87% in 46 storey for 3SM in diagrid models.
9. Base shear is reduced by 6.30% in 13 storey, 5.85% in 37 storey and 5.13% in 46 storey for 3SM in hexagrid models.
10. Time period is reduced by 17.48% in 13 storey, 11.27% in 37 storey and 6.81% in 46 storey for 3SM in diagrid models.
11. Time period is reduced by 11.37% in 13 storey, 7.29% in 37 storey and 2.39 % in 46 storey for 3SM in hexagrid models.

5. Conclusions

In this study, the comparison between bare frame structure, diagrid building and hexagrid building is done using response spectrum and dynamic wind analysis method. For this, 13, 37 and 46 strey building is modelled in ETABS and responses in terms of base shear, fundamental time period, maximum storey displacement, maximum storey drift are calculated. The general conclusions from this study are for 13 storey, 37 storey, & 46 storey building diagrid structural system is better than bare and hexagrid structural systems, 3SM gives better results than 2SM for maximum storey displacement, maximum storey drift, base shear and fundamental time period parameters.

References

Cascone, Francesco, et al. "A Structural Grammar Approach for the Generative Design of Diagrid-Like Structures." Buildings 11.3 , 90, 2021.

Deepika, R. "Performance Study of High Rise Buildings with Diagrid and Hexagrid Systems under Dynamic Loading." International Journal of Engineering Science and Computing 2.6, 114-121, 2016.

Giovanni Maria Montuori, Elena Mele, Giuseppe Brandonisio, Antonello De Luca, "Secondary Bracing Systems For Diagrid Structures In Tall Buildings", Engineering Structures 75, 477–488, 2014.

Jani, Khushbu, and Paresh V. Patel. "Analysis and design of diagrid structural system for high rise steel buildings." Procedia Engineering 51, 92-100, 2013.

Mashhadiali, Niloufar, and Ali Kheyroddin. "Progressive collapse assessment of new hexagrid structural system for tall buildings." The Structural Design of Tall and Special Buildings 23.12, 947-961, 2021.

Moon, Kyoung Sun. "Diagrid structures for complex-shaped tall buildings." Procedia Engineering 14,1343-1350, 2011.

Rahimian, Ahmad Stability of Diagrid Structures", International Journal of High-Rise Buildings December, Vol 5, No 4, 263-270, 2016.

Sorathiya, Ravi, and Pradeep Pandey. "Study on diagrid Structure of Multistorey Building." Development 4.4, 2017.

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