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A Review of Comparison between Frame Structure & Diagrid under Seismic & Wind Load

Kush Prajapati[1], Dharam Unadkat [2], Aakash Suthar[3]

[1]*M.Tech Student, L.J. University, Ahmedabad.*
[2]*Dharam Unadkat, Assistance Professor, Civil Engineering Department, L.J. University, Ahmedabad, Gujarat, India.*
[3]*Aakash Suthar, Assistant Professor, Civil Engineering Department, L.J. University, Ahmedabad, Gujarat, India.*

Abstract - *A diagrid structure is an architectural structure. It is diagonally intersecting members, usually forming a triangular structure. This design improves safety standards and increases the efficiency of distribution. The Diagrid concept refers to the sustainability and innovation of infrastructure by providing high-performance standards and unique designs in modern buildings. Diagrid structures are commonly used for skyscrapers and other large buildings due to their ability to efficiently distribute loads reduce material usage, and offer a visually striking appearance. The project entails the planning, analysis, and design of an institutional building made of steel materials. The analysis and design process includes structural planning, load calculation, 3D modeling with Etabs. The equivalent static and time history analysis method are carried out in terms of displacement, story drift ratio and base shear using ETABS software and compared to a regular building.*

Key Words: **Diagrid Structural System, Time History Method, Displacement, Base Shear, Drift Ratio, Time Period, ETABS**

1. INTRODUCTION

The construction of tall buildings is increasing day by day, so safety assessment and construction are required for high-rise buildings, as the height of the structure increases, the lateral load is also very important according to the protection structure to carry gravity loads. Structures commonly used for interior structures include rigid frames, braced frames, shear walls, and support structures, while exterior structures include tubular, diagrid, pentagonal, hexagonal, and octagonal grid structures. Diagrid is an exterior structural system in which all perimeter vertical columns are eliminated and consists of only inclined columns on the boundary of the building. The axial movement of these diagonals prevents shear forces and overturning moments from occurring compared to the bending of the vertical column frame tube. Vertical columns in the core are designed for carrying only gravity loads and the diagrid is useful for both gravity and lateral loading.

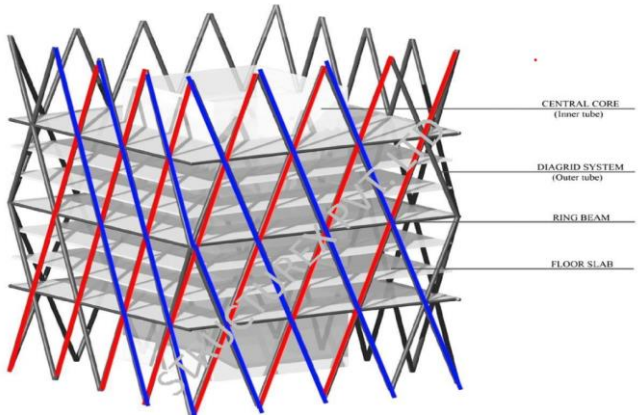

Figure 1 Diagrid of structure

1.1 Advantages of Diagrids

- The advantages of diagrid in building construction greatly enhance the beauty of the building.
- The use of diagrids can reduce steel by up to 20% compared to frame structure.
- The construction process is simple.
- The glass material can shed more light into the structure when used with diagrid.
- The exterior and interior of these models are mostly column-free and allow the use of customized floor plans.

1.2 Disadvantages of Diagrids

- This type of construction requires technical skill and current workers do not have ideas or knowledge of developing diagrids.
- A floor design language is achieved by stacking 2 to 6 floors on a diagrid.
- Only high-rise buildings can install diagrids.
- If diagrids are not properly designed or installed, it affects the economy and safety of the structure.

2. OBJECTIVES

1. Performance evaluation of a tall building (Irregular) with a Diagrid system.

2. To study the diagrid structure with plan regularity for seismic loading.
3. To study the diagrid structure for different diagonal angles and verticle columns.
4. To study the behavior of diagrid structures with plan regularity under seismic loading.
5. To study the parameters such as base shear, top story displacement, top story shear, time period, and story drift.
6. Compare the diagrid model with static regular frame building.

3. LITERATURE REVIEW

[1] Tirkey, N. and Kumar, G.R., 2020. Analysis on the diagrid structure with the conventional building frame using ETABS. Materials Today: Proceedings, 22, pp.514-518.

In this research paper, compares the diagrid structure and the conventional building using ETABS software mainly focusing on seismic and wind analysis parameters. The proposed work was done by the model of G+9, G+20, and G+30 story building. Also, check the displacement, story shear, and story drift.

This research paper concludes that as the height of the structure increases, the lateral load-resistant system can withstand gravity better than the structure. The configuration and efficiency of the diagrid system reduce the number of structures. The ETABS software is used to design and analyze the results such as axial, shear, and bending moments. Diagrid structures are more likely to collapse due to severe vibration during an earthquake than traditional structures.

[2] Shah, M.I., Mevada, S.V. and Patel, V.B., 2016. Comparative study of diagrid structures with conventional frame structures. Int J Eng Res Appl, 6(5), pp.22-29. R. Nicole, "Title of paper with only first word capitalized," J. Name Stand. Abbrev., in press.

In this research paper, compares the diagrid structure and the conventional building using ETABS software. Examine the main effects of external forces such as wind and seismic forces on the diagrid system. While components such as columns, beams, and diagrids are provided with steel material, floors are considered RCC. Composite boxes are used for the construction of diagrids and columns and Indian Standard I-sections are used for the construction of beams. In this study, various parameters such as simple time, maximum upper displacement, maximum base shear force, steel weight, steel weight difference percentage, height maximum story displacement, and maximum story displacement were determined.

This research paper concludes that Diagrid structural systems have better solutions for systems that will withstand external loads of moving objects, heavy steel, and rigidity. It is tight enough to resist wind at high altitudes. Displacements on each story and story drifts are observed to be less in diagrid systems as compared to the conventional frame.

[3] Gorle, A.V. and Gowardhan, S.D., 2016. Optimum performance of diagrid structure. IJER, Volume, (05).

In this research paper, For modeling and analysis of building ETABS software is used. A total of five building models are constructed in ETABS software. In this paper, five diagrid models are constructed by differing diagrid angular orientations 50 11'24'', 67 22'12", 74 28'12", 78 13'48" and 82 5'24" angular orientation of diagrid members and observe the performance of diagrid structure in terms of story displacement, story drift and modal time period.

- Building Configuration

1. Plan - 35.244 x 35.244 m
2. Storey height - 3.524 m
3. Beam - Symmetric I section
   Flange = 180 x 40 mm
   Web = 430 x 40 mm
4. Column
   Flange = 1300 x 50 mm
   Web = 1410.10 x 50 mm
   A = 217 mm
5. Diagrid member
   Pipe – 450mm
   Thickness – 25mm
6. Slab – 130mm

This research paper concludes that Analyzing the above results, it can be concluded that 67 22'12" angle diagrid model is better than other angles. From the results, it can be concluded that the performance of the structure depends on the stiffness of the diagrid elements. The stiffness of the diagrid element depends on the angular direction, length, area, and material of the element. If the materials and areas of the elements are similar, the stiffness of the diagrid structure depends on the angular direction and can be used for a long time.

[4] Panchal, N.B., Patel, V.R. and Pandya, I.I., 2014. Optimum angle of diagrid structural system. International Journal of Engineering and Technical Research, 2(6), pp.150-157.

In this research paper, the comparison study of 24-story, 36-story, 48-story, and 60-story diagrid structural systems with a diagrid angle of 50.2°, 67.4°, 74.5°, and 82.1° is presented here. The comparison of analysis of top story displacement, story drift, time period, angle of diagrid, and steel and concrete consumption is presented here.

This research paper concludes that Diagrid angles in the range of 65° to 75° give the diagrid system a more rigid structure that shows less ground movement. In regions where the diagrid angle is between 65° and 75°, inter-story drift and inter-story shear occur are much smaller. It should be noted that the result for the diagrid angle of 82.1° is quite random with story drift, story shear and time.
When the increase in floors means that the building height also increases, diagrid angles between 65° and 75° give better results in terms of upper displacement, displacement floor, shear floor, time and material.

[5] Jani, K. and Patel, P.V., 2013. Analysis and design of diagrid structural system for high-rise steel buildings. Procedia Engineering, 51, pp.92-100.

In this research paper, analysis and design of 36 story diagrid steel building. Also, the analysis and design results of 50, 60, 70, and 80 story diagrid structures are presented. They analyze the angle of diagrid is 74.5

This research paper concludes that the study found that most of the external loads were carried by the external beams, while gravity was carried by both the internal and external diagrid lines. So, internal columns need to be designed for vertical load. The cross-grid construction system is more effective in protecting the external load due to the increase in the diagonal arms of the cross. Lateral and gravity loads are resisted by the axial forces of the circumferential diagonal elements of the model, making the system more efficient.

[6] Nawale, U.A. and Kakade, D.N., 2017. Analysis of diagrid structural system by E-Tab. *Int Adv Res J Sci Eng Technol*, *4*(6), pp.193-196.

In this research paper, high-story buildings are increasing rapidly due to a lack of land. The design of high-rise buildings is affected by lateral loads caused by wind or earthquakes. The lateral load resistance of the structure is provided by wall load, shear walls, braced piers, and tube systems. In recent years, bidirectional grid-cross grid systems have been widely used in high-rise buildings due to their good performance. This study presents of a 32-story grid without vertical lines on the exterior of the building. Here, we present an analysis and comparison of layer removal and layer drift results.

- ❖ Building configurations

1. Story – 32m
2. Building height - 95m
3. Story height - 3m.
4. Column sizes - 300X600 and 230X600
5. Beam size - 230X450
6. Diagonal member's (Digrid) - 23mmx 230 mm
7. Live load and - 3kN/m2
8. Dead load - 1kN/m2
9. Earthquake load zone factor - 0.16,
10. Soil type – III
11. Importance factor – 1
12. Response reduction - 5 as per IS-1893-2002
13. Wind load - 39m/s
14. Terrain category – 3

This research paper concludes that that external variation is higher in dynamic analysis data than in static analysis data. It was determined that the wind analysis results were lower than the dynamic field spectrum analysis and higher than the static analysis.

Structural efficiency: Diagrid buildings have less external displacement and less energy than conventional buildings.

Material Savings: The volume of stone used in both buildings is estimated. Same, but diagrid steel is more economical in use. Diagrid buildings can save approximately 33% steel without affecting structural performance.

Better lateral load resistance: Diagrid grating has better lateral load resistance due to the diagonal of its perimeter so that the interior is relaxed and carries only gravity loads. In traditional buildings, both interior and exterior lines are designed according to gravity and lateral loads.

Aesthetics: The fact that diagrid structures have a more beautiful appearance than traditional buildings becomes important for high-rise buildings.

[7] Mashhadiali, N. and Kheyroddin, A., 2013. Proposing the hexagrid system as a new structural system for tall buildings. The Structural Design of Tall and Special Buildings, 22(17), pp.1310-1329.

In this research paper, a new technique called hexagonal truss structure. Models using four different diagonal diagrid systems and hexagonal grid systems were created for 30, 50, 70 and 90-storey buildings. Unlike the diagrid system, where there are many hexagonal grids in the building area. The system uses a diagrid and hexagonal grid system consisting of four different diagonals, designed to use strength and stress-based methods for buildings of 30, 50, 70, and 90 floors to withstand wind. In this study, the seismic

performance of the 30-story diagrid structure and the hexagonal grid structure was evaluated using nonlinear static and dynamic analyses. The computer software used to analyze and design the model was **SAP2000, 2009.**

1. Story height – 4m
2. Width – 28m
3. Beam span – 7m
4. Beam spacing – 3.5m
5. Floor live load – 500kg/m2
6. Floor dead load – 600kg/m2

This research paper concludes that In diagrid models with a ratio less than 7, the required hardness is given by the best angles between 60° and 71° and above 71°. By increasing the diagonal angle, the forces of elements resulting from the shear forces will be increased. That's why diagonal angle become greater in size. Using similar bracing techniques in both systems will increase the strength of the six-grid grid by approximately three times compared to the diagrid grid. Therefore, it can be concluded that hexagonal carrier systems can enforce the height limit better than diagrid systems in high-rise buildings.

4. CONCLUSION

Diagrid structures represent a compelling fusion of architectural aesthetics and structural efficiency. Extensive research and case studies have demonstrated their advantages in terms of enhanced lateral stability, reduced material usage, and the ability to create iconic and visually striking buildings.

The widespread use of diagrid frames, especially in high-rise buildings, shows that they are simple and beautiful in different contexts. However, challenges persist in terms of detailing complex connections, fabrication precision, and potential material limitations.

As technology advances, the scope of diagrid applications may expand, with innovations in materials and construction methods. The continued exploration of sustainable alternatives and the integration of diagrids in smart building designs could further redefine their role in the evolving landscape of architecture and engineering.

In essence, the success of diagrid structures lies not only in their structural facility but also in their ability to captivate the imagination and push the boundaries of what is architecturally achievable. Continued research, collaboration between architects and engineers, and a commitment to refined construction practices will likely shape the future direction of diagrid structures in the built environment.

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[3] Gorle, A.V. and Gowardhan, S.D., 2016. Optimum performance of diagrid structure. IJER, Volume, (05).

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