Comparative study of Diagrid System with Conventional Framed Structure

Mayur Navasare[1], Prof. Rohan Choudhary[2]

[1] M. Tech, Student, Dept. of Civil Engineering, School of Engineering and Technology, Sandip University, Nashik, Maharashtra, India
[2]Assistant Professor, Dept. of Civil Engineering, School of Engineering and Technology, Sandip University, Nashik, Maharashtra, India

---***---

Abstract - *Nowadays, India's population is increasing day by day and soon India will be the most populated country in recent coming years. People go to urban cities for career growth and there they face fewer land spaces with higher prices for living purposes. So, its civil engineers' duty and responsibility to construct a tall building in less space with safety throughout its life. So, diagrid structures becoming a solution over this for tall buildings with a good aesthetic view of the economy. In this paper, a comparative study of the diagrid system with conventional framed structure is carried out through static and dynamic analysis on different gravity and different lateral loads on symmetrical buildings diagrid and conventional with (42 X 42) m in plan and with a height of 82m of G+25 storey by ETABS 2019. Various parameters are carried out such as storey stiffness, the seismic weight of building and base shear, maximum storey displacement, maximum storey drifts, time period and frequencies for comparative study. This concludes that the Diagrid structure is far better than the conventional structure in all parameters and also because of the less seismic weight of the building, the foundation load will be less so finally the diagrid structure is more economical than the conventional structure. Diagrid system is used 20% less steel as compared to conventional structures.*

Key Words: Comparative Study, Conventional Framed Structure, Diagrid System, Dynamic Analysis, ETABS

1. INTRODUCTION

Diagrids are load-bearing structures in which diagonal members are formed as a framework made by the intersection of different materials like metals, concrete, or wooden beams which are used in the construction of buildings and roofs. Diagrid structures of the steel members are efficient in providing a solution for both strength and stiffness. The Diagrid also removes the need for large corner columns and provides a better distribution of load. Recently study shows that the application of diagrid used in large-span and high-rise buildings are increasing.[1].

Nowadays, with the increasing population, we have limited space for living purposes and that's why a civil engineer needs to focus on stiffer, lighter, and new technology-savvy methods for construction. Until now, tall buildings have been built in an angular, round, or slightly modified form, with their technology focused on height, rather than shape. But the Diagrid structure is becoming a solution for limited space and limitations of the height of building with complex geometries and curved shapes. A recent study shows that the Diagrid structural system is becoming more popular in the design of tall buildings due to its structural and architectural advantages. [2]

The Diagrid structure is the method in which vertical columns are eliminated and only inclined columns on the façade of the building carry both gravity loads as well as lateral loads. Shear and overturning moments developed are resisted by axial action of these diagonals compared to bending of vertical columns in framed tube structure. The diagonal members in diagrid structures act both as inclined columns bracing elements and due to Usage of steel is also reduced nearby 20% (1/5th) compare to a conventional building. [3]

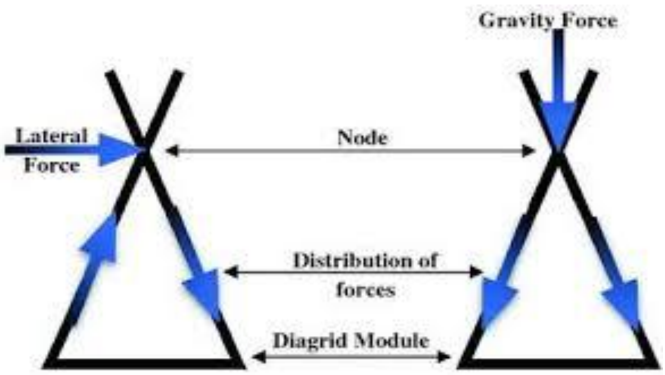

Fig -1: Distribution of Forces of Diagrid System by Triangulation

1.1 Types of Diagrid Structural System

a) Steel Diagrid Structural System

The most common and popular material used in the Diagrid system is Steel. The sections commonly used are rectangular HSS, rounded HSS, and wide flanges. The weight and size of the sections are made to resist high bending loads. They can be easily erected and the labor is also low.

b) Concrete Diagrid Structural System

The most common material in the diagrid system is concrete. The concrete diagrids are used both in precast and cast-in-situ. As the precast sections are more flexible, it allows them to fit in the structure geometry.

c) Timber Diagrid Structural System

The materials which are least used in diagrid system is timber also it has many disadvantages. The only advantage is that it is easily available in any shape and size and the installation cost is low. Timber has low strength. It has durability and weathering issues.

1.2 History

The Shukov tower in Plibino is the world's first diagrid hyperboloid structure designed by Russian engineer and architect Vladimir Shukhov in 1986 and built in the period between 1920 to 1922 at 160m in height. Its steel shell experiences minimum wind load.

Fig -1.2: First Diagrid Hyperboid Structure

2. METHODOLOGY

The physical properties and data of the building and other data related to analysis are formulated in the table as follows:

Table -2.1: Building Details

Dimensions of Building	42m X 42m
Height of Building	82m
No. of Storeys	G+25
Storey Height	3.3m
Type of Structure	Compare Diagrid System and Conventional System

Table -2.2: Building Materials

Grade of Concrete	M40 and M50
Rebars	HYSD 500 and HYSD 550
Steel	Fe345
No Structural Walls	Light Weight Blocks
Glazing Panels	Glass Sheets

Table -2.3: Section Properties

Beams	ISWB 600 of Fe345
Columns	Circular 1000mm of M50
Braces (Diagrid System)	Steel Tube 1100X1100X30
Shear Walls	300mm thick of M50
General Slab	200mm thick of M40

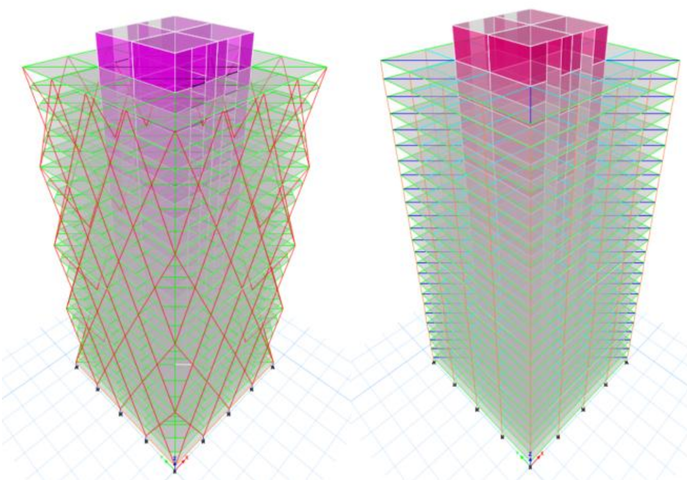

Fig -2.1: 3D view of G+25 (82m height) Diagrid Structure and Conventional Structure

3. RESULTS

1) Design Base Shear and Seismic Weight of Building

The following table shows that seismic weight is more of a conventional structure as compared to diagrid structure in both the x and y direction, due increase in the weight of building its obvious that the design base shear will be more by formula VB = Ah X W by IS1893(Part 1): 2016.

And if we compare both weights of buildings, nearby 14% weight is more of the conventional system so an increase in weight of the building will increase the foundation as well as in cost also.

Table -3.1: Seismic Weight of a Building and Base Shear

	Diagrid		Conventional	
Name	EQx	EQy	EQx	EQy
Seismic weight, W	519936.44	519936.44	601701.79	601701.79
Design Base Shear, VB	20696	20696	23950.67	23950.67

2) Maximum Lateral Loads to Storeys

The following table shows the maximum lateral loads to both diagrid and conventional structure which acts on storey 24 to storey 26 of earthquake and wind loads in direction of x and y. Nearly the values of lateral loads for all are almost the same and the unit is force, kN.

Table -3.2: Maximum Lateral Loads to Storeys

	EQy	EQy	WLx	WLy
Diagrid	2687.77	2687.77	576.22	576.22
Conventional	2637.26	2637.26	557.43	557.43

3) Maximum Storey Displacement

Maximum storey displacement is the storey displacement with respect to the base of the building. The below figures show that conventional structure always has higher displacement than diagrid structures on earthquake load in x direction.

Fig -3.3a: Maximum storey displacement due to EQy on Diagrid

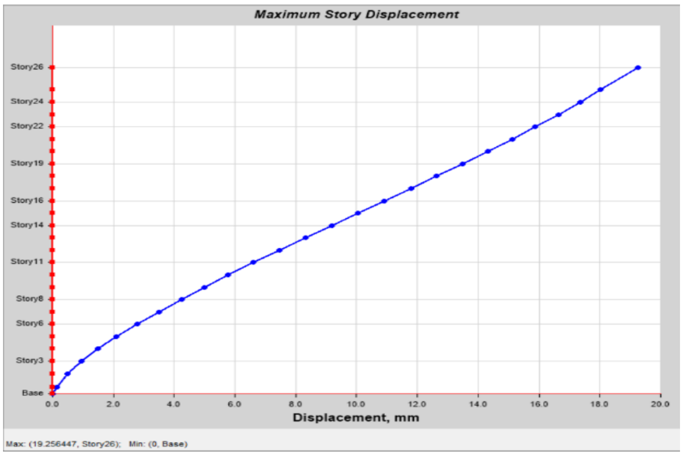

Fig -3.3b: Maximum storey displacement due to EQy on Conventional

4) Maximum Storey Drift

The below figures show that conventional structures always have maximum storey drift than diagrid structures on earthquake load in x direction

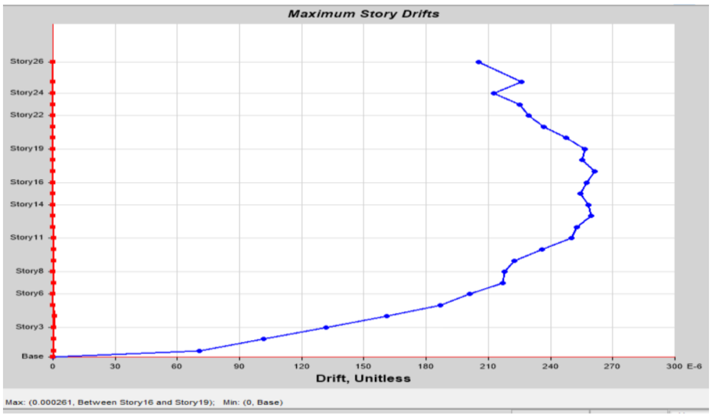

Fig -3.3a: Maximum storey drift due to EQx on Diagrid

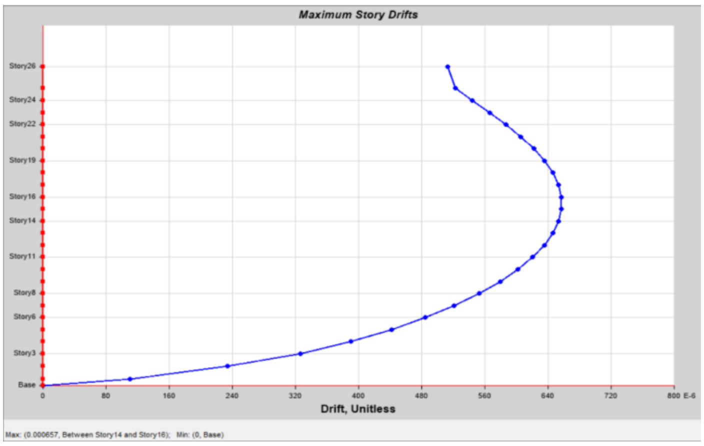

Fig -3.3b: Maximum storey drift due to EQx on Conventional

5) Time Period and Frequency

The time period (T)is the time taken by any building to complete one cycle of oscillation, its unit is second. Less time period indicates more stiffness. It is indirectly proportional to stiffness. Frequency (n) is reciprocal of time period is a number of vibrations per second are frequency, its unit is Cyc/sec or Hz.

Table -3.5a Time Period and Frequencies of Diagrid Structure

Case	Mode	Period sec	Frequency cyc/sec
Modal	1	0.897	1.115
Modal	2	0.85	1.177
Modal	3	0.534	1.873
Modal	4	0.261	3.829
Modal	5	0.224	4.474
Modal	6	0.177	5.64
Modal	7	0.134	7.45
Modal	8	0.109	9.144
Modal	9	0.106	9.426
Modal	10	0.092	10.83
Modal	11	0.077	13.026
Modal	12	0.073	13.697

Table -3.5b Time Period and Frequencies of Conventional Structure

Case	Mode	Period sec	Frequency cyc/sec
Modal	1	1.877	0.533
Modal	2	1.415	0.707
Modal	3	1.307	0.765
Modal	4	0.498	2.007
Modal	5	0.392	2.551
Modal	6	0.304	3.292
Modal	7	0.24	4.161
Modal	8	0.195	5.127
Modal	9	0.154	6.511
Modal	10	0.141	7.089
Modal	11	0.129	7.772
Modal	12	0.111	8.983

3. CONCLUSIONS

1)Diagrid structures have more storey stiffness than conventional structures in both static and dynamic analysis.

2) Because conventional has 15 % more seismic weight than diagrid structures, they will be more uneconomical than diagrid.

3) Only the lateral force earthquake and wind load act a little bit more on diagrid structures.

4) Conventional structures have more storey displacement and storey drifts compared to diagrid on earthquake load in x direction.

5) Also, the time period of conventional structures is more than diagrid. Because time period is inversely proportional to stiffness, it also indicates that diagrid is stiffer than conventional.

6) Finally, the Diagrid system is more powerful than conventional framed structures in all parameters.

REFERENCES

[1] Harish Varsani, Narendra Pokar and Dipesh Gandhi, "Comparative Analysis of Diagrid Structural System and Conventional Structural System for High Rise Steel Building", IJAREST, Volume 2, Issue 1, January-2015.

[2] Manthan I. Shah, Snehal V. Mevada, Vishal B. Patel, "Comparative Study of Diagrid Structures with Conventional Framed Structures", IJERAA, ISSN: 2248-9622, Vol. 6, Issue 5, (Part-2) May 2016. pp. 22-29

[3] Neha Tirkey and G. B. Ramesh Kumar, "Analysis on the diagrid structure with the conventional building frame using ETABS", International Conference on Materials engineering characterization 2019.

[4] Jayesh Akhand, Dr.J. N Vyas, "Comparative Study of Different shapes of Diagrid Structure System with Conventional System using Response Spectrum Analysis", International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056 Volume: 06 Issue: 04, Apr 2019.

[5] Khushbu Jania, Paresh V. Patel, "Analysis and Design of Diagrid Structural System for High Rise Steel Buildings," Procedia Engineering 51 (2013) 92 – 100

[6] Kyoung-Sun Moon, Jerome J. Connor and John E. Fernandez, "Diagrid Structural Systems for Tall Buildings: Characteristics and Methodology for Preliminary Design," The Structural Design of Tall and Special Buildings Struct. Design Tall Spec. Build. 16, 205–230 (2007)

[7] Narsireddy, Vinayak Vijapur, "Some Comparative Study on Steel Diagrid Structure with Conventional Steel Structure," International Research Journal of

Engineering and Technology (IRJET), Volume: 05 Issue: 07 | July-2018

[8] Neha Thakare, Dr. B. H. Shinde, "Comparative Study of Seismic Performance of Multistorey Diagrid Structures with Conventional Structures," International Journal of Innovative Science and Research Technology Volume 6, Issue 7, July – 2021

[9] Divya M. S.1, B. Saraswathy, "Comparative Analysis of High-Rise Steel Building With hexagrid, Diagrid and Conventional Structural System", International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056, Volume: 04 Issue: 04 | Apr -2017.

[10] Khushbu Jani, Paresh V. Patel (2013). "Analysis and Design of Diagrid Structural System for High Rise Steel Buildings", Elsevier, Procedia Engineering 51 (2013) 92-100.

[11] Kiran Kamath (2015), "A comparative study on a circular plan with different angles of diagrid", International Journal of Advanced Technology in Engineering and Science, 4(1), 226-236.

[12] Ravish Khan, S. B. Shinde, "Analysis of Diagrid Structure in Comparison with Exterior Braced Frame Structure", IJRET, Volume: 04, Issue:12, Dec-2015, Page No. 155-165.

[13] K. S. Moon, J. J. Connor, and J. E. Fernandez, (2007) "Diagrid structural systems for tall buildings: Characteristics and methodology for preliminary design," Struct. Des. Tall Spec. Build.

[14] Bhavani Shankar1, Priyanka M. V.," Comparative Study of Concrete Diagrid Building and Conventional Frame Building Subjected to Seismic Force," International Research Journal of Engineering and Technology (IRJET), Volume: 05 Issue: 06 | June -2018

[15] Ar. Megha Shroti, "Constructability of Diagrid Structures," International Journal of Engineering Research & Technology (IJERT), ISSN: 2278-0181, Vol. 6 Issue 05, May – 2017