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A Study on Obtaining Optimum Angle for Diagrid Structures

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Abstract - *In the present work a study on diagrid structures is done for finding out the optimum angle required for the diagrid structures. In this study a 40 storey steel diagrid structure with different diagrid module and different angle of diagrid is done. The building is considered same except the angle of diagonal members. From the pattern of results of this study it was concluded that the diagrid structure of 8 storey module has better results in terms of lateral displacement, storey drift, storey shear and time period. So, the diagrid structure of higher angle is giving better performance for resisting lateral loads in diagrid structural system.*

Key Words: **Diagrid Structural System, Optimum angle, Tall Structures, Lateral load Resisting System**

1. INTRODUCTION

The evolution of structural system concepts for tall structures has pushed us towards the need of achieving greater heights. For more than 100 years architects and structural engineers had come up with an ideas of designing and constructing buildings which has risen higher and higher. This continuous process has evolved so many outstanding advances and numerous new and innovative structural systems. Starting from the steel and reinforced concrete rigid frame at the end of nineteenth century which was 20 to 30 stories tall, today's structural advances allows the engineers to build structures more than 100 stories high using some advanced structural systems. In this process, many new ideas have emerged among which the relatively new and ground breaking high-rise diagrid structural system. The appearance of the diagrid structural system occurred as a result of the architectural appreciation of aesthetic potential of diagonal members which started with braced tube structures. The expansion of this concept without any vertical columns led to the birth of the diagrid structure.

"A diagrid is a framework of diagonally intersecting metal, concrete or wooden beams that is used in the construction of buildings and roofs. The diagrid obviates the need for columns and can be used to make large column-free expanses of roofing".

The diagrid structural systems are the evolution of braced tube structures. The major difference between a braced tube structure and a diagrid structure is that, there are no vertical columns present in the perimeter of diagrid building.

The diagrid structural system has been proved very effective in resisting lateral loads than the conventional framed system or any other system. Several Short case studies are presented here to explain the diagrid structural system. These studies also help in illustrating the versatility of diagrid structural system and its extensive architectural advantages.

Fig -1: (a) Capital gate, Abu Dhabi (b) Swiss Re building, London (c) Aldar Headquarter, Abu Dhabi

In the past, several diagrid structures are constructed all over the world. Some of the case studies on diagrid structures are presented here. Some of a recent examples of a diagrid structure are capital gate tower in abu dhabi, Aldar headquarter in abu dhabi, Swiss Re building in London, hearst tower in Newyork and many more diagrid buildings has been constructed all over the world in last few decades are shown in fig -1.

2. Literature Review

Moon, (2009) investigated the 40, 50, 60, 70 and 80 storey tall diagrid structures with uniform angle and varying angle diagrids for understanding the design procedure for diagrid structures. It was concluded that the structural efficiency of diagrids for tall buildings can be maximized by configuring them to have optimum grid geometries.

Moon, (2011) investigated the complexed shaped tall diagrid structures for finding impact of variation in results. The complexities are rate of twisting and angle of tilting for 60 storey tall diagrid structures. It was concluded that the highest performance is achieved in model with 2 degree of twisting per floor for diagrid structure. For the tilted towers the non-tilted tower gives the best performance.

Moon, Gerasmidis, Pantidis & Knickle, (2016) investigated the diagrid structure for obtaining the optimum angle and size of members required for the structure and also they studied the behaviour of axial forces on the diagonal members. It was concluded that this paper discusses the topic of tall building robustness and optimization, two major fields in tall buildings design.

Boake, (2014) studied the diagrid structures designed and constructed in last few decades. It explains the variations in the diagrid system that has evolved to the point of making its use non-exclusive to the tall building. It stated that diagrid construction is also to be found in a range of innovative mid-rise steel projects.

Kwon & Kim, (2014) investigated the progressive collapse resisting capacities of tall diagrid buildings based on arbitrary column removal scenario, and the seismic load resisting capacity for diagrid buildings. It was concluded that the analysis model structures were turned out to be safe against progressive collapse caused by arbitrary removal of one or two pairs of diagrids from the first storey.

3. Analysis and Design of 40 Storey Diagrid Structure

3.1 Building Configuration

The 40 storey tall steel diagrid and framed structures of 32 × 24m plan dimensions are modelled for study as shown in figure.1. The storey height of the structure is taken as 3m for the diagrid structures. For diagrid structure three modules are taken as 4 storey module, 6 storey module and 8 storey module for the structure.

The interior columns of the diagrid structure are designed only for gravity loads while the diagrid frame on the periphery of the structure is designed for gravity and lateral loading. The design dead loads and live loads on floor slabs are 3.75 kN/m^2 and 2.5 kN/m^2 respectively.

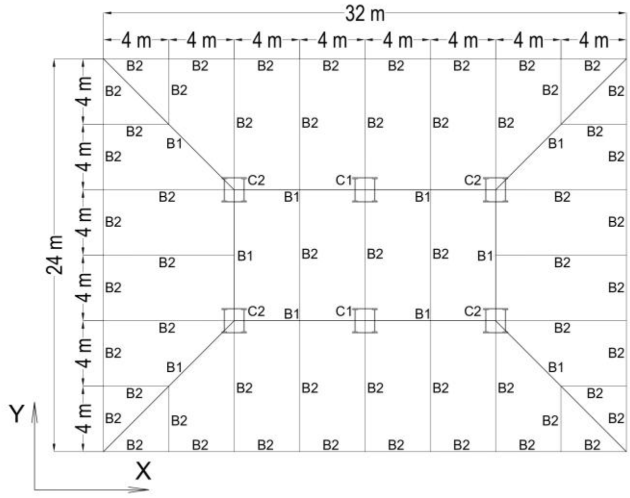

Fig -1: Floor Plan of a 40 storey tall diagrid structure

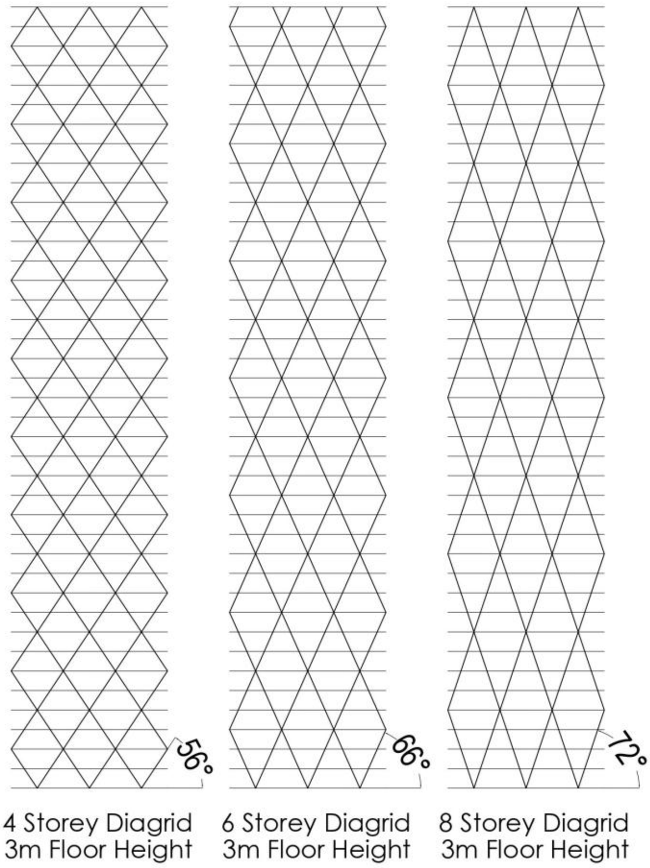

Fig -2: Elevation of diagrid structure with different diagrid modules

The design earthquake load is computed based on the zone factor of 0.16, medium soil, importance factor of 1.5 and response reduction factor of 5 based on the IS: 1893(Part-1)-2016. The dynamic along wind and across wind loading is computed based on the basic wind speed of 39 m/sec and terrain category III as per IS: 875(III)-2015 (Gust factor method). Modelling, analysis and design of diagrid as well as framed structures are carried out using ETABS software. The support conditions are assumed as hinged. All structural members are designed using IS: 800-2007. Secondary effects like temperature variation is not considered in the design, assuming small variations in inside and outside temperature. Based on this study the optimum angle for the diagrid structure is found out based on the results such as, lateral displacement, storey drift, storey shear, base shear and steel time period for different diagrid structures.

3.2 Results and Discussion

The analysis results in terms of lateral displacement, inter storey drift, storey shear and time period of diagrid structures are investigated here to decide the optimum angle required for the diagrid structure. These results are presented for the case of dynamic wind loading (WX &WY) because the deformations due to wind load has been higher than the deformations due to earthquake loads.

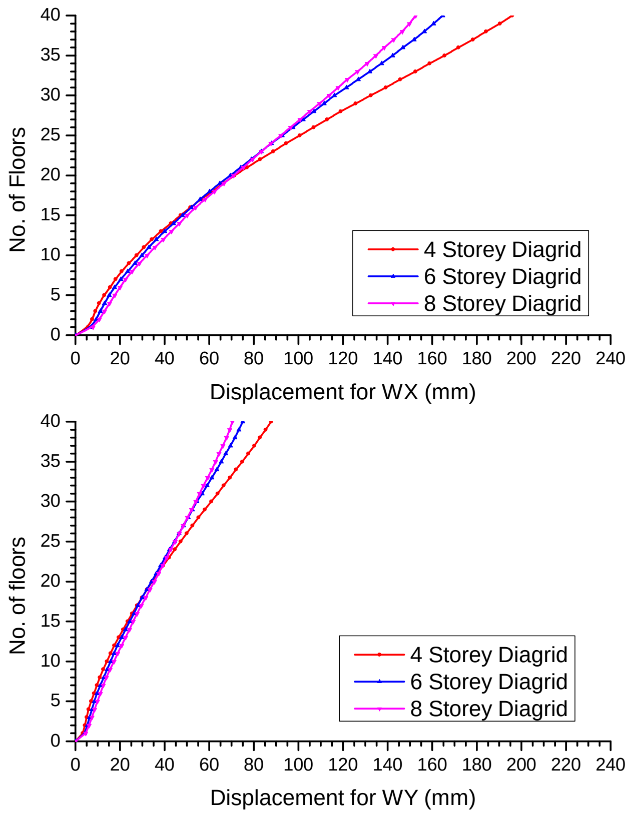

Chart -1: Lateral displacement for diagrid structures of different diagrid modules

The results of lateral displacement in X and y direction for diagrid structures of different modules are shown in chart 1. It is observed that the displacement in both direction is maximum for 4 storey module diagrid while it is minimum in 8 storey module diagrid.

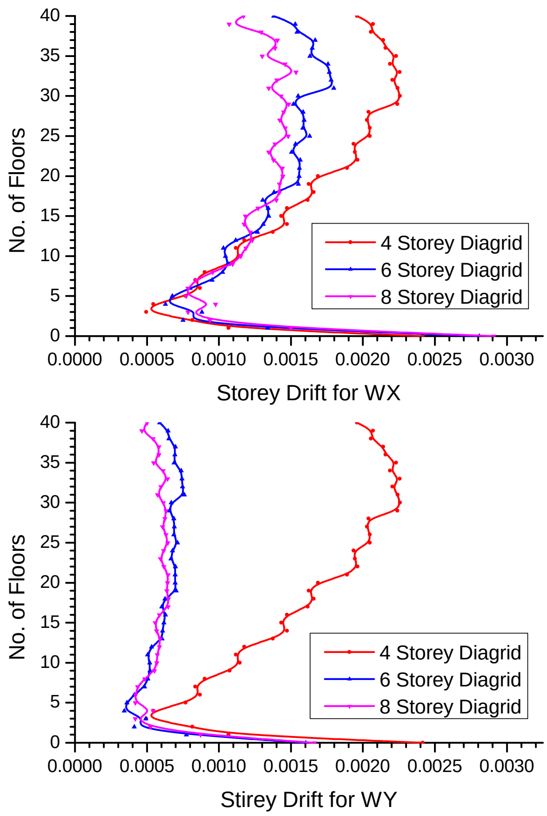

Chart -2: Lateral displacement for diagrid structures

The storey drift in X and Y direction for diagrid structure is shown in chart 2. The minimum value of storey drift is observed in 8 storey module diagrid structures while it is maximum for the diagrid structure of 4 storey module.

The results of storey shear for diagrid structures are shown in chart 3. It is observed that that results of storey shear in 8 storey module diagrid structure are minimum and it increases in 6 storey module and 4 storey module diagrid respectively. It is because the 8 storey module diagrid structure has larger angle of diagonal members thus it can resist the lateral forces more effectively than other diagrid modules.

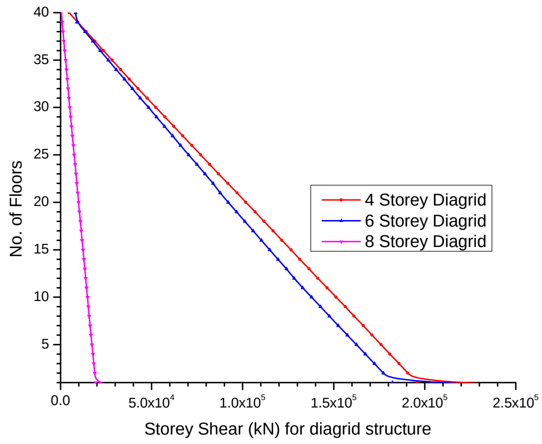

Chart -3: Storey shear for diagrid structures of different diagrid modules

The results of time period for diagrid structure of different modules are shown in chart 4. From the results we can see that the value of time period for 8 storey module is minimum in first and second modes and it increases for other modes. The time period for 4 storey diagrid module is maximum in first two modes and it decreases for other modes. So, the time period for 8 storey module diagris is lesser than other diagrid modules for first two modes and it is vice-versa for other modes.

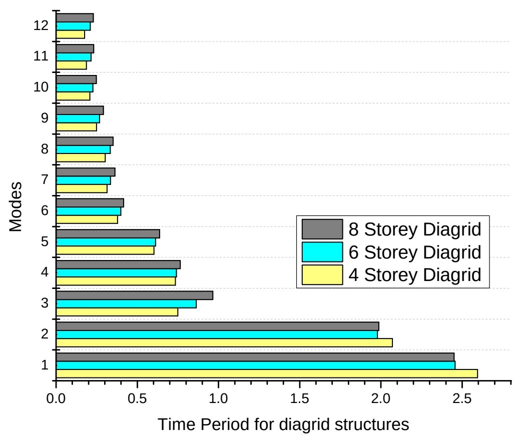

Chart - 4: Time period for diagrid structure of different modules

4. CONCLUSIONS

In this paper a study on diagrid structure for three different diagrid modules are presented. Based on the results it is concluded that the diagrid structure of 8 storey module has better results in terms of lateral displacement, storey drift, storey shear and time period. So, the diagrid structure of higher angle is giving better performance for resisting lateral loads in diagrid structural system.

In these three structures as the height of structure increases the optimum steel usage is found in diagrid with lower angles as compared to the other models.

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REFERENCES

1. Al-Kodmany, K., & Ali, M. M. (2016). An overview of structural and aesthetic developments in tall buildings using exterior bracing and diagrid systems. IJHRB, 271-291.
2. Boake, T. M. (2014). Diagrids, the new stability system: combining architecture with engineering .
3. Jani, k., & Patel, P. V. (2013). Analysis and design of diagrid structural system for high rise steel buildings. NUiCONE-2012, (pp. 92-100).
4. Kwon, K., & Kim, J. (2014). Prograssive collapse and seismic performance of twisted diagrid buildings. IJHRB, 223-230.
5. Moon, k. (2009). Design and construction of steel diagrid structures. NSCC, (pp. 398-405).
6. Moon, K. S. (2009). Design and construction of steel diagrid structures. NSCC, (pp. 398-405). New Haven, USA.
7. Moon, K. S. (2011). Diagrid structures for complex shaped tall buildings. 12th East Asia-Pacific conference on Structural Engineering and Construction, (pp. 1343-1350).
8. Moon, K. S., Gerasimidis, S., Pantidis, P., & Knickle, B. (2016). Diagrid structural system for high-rise buildings: Application of a simple stiffness-based optimized design . IJHRB, 319-326.
9. IS 800: 2007 General construction in steel - Code of Practice
10. IS 456: 2000 Plain and reinforced concrete – Code of Practice

11. IS 16700: 2017 Criteria for Structural Safety of Tall Concrete Buildings

12. IS: 875 (Part-I, II)-1987, Code of Practice for Design Loads (other than Earthquake) for Buildings and Structures, Bureau of Indian Standard, New Delhi.

13. IS: 875 (Part-III)-2015, Code of Practice for Design Loads (other than Earthquake) for Buildings and Structures, Bureau of Indian Standard, New Delhi.

14. IS: 1893(Part-I)-2016, Criteria for Earthquake Resistant Design of Structures, Bureau of Indian Standard, New Delhi.

15. An Explanatory Handbook on Proposed IS 875 (Part 3) Wind Loads on Buildings and Structures by N. M. Bhandari, Department of Civil Engineering, IIT Roorkee

16. Book of "Reinforced Concrete Design of Tall Buildings" by Bungale S. Taranath