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Optimization of Diagrid Structural System

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Abstract— Now a day's, increase in population and limited land availability and also advancement in construction technology, structural system, material, analysis and design facilitated the growth of high rise buildings. Due to high rise building lateral load increases with respect to height. For resistance of such a lateral load different structural systems are used. The Diagrid structural system is one of the preferred system used in tall building due to their structural efficiency and also aesthetical view for structure.

The diagrid structure consists of inclined columns on peripheral of a building which replaces closed space vertical column in framed structure. This inclined column resists the lateral load due to wind load and earthquake force. This paper is about optimizing structural performance of the diagrid structural system. This paper also includes different angle of diagrid for different module height, which compared by using storey displacement, storey drift, and time period. Also study about how diagrid structure achieved economy.

Keywords— Diagrid structure, Structural system, Storey displacement, Storey drift, Time period, Economy, Etabs, Diagrid angle and Module height.

I. INTRODUCTION

This The rapid growth of the urban population and the consequent pressure on limited space have strongly influenced the residential development of the city. The high cost of the land, the desire to avoid a continuous urban expansion and the need to preserve an important agricultural production have helped to push up residential buildings. As the building height increases, the side load resistance system becomes more important than the structural system that resists gravitational loads. The side load resistance systems that are widely used are: rigid frame, cutting wall, wall frame, reinforced pipe system, stabilizer system and tubular system. Recently, the diagonal grid system - Diagonal Grid - is widely used for tall steel buildings thanks to its structural efficiency and the aesthetic potential provided by the exclusive geometric configuration of the system.

Diagrid means diagonal and gird. The diagrid structure made by triangulated and straight or curved beam. Structural effectiveness and flexibility in architectural planning is the key reason to adopt the diagrid structures in modern high rise buildings. In this system is that up to 20% to 30% of steel can be saved due to elimination of peripheral vertical column. The angle of inclination of diagrid is main factor because the 90° angle gives bending rigidity and 35° angle gives shear rigidity in the framed structure, but diagrid carry both bending as well as shear.

A . Components of diagrid structural system

- Nodes: Joints that connects all the members Typically formed by bolting or welding the ends of the members to a gusset plate. When diagrid is to be exposed internally or externally then we have to weld the connection. The bolted connection used only in internally. Nodes having two type hinged and fixed depending upon condition. For concentrated load and high diagrid angle hinged support is used but when loads are eccentric and diagrid angle is small then fixed nodes is providing

- Diagonal member: Diagonal Members transfer lateral and gravity loads through axial action. It made by different material but steel is preferred in all condition.

- Horizontal member: Horizontal member transfer gravity load by shear action to the diagonal Members that transfer lateral loads to diagonal members through axial action is used.

- Tia beam: Transfer load from central core to diagrid structural member. The unbalanced forces can be compensated with ring beams and tia beam.

- Core: For carry gravity load central core give the contribution. It made by steel or concrete column.

- Triangular diagrid module: The Diagrid structure is modelled as a cantilevered vertical beam on the ground and divided longitudinally into modules according to the repetitive pattern of Diagrid. Each graphics module is defined by a single layer of diagonals that span "n" stories.

- Optimal angle: the diagonal element of the diagram conveys the shear and the moment. The optimum angle of the diagonal depends, therefore, on the height of the building. The optimum angle of the supports for the maximum bending stiffness in the normal construction is 90° and for the diagonal for the 35° shear rigidity. It is assumed that the optimal angle of the graph between the two fails. Normally, the optimum angle is between 60° and 70°.

B . Merits of diagrid structural system

- The diagrid structure consists of free exterior and interior space due to removal of vertical column. Therefore, exclusive and free floor plan available.
- By using diagrids, steel is reduced by approximately 28% compared to conventional frame constructions.
- Construction need simple and accurate work; therefore, it should be perfect.
- The construction requires a simple and precise work. therefore, it must be perfect.
- Diagrid uses the material optimally.
- Diagrid offers good aesthetic vision and greater structural efficiency.
- Diagrid transports gravity and lateral loading without difficulty.

C . Demerits of diagrid structural system:

- The diagrid can administrate astatically, due to wrong design or wrong arrangement.
- It is difficult to arrange window and make regular floor.
- Diagrid is uneconomical if the preparation of diagrid and used member is improper.
- The inadequacy of the height in the diagrid structure.
- Design procedure is complex, trial and error method used for design.

II. OBJECTIVES

- The main objective of study is to know the most effective system in diagrid structural system.
- To know the most economical structural system in diagrid structure.
- The objective of this study is to know the structure is safe in storey displacement and natural time period if diagrid is used in place of outer column.
- To analyse the building by using different cases by using different angle of diagrid and different module height.
- To minimize the storey displacement and time period of unsafe system by adding some additional features.

III. LITERATURE REVIEW

The diagrid has good architectural appearance and easy construction therefore from some decade the scope for construction in diagrid get increased. For construction the analysis and design of structure is important for that the previous work carried out on this where the analysis and design of diagrid by using wind force along and across the structure for high rise building of 36 storey compared on the base of time period, inter storey drift and storey displacement, the conclusion come out that the gravity load and lateral load is take by diagrid about 50% and 90% respectively [1].

If we providing the diagrid structure in building there is important to know the preference above the different structural system which work same as diagrid therefore the comparison of diagrid with outrigger with different position, shear wall using gust factor approach is worked out and conclusion show that the diagrid structural system is effective in all factor i.e. storey displacement, axial force on column, time period [2]. Also the work done on concrete filled steel tubular connection under axial compression by considering deflection, stress, failure modes, and bearing capacity of the specimens were obtained. And conclusion comes that the angle of diagrid in connection is take more than 35°, and also the member is fail due bucking of angle less than 20° [3]. In complex shape building the performance is studied in which twisted, tilted and freeform towers are considered that the constructability of diagrid for this type of building is check the conclusion comes that for application of diagrid the optimization is needed [4], therefore for optimization purpose the different parameters is considered. In that the variation of granularity pattern for vertical structure is work out in this the three granularity greater, medium, and smaller with varying angle is take for study because the efficiency of structure is based on it. After all the conclusion comes that greater granularity was more efficient in resisting vertical loads. While for lateral loads, there was no effect of variation of granularity to the structural efficiency. And also the smaller granularity is performing better than larger one [5], also optimization in member size by stiffness based analysis in this three different model are used of 48 storeys, 60 storeys and 72 storeys with two different angle 63° and 69°, for 6 storeys and 8 storey module respectively. conclusion comes out that time period is least for 63° angle module [6].

Optimization in grid the diagrid, hexagrid and octagrid are used in structure with total 12 model, in this diagrid with 2, 4, 6, 8, 10, 12, storey module also in hexagrid 3m, 6m, and 12m module, in octagrid 9m and 12m module is used for comparison. After study its conclude that 4 storey module gives better result in storey drift and storey displacement, also in hexagrid and octagrid the module density is decrease. Diagrid system gives better flexibility in designing [7]. In optimization strength of diagrid member there are 4 model from that outrigger with two plane, and diagrid with 42°, 60° and 75° angle. it finalizes that Diagrid 42°being the stiffest and of Diagrid 75°the most flexible, best overall behaviour results to be the one with 60°diagonal element inclination. [8]. In diagrid the total dead load is increase due to that the investigation in done by optimizing the size of column by replacing the diagrid in the place of external vertical column which reduce the dead load [9]. In designing of diagrid system there is problem of stability of interior column and flexibility which solve by replacing diagrid by secondary bracing system [10]. After all, designing optimization in joint node is important because of failure due to cyclic loading for that purpose the box type section is provided which gives better result against strength, stiffness and ductility [11]. Also angle in node is found out by stiffness based analysis with varying angle from 35° to 90°, after investigation it finalize the angle 60° to 70° is best for both shear and bending [12].

IV. MODELLING AND ANALYSIS

A square shaped 48 storey building with 36m x 36m, with storey height 3m for comparative analysis. Nine different models are draft with different module height and diagrid angle. The model content three different module height i.e. 4storey, 6storey and 8 storey module with three different angle 63°, 69° and 79°. Namely it written as A63°M4, A63°M6, A63°M8, A69°M4, A69°M6, A69°M8, A79°M4, A79°M6 and A79°M8, in this ‘A’ means diagrid angle and ‘M’ means module storey height.

The floor plan shows in **fig.1** and elevation for different modules shows in **fig.2 (a, b, c, d, e, f, g, i)**. for all models. In outer periphery only corner columns are provided. Material used in model is fe500 for reinforcement, for RCC member M30 and M40 grade of concrete is used, and for steel diagrid member fe325 steel is used. All properties as per IS456-200 [14] and Indian standard steel table. The sectional properties and detail of beam and column is shown in **Table I**.
The design live load on slab is 3Kn/m2. Wind load is as computer based as per wind speed 50m/s as per IS875 (part3). The design earthquake load is for medium soil type with zone factor 0.16, response reduction factor 5 and important factor 1.5 for special RC moment resistance frame as per IS1893-2002 [13]. The analysis is performing by using Etabs-16.2.2 and result is in form of story displacement, storey drift, and time period.

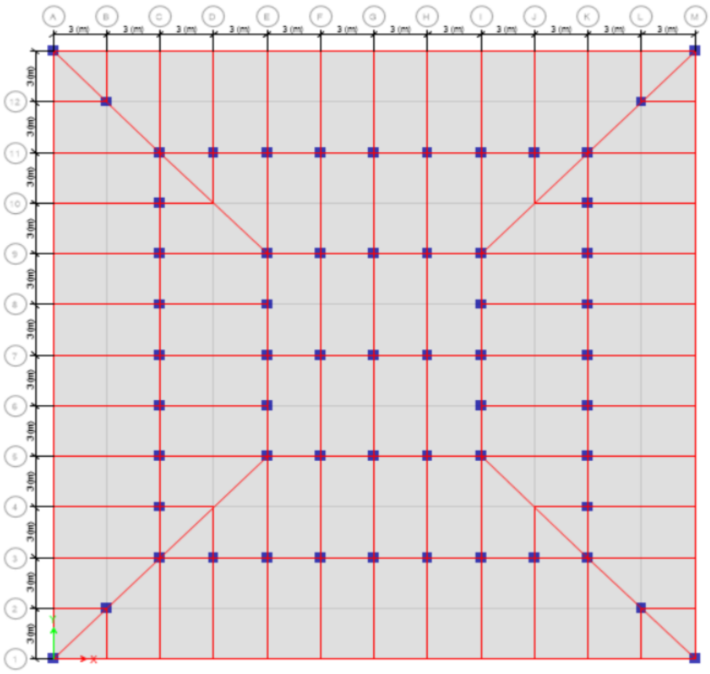
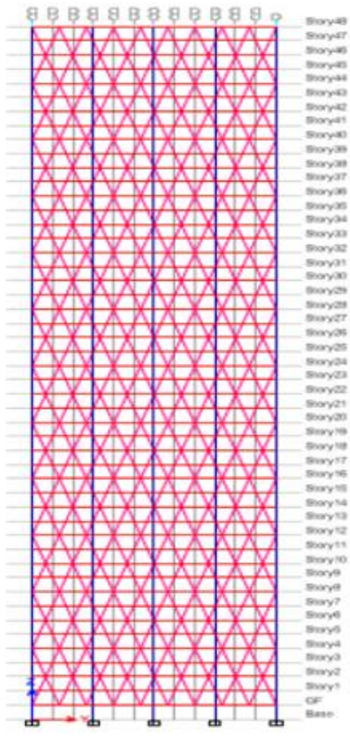


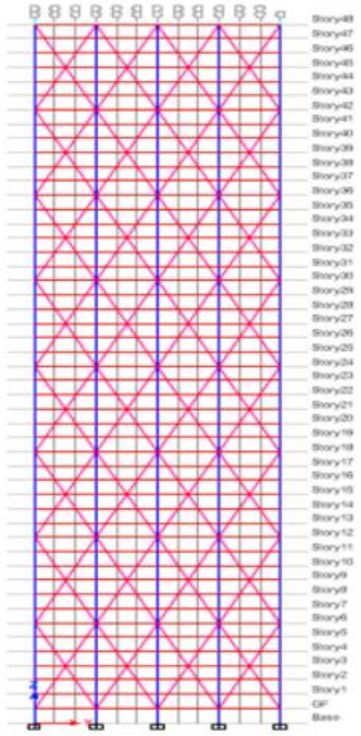
Fig. 1 floor Plan of arrangement of beam and column

TABLE I
SECTIONAL PROPERTIES

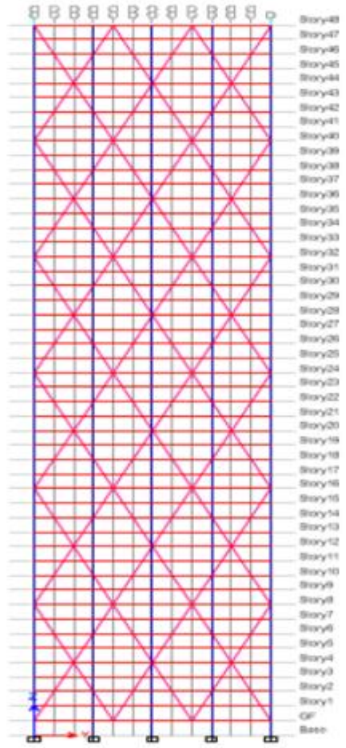
Type of section	***Sectional area***
External beam	300X600mm
internal beam	300X600mm
column	600X600mm
slab thickness	150mm
wall thickness	150mm
diagrid section	ISWB450



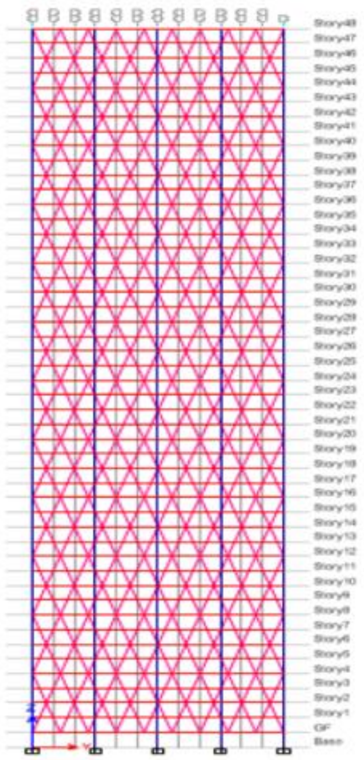
a) A63°M4



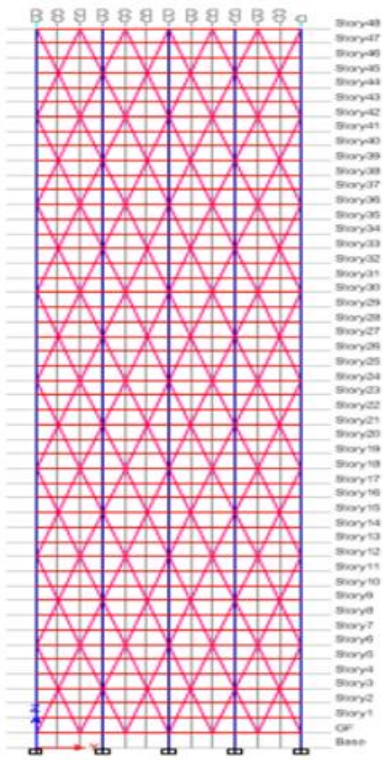
b) A63°M6



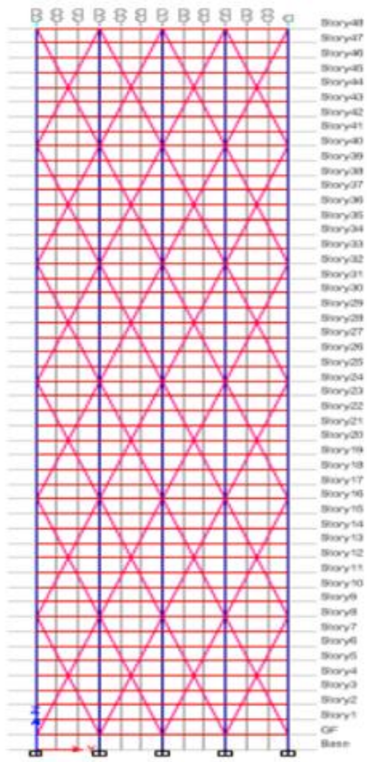
c) A63°M8



d) A69°M4



e) A69°M6



f) A69°M8

g) A79°M4　　h) A79°M6　　i) A79°M8

Fig. 2 Elevation for all model

V. RESULTS AND DISCUSSION

A. Lateral displacement

In **fig.3**.and **fig.4**. shows the maximum top storey displacement due to earthquake and wind for all cases which is as per IS1893-2002 (part 1) [13] is h/500 144/500 = 0.288m within permissible limit.

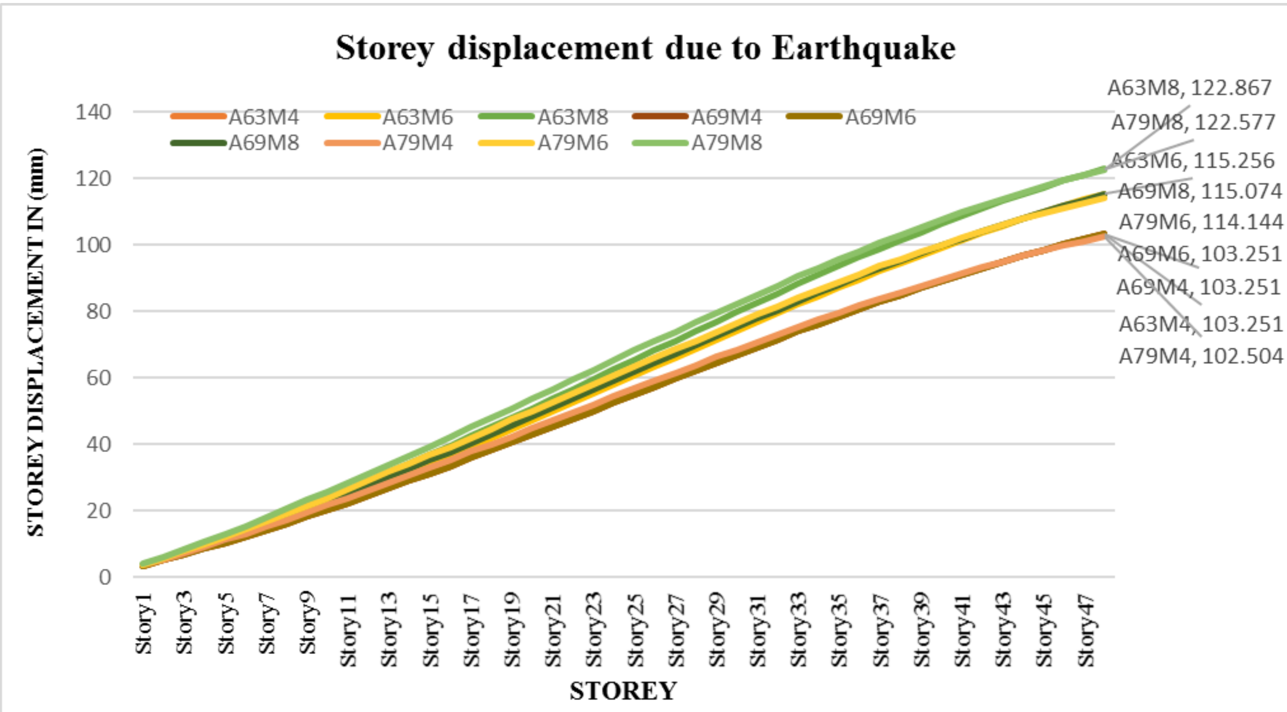


Fig. 3 Storey displacement due to earthquake force

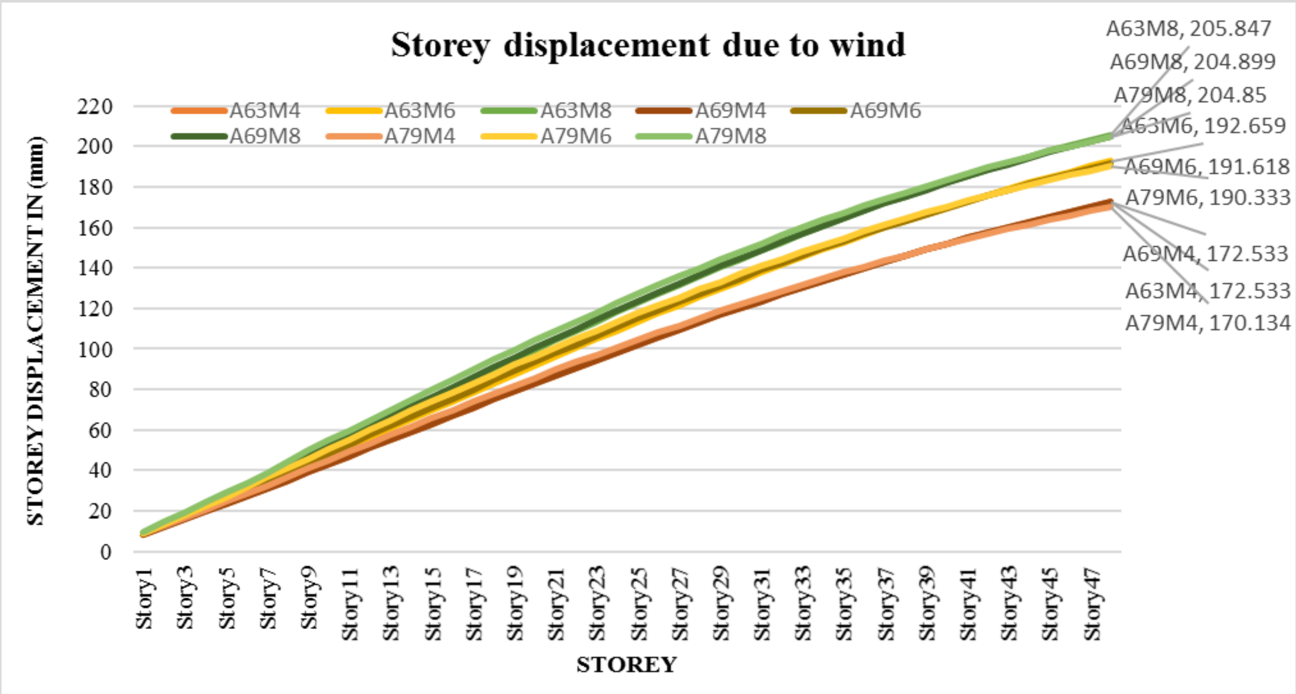


Fig. 4 Storey displacement due to wind force

The least value for displacement is for model A79°M4 both for wind earthquake. And approximately highest displacement for model A79°M8.

B. Story drift

In **fig.5**. the storey drift is shown for Earthquake and fig.5. shows the drift for earthquake which is within permissible limit as per IS1893-2002 (part1) [13] is 0.004h = 0.004*3 = 0.012m.

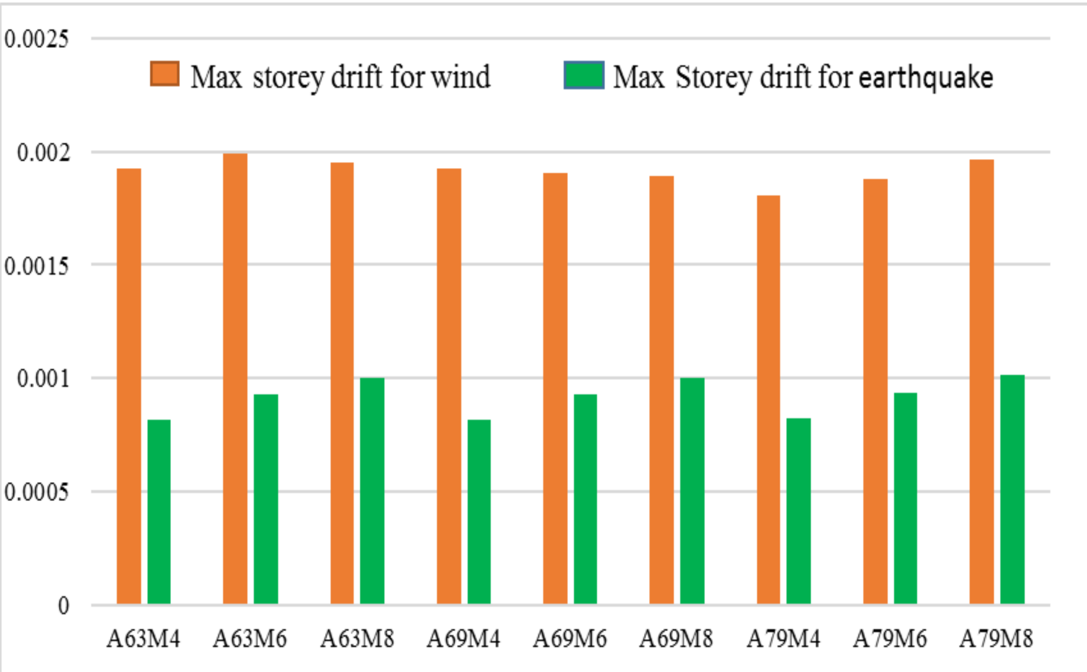


Fig. 5 Storey drift for earthquake and wind force

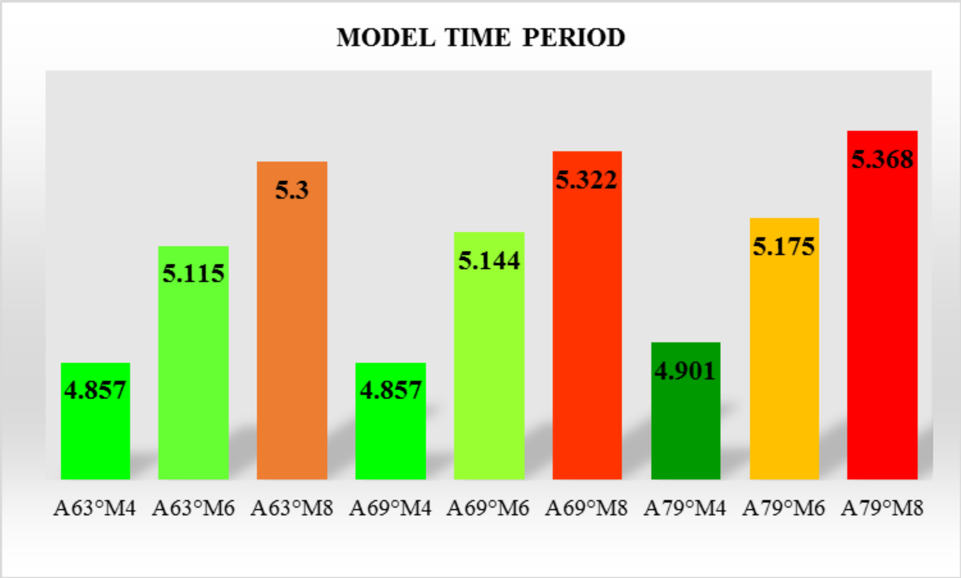


Fig. 6 Time period for all model

The lowest storey drift for earthquake is for model A63°M4 and A69°M4, where for wind it is in model A79°M4.

C. Time period

In fig the time period for first mode is given for all model least time period for model A63°M4 and A69°M4 and highest for A79°M8.

D. Diagrid material weight

On comparison of the structural weight of all the models, it was found out that the quantity of concrete weight for all model is same only effect due to outer diagrid member therefore it is easy to compared the model by considering its diagrid member weight and find economy. The **fig.7**. shows the diagrid weight The highest weight in the model A79°M4 and least in model A63°M8 and A69°M8.

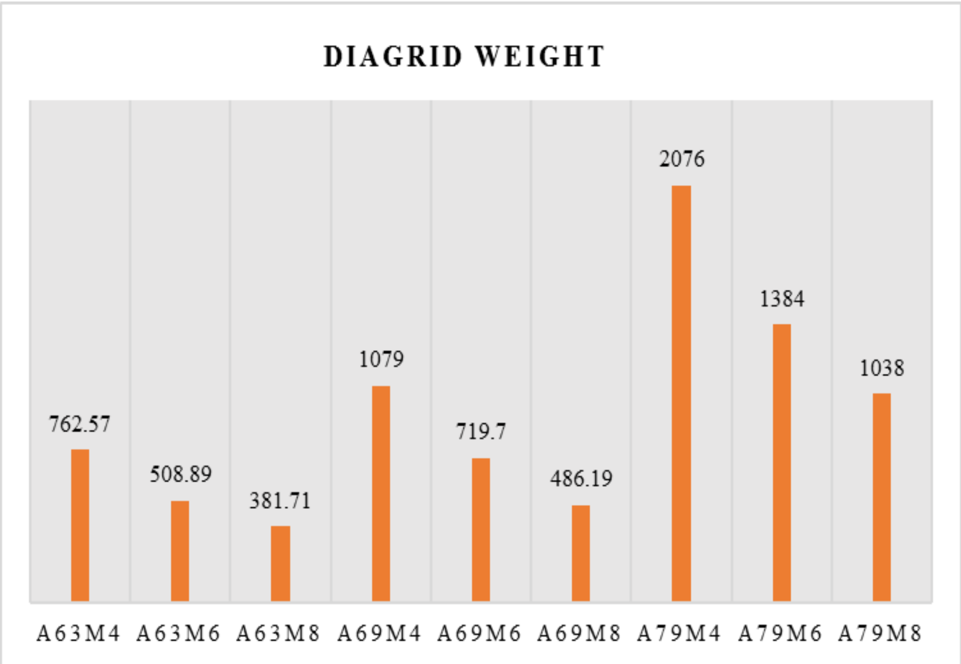


Fig. 7 Diagrid weight for all model

VI. CONCLUSIONS

- From the above result, it can be concluded that the most effective model of a diagrid structure system is A79°M4, based on its storey displacement and storey drift, i.e. Of the lowest value compared to other models.
- For the diagrid angle 79°, it is observed that the displacement and drift are minimal, and when the diagrid angle decreases to 63°, the displacement increases. It follows that as the angle decreases the displacement and drift, it increases.
- The height of the 4-story module gives a lower value for displacement and drift, and 8 floors give a higher value. It follows that the height of the module increases inversely.
- For the optimization of a model with an angle of inclination of 63°, this increases to 69°, therefore, it is examined if 69° is the best angle for both displacement and drift.
- Storey displacement and drift are within the allowed limit also if the outer columns are replaced by Diagrid.
- The previous models have a displacement and drift are within the allowed limit, but if we use (A63°M8), this is economical for us.

REFERENCES

[1] K. Jani and P. V. Patel, “Analysis and design of diagrid structural system for high rise steel buildings,” Procedia Eng., vol. 51, pp. 92–100, 2013.
[2] T. J. Shaikh, S. B. Cholekar, and H. L. Sonawadekar, “Comparative Study of Wind Analysis of High Rise Building with Diagrid and Outrigger Structural Systems Using Gust Factor Approach,” Int. Res. J. Eng. Technol., vol. 4, no. 6, pp. 1909–1914, 2017.
[3] Chao Huang, Xiao-lei Hana, Jing Ji, Jia-min Tang, “Behavior of concrete-filled steel tubular planar intersecting connections under axial compression, Part 1: Experimental study,” Engineering Structures vol.32, pp 60-68, 2010
[4] K. S. Moon, “Diagrid structures for complex-shaped tall buildings,” Procedia Eng., vol. 14, pp. 1343–1350, 2011.
[5] E. K. Julistiono, “Structural Pattern’s Granularity Variation to Optimize a Vertical Structure,” Procedia Eng., vol. 180, pp. 725–734, 2017.
[6] K. S. M. Simos Gerasimidis, Panos Pantidis, Brendan Knickle, “Diagrid Structural System for High-Rise Buildings: Applications of a Simple Stiffness-based Optimized Design,” Int. J. High-Rise Build., vol. 5, no. 4, pp. 319–326, 2016.
[7] P. Isaac, B. I.-I. R. J. of E. And, and U. 2017, “Comparative study of performance of high rise buildings with diagrid, hexagrid and octagrid systems under dynamic loading,” Irjet.Net, vol. 04, no. 05, pp. 2840–2846, 2017.
[8] G. Milana, P. Olmati, K. Gkoumas, and F. Bontempi, “Ultimate capacity of diagrid systems for tall buildings in nominal configuration and damaged state,” Period. Polytech. Civ. Eng., vol. 59, no. 3, pp. 381–391, 2015.
[9] N. B. Panchal and V. R. Patel, “Diagrid Structural System: Strategies to Reduce Lateral Forces on High-Rise Buildings,” Int. J. Res. Eng. Technol., vol. 3, no. 4, pp. 374–378, 2014.
[10] Giovanni Maria Montuori, Elena Mele, Giuseppe Brandonisio, Antonello De Luca, “Secondary bracing systems for diagrid structures in tall buildings,” Engineering Structures vol.75, pp 477-488, (2014).
[11] Young-Ju Kima, Myeong-Han Kim, In-Yong Jung, Young K. Ju, Sang-Dae Kim, “Experimental investigation of the cyclic behavior of nodes in diagrid structures,” Engineering Structures vol.33, pp 2134-2144, (2011).
[12] Kyoung Sun Moon, “Optimal Grid Geometry of Diagrid Structures for Tall Buildings,” Archit. Sci. Rev., vol. 51, no. 3, pp. 239–251, 2008.
[13] Bureau of Indian Standards IS 1893 (part 1): 2016: Criteria for Earthquake Resistant Design of Structures: Part 1 General Provisions and Buildings (Sixth Revision)
[14] IS 456-2000 Plain and reinforced concrete – code of practice is an Indian standard code of practice for general structural use of plain and reinforced concrete.
[15] IS 875 (part3): Code of practice for design loads (other than earthquake) for building and structures.