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# Analytical Investigation for Optimization of Diagrid Structural System for Sustainable Structural Performance of High-Rise Buildings

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***Abstract: India is a developing country and a lot of companies are starting their business day by day. India is also working on the self-reliant model so there is a need of office areas, living area for the industry. High-rise buildings are the best plan for providing the space under a same roof. Diagrid structures are the new advancement in the history of high-rise building. Diagrid structures are known for their architectural appearance and its skyrocketing height. As it is a new technique it is still in developing stage. So, the new techniques or methods are still in its way to make a change in diagrid structures. Therefore, this study is dedicated to find out the best optimal angle for varying diagrid angles with varying diagrid modules. In total five models are prepared and designed, analysed and modelled with the help of ETABS. The models are analysed for maximum storey displacement, storey drift, storey shear and material consumption.***
***Keywords: ETabs, Maximum Storey Displacement, Storey Drift, Storey Shear and Material consumption.***

## I. INTRODUCTION

Diagrid is the external or exoskeleton of the structure which excludes the vertical columns and instead of that inclined columns are used known as diagonal columns or diagrid. Diagrid structures generally consists of vertical core made up of concrete nowadays prestressed concrete is generally used for the making the core part of the diagrid structures. The vertical core plays an important part in carrying and transferring the loads which acts on the structures it carries the gravity load coming over it while the diagrid part of the structure carries the lateral as well as gravity load. Even though diagrid structures were designed in 1896 the actual implementation of these diagrid structures started from the early 2000's., example Swiss Re (2004), London, the Hearst Magazine Tower (2006) New York City and the Mode Gakuen Cocoon Tower (2008) Tokyo [1]. Diagrid structures carries the lateral as well as axial loading due to its joint connection as these structures have triangular formation of joints which helps in carrying the loads easily. The load is easily carried by the diagonals of structures and strength and stiffness parameters of the structures is met. As the vertical columns are not used in the building the structure obtained has more space and looks elegant to see as the aesthetic appearance of building is improved.

## II. ADOPTED METHODOLOGY

Conventional buildings are heavier and is difficult to build upto this height so the new techniques are introduced and is known as diagrid structure. So, in this study the diagrid structure is designed, modelled and analyzed. Various studies are already done on finding the optimum angle of diagrid structure whereas in this study the parametric study is done to find out the optimum varying diagrid angle for varying diagrid modules. In this study the suitable or optimum angle is to be find out which will provide suitable strength and stiffness to the structure. To find out this optimum angle the analysis software is used to analyze, design and model the structure.

## III. EXPERIMENTAL PROCEDURE

### *A. About Software*

The software which is used to analyze, designing and to model the structure is Extended Three-Dimensional Analysis of Building System (ETabs) v20. ETabs evaluates basic or advanced systems under static and dynamic conditions. It is the most used software by the structural engineers to analyze and design software for structural and earthquake engineering.

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*B. Geometrical Data and Loading Conditions According to IS Code*

Before designing the structure some of the data is to be assumed. The various data which is assumed is listed below: -

1) Shape- Circular
2) Diameter of structure- 120m
3) Diameter of core- 40m
4) Thickness of core- 0.5m
5) Storey height- 4m
6) Number of floors- 120
7) Slab thickness- 0.2m
8) Characteristics strength of concrete- 50N/mm$^2$
9) Characteristics strength of steel- 500N/mm$^2$

As the building is high rise building the effect of the wind load is important. So, the dynamic wind loading is computed as per IS: 875 (Part 3)-2015.

a) Assuming location- Mumbai
b) Wind speed- 50m/s
c) Terrain category- 3
d) Risk coefficient- 1.08
e) Topography factor- 1

Next most important load which is considered in the construction of the high-rise building is earthquake loading. Seismic loading is computed as per IS: 1893(Part 1).

- Zone factor- 0.16
- Soil type- III
- Importance factor- 1.5
- Response reduction- 5

## IV. DESIGN AND PARAMETRIC STUDY

The structure is designed using ETabs with the help of various IS codes. The various load combinations which are considered while designing the structure as per IS 456:2000 is: -

1) 1.5(D. L+L.L)
2) 1.2(D. L+L.L+W. Lx) (X-DIRECTION)
3) 1.2(D. L+L.L+W. Ly) (Y-DIRECTION)
4) 1.2(D. L+L.L-W. Lx) (X-DIRECTION)
5) 1.2(D. L+L.L-W. Ly) (Y-DIRECTION)
6) 1.2(D. L+L.L+E. Lx) (X-DIRECTION)
7) 1.2(D. L+L.L+E. Ly) (Y-DIRECTION)
8) 1.2(D. L+L.L-E. Lx) (X-DIRECTION)
9) 1.2(D. L+L.L-E. Ly) (Y-DIRECTION)

After having the load combinations, the variation in diagrid modules is done which is same for the all models. The variation done in diagrid module is shown below: -

As the variation in module is same for all the models, the variation in diagrid angle is done by changing the base width and grid angles in circular plan. The angle varied for different models are (84° to 62° in Model A), (81° to 51° in Model B), (80° to 48° in Model C) (78° to 43° in Model D), (75° to 37° in Model E) for a varying diagrid module of 15 storeys, 14 storeys and so on to 3 storey modules.

## V. RESULT

The models are analyzed for Maximum Storey Displacement, Storey Drift, Storey Shear and Material consumption.

According to IS Code 456:2000 clause: 20.5 the maximum top storey displacement due to wind load should not exceed H/500 where H= total height of the building.

So, the permissible maximum storey displacement (480/500) = 0.960m or 960mm.

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TABLE I
VARIOUS MODEL SHOWING THE VALUES OF DISPLACEMENT DUE TO EARTHQUAKE AND WIND LOAD.

| Model | EQ(x) (mm) | EQ(y) (mm) | WIND(x) (mm) | WIND(y) (mm) |
|---|---|---|---|---|
| A | 1067.20 | 1067.20 | 125.52 | 125.52 |
| B | 932.8728 | 932.8728 | 113.3023 | 113.3023 |
| C | 925.15 | 925.15 | 113.15 | 113.15 |
| D | 940.01 | 940.01 | 115.61 | 115.61 |
| E | 1014.18 | 1014.18 | 127.05 | 127.05 |

As per IS Code 1893:2016 (part 1) clause 7.11.1 the storey drift in any storey shall not exceed 0.004 times the storey height (h).
So, the permissible storey drift for 4m is = 0.004*4
=0.016m.

TABLE II
VARIOUS MODELS SHOWING THE VALUES OF DRIFT DUE TO EARTHQUAKE AND WIND LOAD

| Model | EQ(x) (m) | EQ(y) (m) | WIND(x) (m) | WIND(y) (m) |
|---|---|---|---|---|
| A | 0.004162 | 0.004162 | 0.000496 | 0.000496 |
| B | 0.003174 | 0.003174 | 0.00039 | 0.00039 |
| C | 0.002974 | 0.002974 | 0.000368 | 0.000368 |
| D | 0.002684 | 0.002684 | 0.000334 | 0.000334 |
| E | 0.002482 | 0.002482 | 0.000313 | 0.000313 |

TABLE III
VARIOUS MODELS SHOWING STOREY SHEAR IN EARTHQUAKE AND WIND LOADING CONDITIONS.

| Model | EQ(x) kN | EQ(y) kN | WIND(x) kN | WIND(y) kN |
|---|---|---|---|---|
| A | 37508.93 | 37508.93 | 5121.22 | 5121.22 |
| B | 46040.32 | 46040.32 | 6266.36 | 6266.36 |
| C | 47967.07 | 47967.07 | 6508.44 | 6508.44 |
| D | 51444.32 | 51444.32 | 6758.43 | 6758.43 |
| E | 53680.02 | 53680.02 | 7110.51 | 7110.51 |

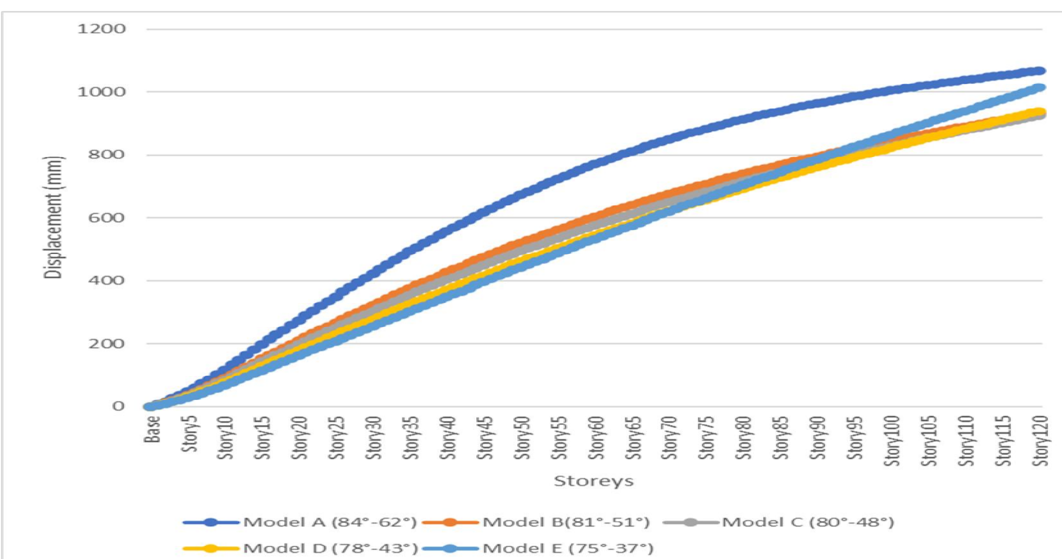

Fig. 1. Maximum Storey Displacement in case of earthquake load.

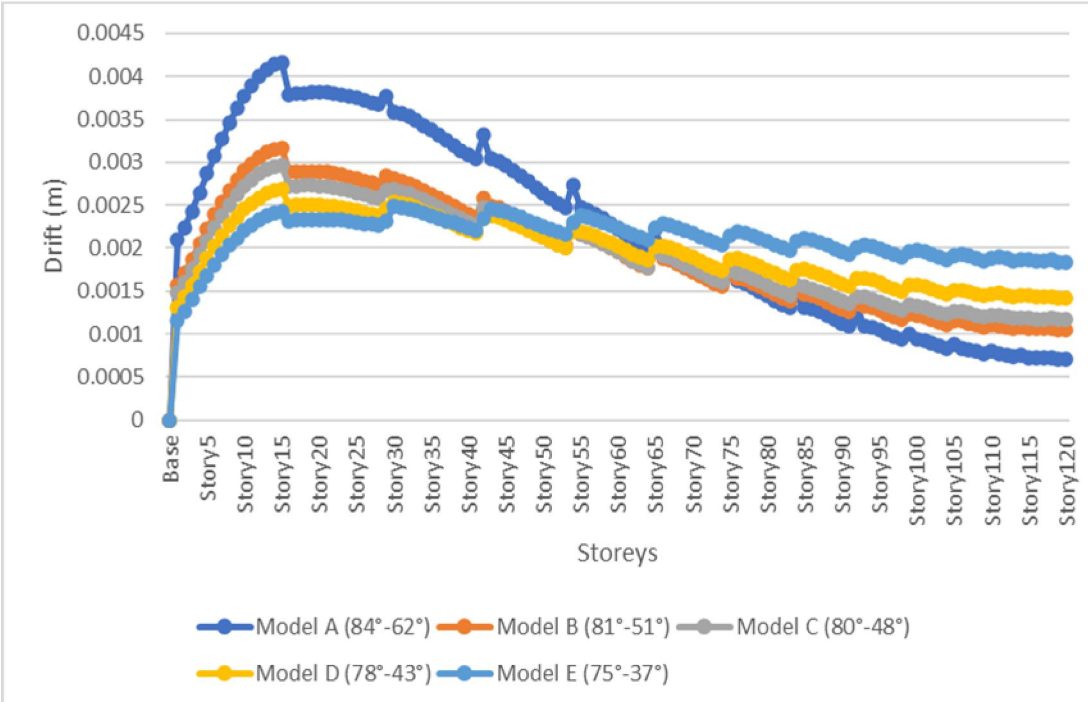


Fig. 2. Maximum Storey Drift in case of earthquake load.

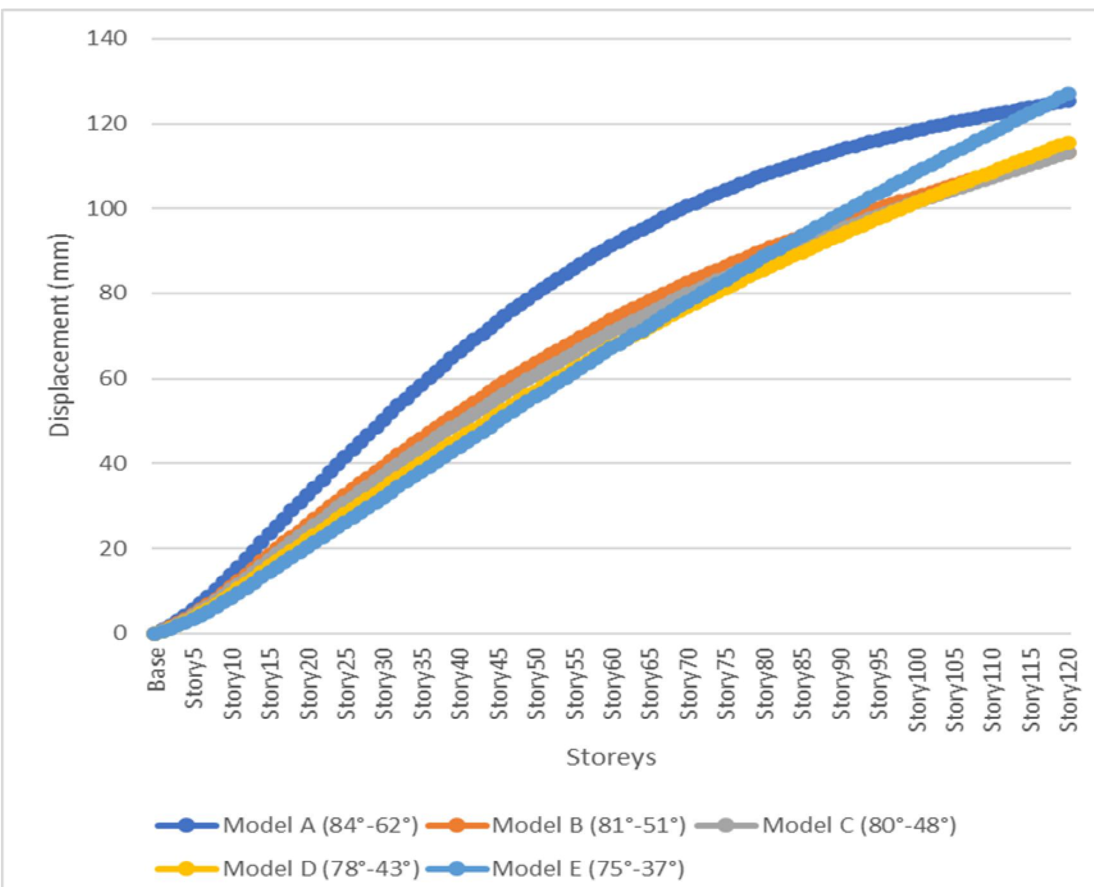


Fig. 3. Maximum Storey Displacement in case of wind load.

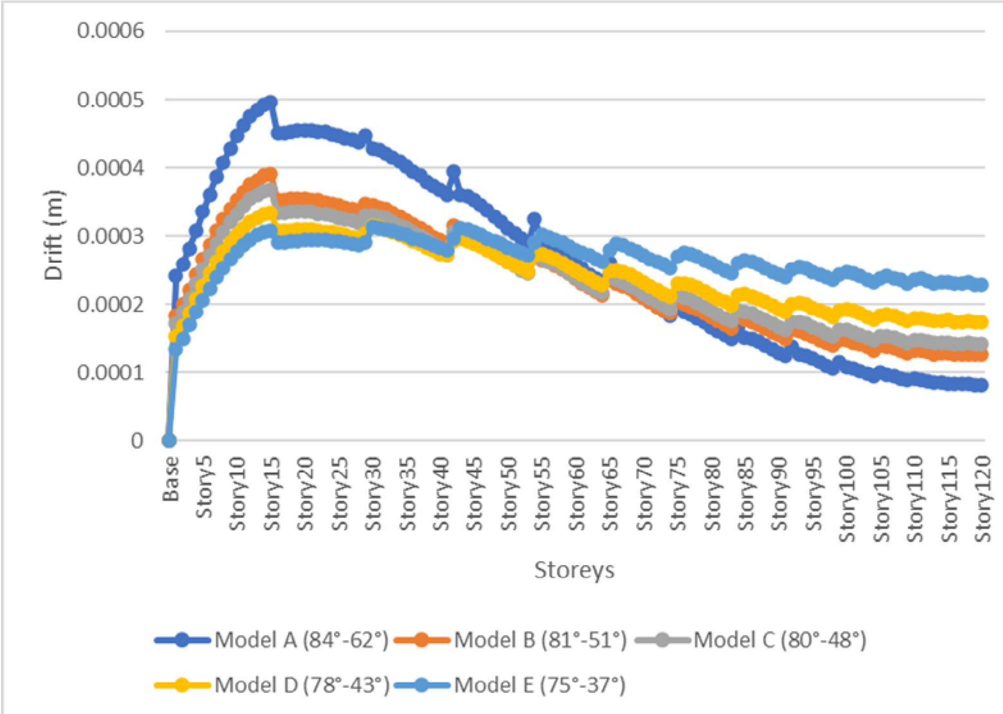


Fig. 4. Maximum Storey Drift in case of wind load.

## VI. CONCLUSION

1) By reviewing the results, it is clear that the varying diagrid angles of Model C gives us the best result other than any Model.
2) From all the models designed above, only Model B, Model C and Model D satisfy the maximum storey displacement. All these models have value within permissible limit as per IS code 456.
3) All the models satisfy the permissible limit of storey drift as per IS code 1893.
4) After analyzing the results, it is seen that grid angle plays an important role in the construction of the circular building in Etabs.
5) As the diagrid columns are in outer periphery, the diagrid structure is very much effective in carrying lateral load. Due to this vertical core placed in the center carries only gravity load.
6) The optimal angle of the diagrid increases with the increase in the height of the structure.

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