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Comparative Study of Cylindrical and Square Diagrid Building Structures

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Abstract: In present study comparison of structural performance is made to understand the behavior of two differently planned 36-storey diagrid structures with identical floor area. Square and circular plan diagrid structural performance is evaluated for two important loadings viz. earthquake and wind loading. ETABS 2013 software is used for analyzing the models subjected to gravity, wind and seismic forces with appropriate load combinations all structural members are designed as per IS 800:2007 considering all load combination. The angle of diagrid provided is 74.5^0 for square and cylindrical model. The comparison of results in terms of storey drift, top-storey displacement, time period, base shear is presented here.

Index Terms **- diagrid structure, square and cylindrical plan, storey drift and top-storey displacement**

I. Introduction

As height of building increases, lateral load resisting system dominates over gravity system. With the concept of tubular structure, buildings are taken to a remarkable height. They possess greater flexural rigidity than shear rigidity. Diagrid structures contain inclined columns in the periphery as a result of which a diagrid structure possess greater flexural rigidity as well as shear rigidity. Lateral forces are transferred to ground by axial forces though diagonal columns whereas by bending in structure containing vertical columns. A diagrid structure may not require shear core as it possesses greater shear rigidity. Plan of the structure so far considered is square. No much research is made on diagrid structure circular in plan.

Diagrid is a design for constructing large buildings with steel that creates triangular structures with diagonal support beams. It is a system of triangulated beams, straight or curved, and horizontal rings that together make up a structural system for a skyscraper. Similar in idea and execution to a typical moment frame – just more evolved. The diagrid system offers several advantages in addition to eliminating perimeter columns. Most notably it optimizes each structural element. Typically, columns are used to provide vertical-load-carrying capacity, and diagonals or braces provide stability and resistance to large forces, such as wind and seismic loads.

II. LITERATURE REVIEW

In the paper by Kamath and Ahemed (2015) an attempt is made to understand the behaviour of diagrid structure circular in plan. A circular plan is developed. ETABS 2013 software is used for analyzing the models subjected to gravity, wind and seismic forces. Various models are developed for aspect ratios of 3.6, 5, 6, 7 and 8 and for varying angle of diagonal column. The angles of the diagrid provided are 64.00°, 72.00°, 76.30° and 90.00°. Graphs indicating top story displacement, time period for various mode shapes, inter-story drift and lateral load distribution on diagrid and internal columns are plotted. Optimum brace angle for diagrid structures circular in plan is determined for various parameters.

In this paper by khushbu jani (2013) an Analysis and design of 36 storey diagrid steel building is presented. A regular floor plan of 36 m × 36 m size is considered. ETABS software is used for modeling and analysis of structural members. All structural members are designed as per IS 800:2007 considering all load combinations. Dynamic along wind and across wind are considered for analysis and design of the structure. Load distribution in diagrid system is also studied for 36 storey building. Similarly, analysis and design of 50, 60, 70 and 80 storey diagrid structures is carried out. Comparison of analysis results in terms of time period, top storey displacement and inter-storey drift is presented in this paper.

In this paper by khalid k. shadhan (2015) study was to find the optimal diagrid angle to minimize the lateral drift in high-rise building. Five different diagrid angle configurations (27^o, 45^o, 56^o, 72^o, and 81^o) have been considered for 24, 48 and 72-storey steel buildings. The results were tabulated by performing finite element analysis using ETABS version 15 in the form of lateral displacement and storey drift. It is shown that the optimal diagrid angle is smaller than 56^o for 24-storey model, and between (56^o-72^o) for 48- storey model, and 72^o for 72-storey model.

III. SQUARE BUILDING CONFIGURATION

The 36 storey tall building is having 36 m × 36 m plan dimension. The storey height is 3.6 m. The typical plan and elevation are taken from "Analysis and Design of Diagrid Structural System for High Rise Steel Buildings" by Jani, K.and Patel, published in Procedia Engineering, 51, 92-100 as shown in Fig.1&2 respectively. In diagrid structures, pair of braces is located on the periphery of the building. The angle of inclination is kept uniform throughout the height. The inclined columns are provided at six meter spacing along the perimeter. The interior frame of the diagrid structures is designed only for gravity load. The design dead load and live loads on floor slab are 3.75 kN/m2 and 2.5 kN/m2 respectively. The dynamic along wind loading is computed based on the basic wind speed of 30 m/sec and terrain category III as per IS:875 (III)-1987. The overall Description of Structural Member is as shown in table 1.

Table no.1- Description of structural Member

Sr. no	Description	values
1	No of story	36
2	Plan size	36m x 36m
3	Story height	3.6m
4	Dead load	3.75kN/m2
5	Live load	2.5kN/m2
6	Seismic zone	II
7	Structure type	Steel frame
8	Diagrid angle	74.40
9	Diagrid member	Pipe section
10	Beams 1.B1and B3 2.B2	ISMB 550 ISWB 600with top and bottom cover plate of 220 x 50mm
11	columns	1500 x 1500mm
12	Module geometry	triangle
13	Building shape	Square

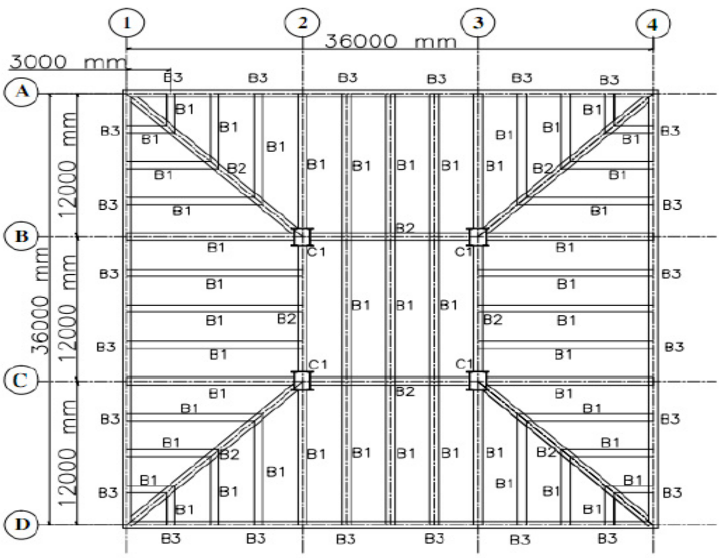

Figure no.1-Typical floor plan

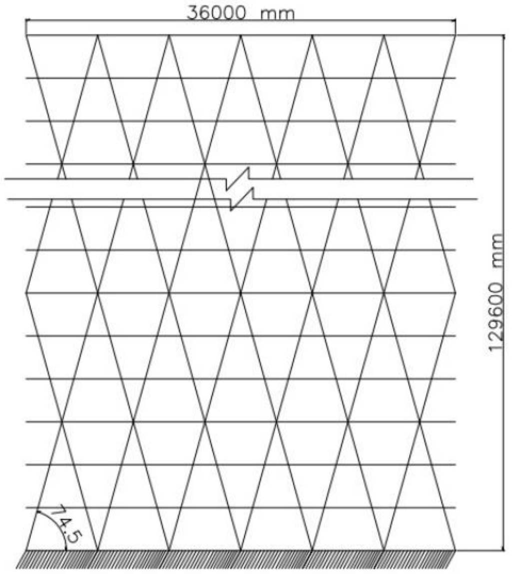

Figure no.2- Elevation of building

IV. Cylindrical building plan and analysis

Circular plan with radial and circular beams is considered. Plan is shown in Figure 3. Elevations of 36 storied diagrid cylindrical structure with diagonal columns inclined at 74.50^0 as shown in Figure 4. Diameter of the structure is 40.62m. Floor height is 3.6m and slab thickness is 150mm. Live loads applied are 2.5kN/m2. Diagonal columns are provided along the perimeter at angles of 74.5°. Wind loads as provided assuming wind speed of 30m/s and terrain category III. Seismic forces are provided for zone factor 0.16, importance factor 1 and response reduction factor 5. The structure is analysed in ETABS 13 software. Along dynamic wind loads are computed by gust factor method as per IS 875-III (1987). The overall Description of Structural Member is as shown in table 2.

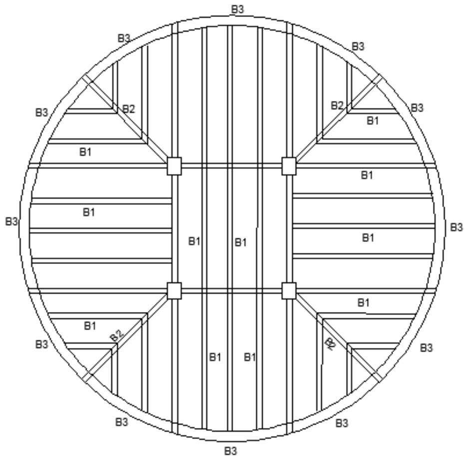

Figure no.3- Typical floor plan

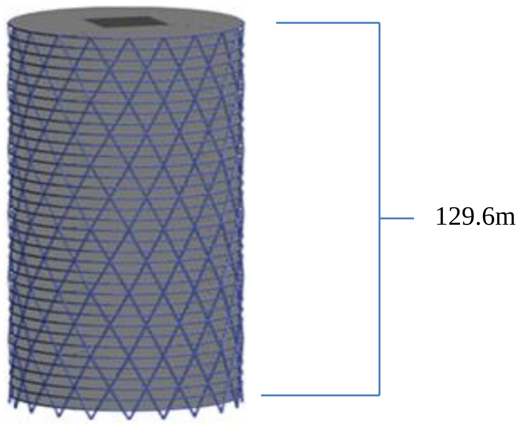

Figure no.4- 3D view of diagrid model

Table no.2- Description of Structural Member

Sr. no	Description	values
1	No of story	36
2	Plan size	40.62(Dia)
3	Story height	3.6m
4	Dead load	3.75kN/m2
5	Live load	2.5kN/m2
6	Seismic zone	II
7	Structure type	Steel frame
8	Diagrid angle	74.40
9	Diagrid member	Pipe section
10	Beams 1.B1and B3 2.B2	ISMB 550 ISWB 600with top and bottom cover plate of 220 x 50mm
11	columns	1500 x 1500mm
12	Module geometry	triangle
13	Building shape	cylindrical

V. Analysis result for square model

The displacement of 36 storey square diagrid structure is shown in Fig 5. It is observed that displacement in x-direction and y-direction due to dynamic wind load is higher compared to earthquake load. The inter-storey drift of 36 storey square diagrid structure is shown in Fig 6. It is observed that inter-storey drift in x-direction and y-direction due to dynamic wind load is higher compared to earthquake load

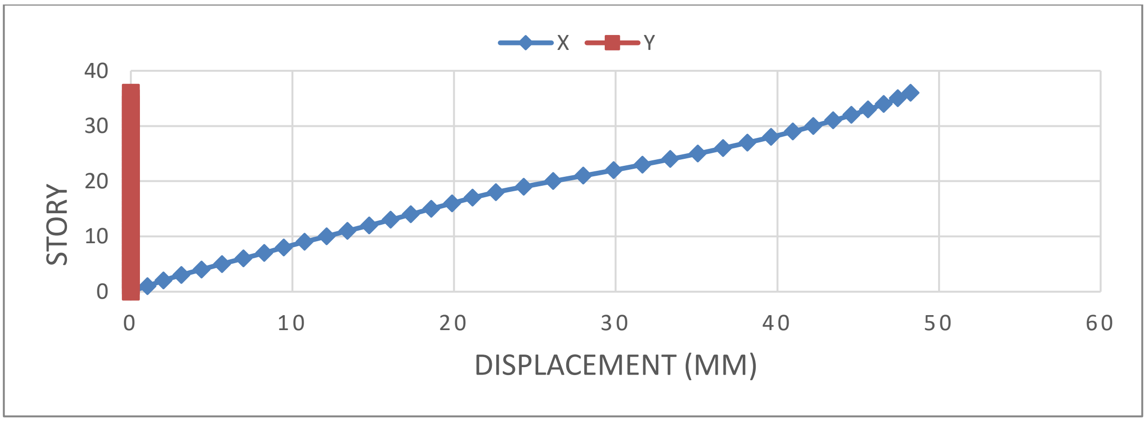

Figure no.5- Maximum story displacement

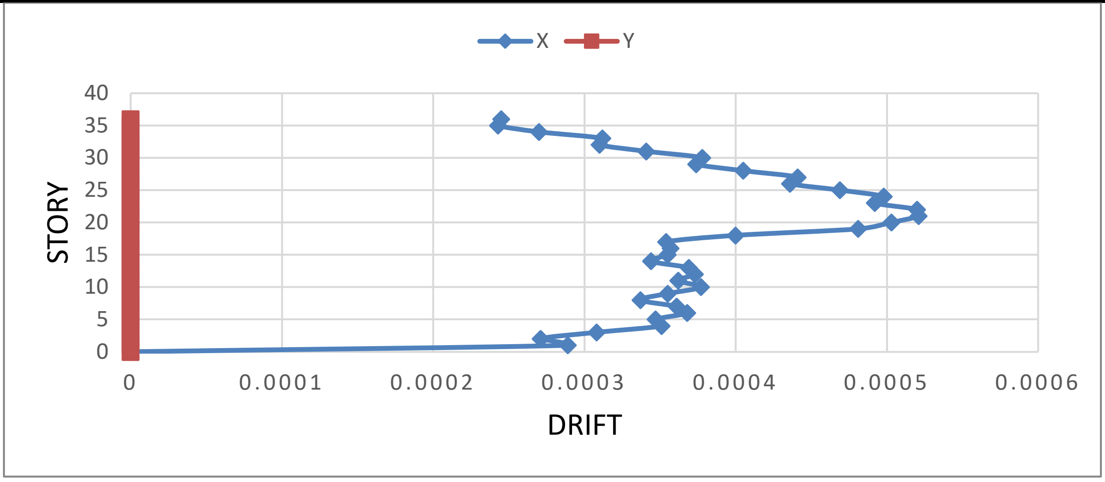

Figure no.6- Maximum story drifts

VI. Analysis result for cylindrical model

The displacement of 36 storey cylindrical diagrid structure is shown in Fig 7. It is observed that displacement in x-direction and y-direction due to dynamic wind load is higher compared to earthquake load. The inter-storey drift of 36 storey cylindrical diagrid structure is shown in Fig 8. It is observed that inter-storey drift in x-direction and y-direction due to dynamic wind load is higher compared to earthquake load.

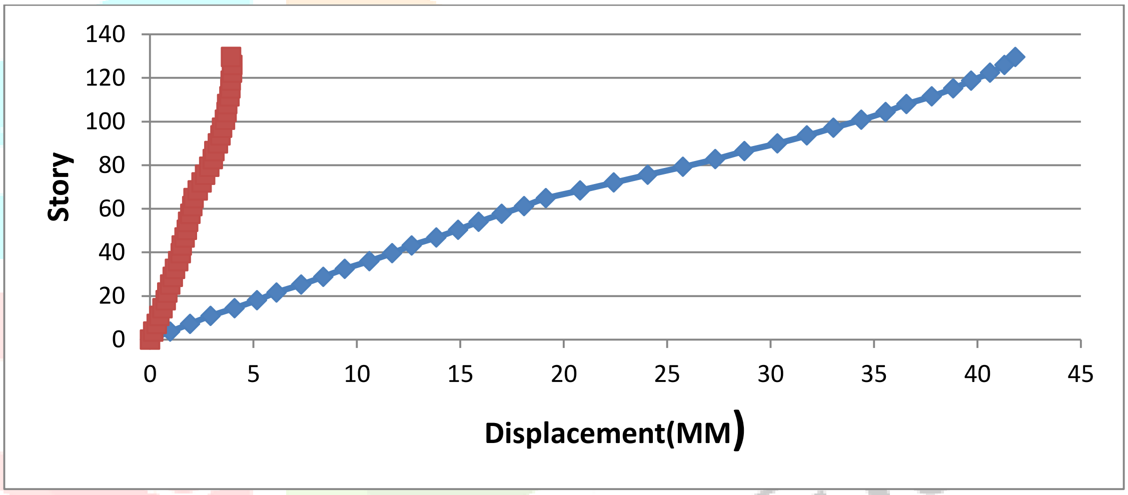

Figure no.7- Maximum story displacement

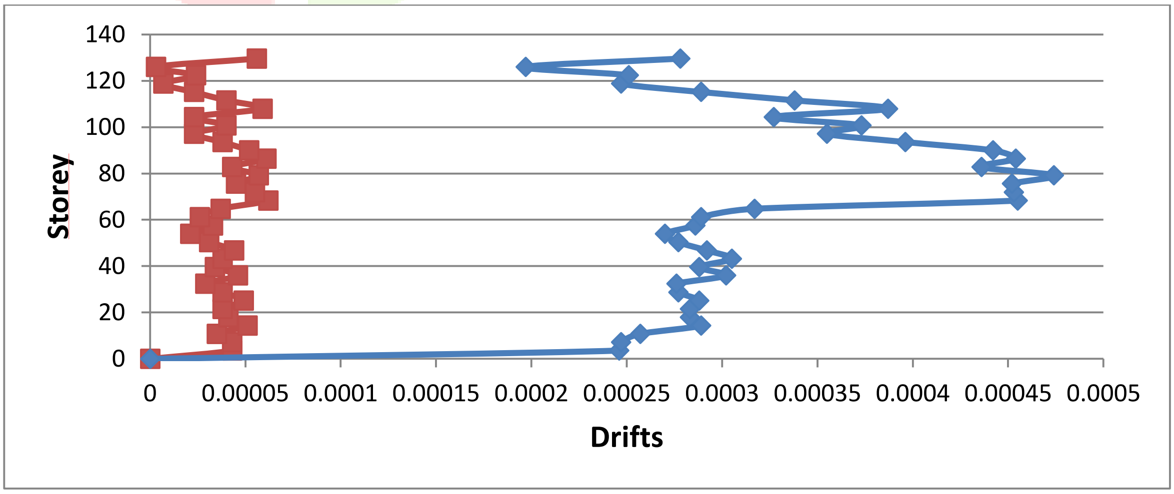

Figure no.8- maximum storey drift

VII. Comparisons of results

Table no.2- Comparisons of result

Sr. no.	Result	Rectangular model	Circular model
1	Gravity Loading	347,582.26 kN	324,252.26 kN
2	Base shear in X-direction due to EQX	1961.44 kN	1757.74 kN
3	Base shear in X-direction due to EQ-X	3274.03 kN	2102.36 kN
4	Time Period	3.15 sec	4.38 sec
5	Top Displacement in X-direction due to WLX	0.482 m	0.0436 m
6	Inter Storey Drift in X-direction due to WLX	0.000245 m	0.000291 m

VIII. conclusion

a) Cylindrical building is economical than square building.

b) In circular building top displacement is less as compare to square building.

c) Time period of square building is less as compare to circular building.

d) The performance of circular building is good as compare to square building.

e) Circular building is more efficient than square building.

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