# Evaluate the Performance of Diagrid Building for Bracing Angle and Shape

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***Abstract-* The rapid growth of urban population and limitation of available land, the taller structures are preferable nowadays. So when the height of structure increases then the consideration of lateral load is very much important. For that the lateral load resisting system becomes more important than the structural system that resists the gravitational loads In this era, there is rapid increasing in construction of high rise building all over the world. Development of building types, forms, spans, construction technology, analysis and design software ease the growth of the high rise building. So when the height of structure is increases then the consideration of lateral force is become vital. The major problem of tall buildings now-a days is the displacement and drift parameters which causes problems for the people accommodating at the top story, to prevent such problems different structural systems are analyzed to minimize top story displacement To solve the above-mentioned problem the use of diagrid structure system shall be beneficial to mitigate the displacement to a particular limit. Till now the study of diagrid system was limited the square and rectangular shaped tall building with or without irregularity. In present study comparison of structural performance is made to understand the behavior of two differently planned 30-storey diagrid structures. Hexagonal and Octagonal plan diagrid structural performance is evaluated for two important loadings viz. earthquake and wind loading. ETABS 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 comparison of results in terms of storey drift, top-storey displacement, time period is presented here and optimal diagrid angle for Hexagonal and Octagonal diagrid structure.**

***Keywords-*** Diagrid Structural System, diagrid structure, Hexagonal and Octagonal plan, story drift and story displacement

## I.INTRODUCTION

Tall commercial buildings are primarily a response to the intense pressure on the available land. Advances in materials, construction technology, analytical methods and structural systems for analysis and design accelerated the development of tall structures. The lateral loading due to wind and earthquake is the major factor that causes the design of high-rise buildings. These lateral loads are resisted by exterior structural system or interior structural system. The lateral load resisting systems that are widely used are mainly rigid frame, shear wall, wall-frame, braced tube system, outrigger system, diagrid system and tubular system. Recent trend shows that the diagrid structural system is becoming popular in the design of tall buildings due to its inherent structural and architectural advantages. Diagrid is an exterior structural system in which all perimeter vertical columns are eliminated and consists of only inclined columns on the façade of the building. Shear and over-turning moment developed are resisted by axial action of these diagonals compared to bending of vertical columns in framed tube structure. Vertical columns in the core are designed for carrying gravity loads only and the diagrid is useful for both gravity and lateral loading. Diagonal zed applications of structural steel members for providing efficient solutions both in terms of strength and stiffness are not new, however nowadays a renewed interest in it and a wide spread application of diagrid is registered with reference to large span and high rise buildings, particularly when they are characterized by complex geometries and curved shapes.

The diagrid systems are the evolution of braced tube structures. The major difference between a braced tube building and a diagrid building is that, there are no vertical columns present in the perimeter of diagrid building. The diagonal members in diagrid structures act both as inclined columns and as bracing elements and due to their triangulated configuration, mainly internal axial forces arise in the members. Diagrid structures do not need high shear rigidity cores because shear can be carried by the diagrid located on the perimeter. The concept of diagrid is not new at all; people have always been intuitively familiar with the inherent stability of triangular structures. Placement of diagonals is the oldest and most natural solution in steel structures, and has widespread applications, receiving great popularity among engineers and architects; however the past architects considered diagonals highly obstructive and usually embedded them within the building interior cores.

## II.LITERATURE SURVEY

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 minimizethe lateral drift in high-rise building. Five different diagrid angle configurations (27˚, 45˚, 56˚, 72˚, and 81˚) 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˚ for 24-storey model, and between (56˚- 72˚) for 48- storey model, and 72˚ for 72- storey model.

III. HEXAGONAL BUILDING CONFIGURATION

Hexagonal plan with straight beamis considered. Plan is shown in Figure view of 30 storied Hexagonal diagrid structures with diagonal columns inclined at 65 as shown in Fig Diameter of the structure is 40 m. Floor height is 3.5m and slab thickness is 110 mm. Live loads applied are 2 kN/m$^2$. Diagonal columns are provided along the perimeter at angles of 65 °. Wind loads as provided assuming wind speed of 50 m/s and terrain category III. Seismic forces are provided for zone factor 0.36, importance factor 1 and response reduction factor 5. The structure is analysed in ETABS 16 software. Along dynamic wind loads are computed as per IS 875-III (2015).

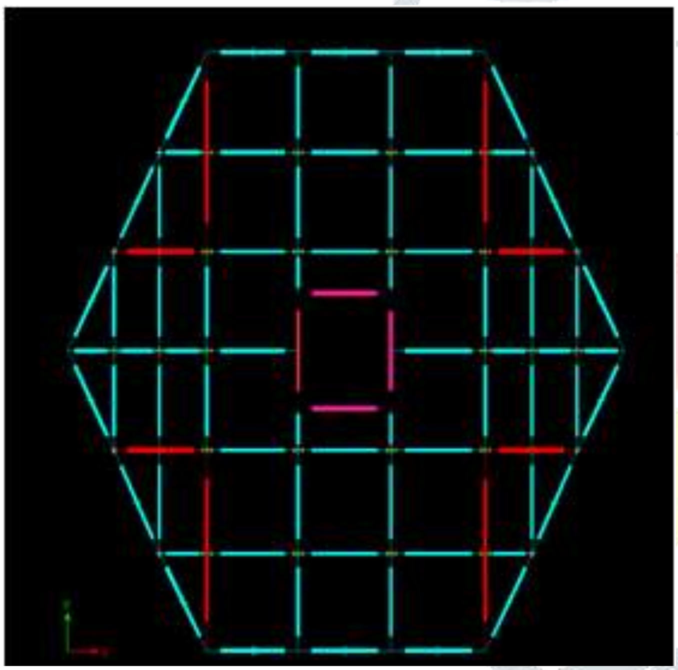

**Figure1:** Hexagonal Building Configuration

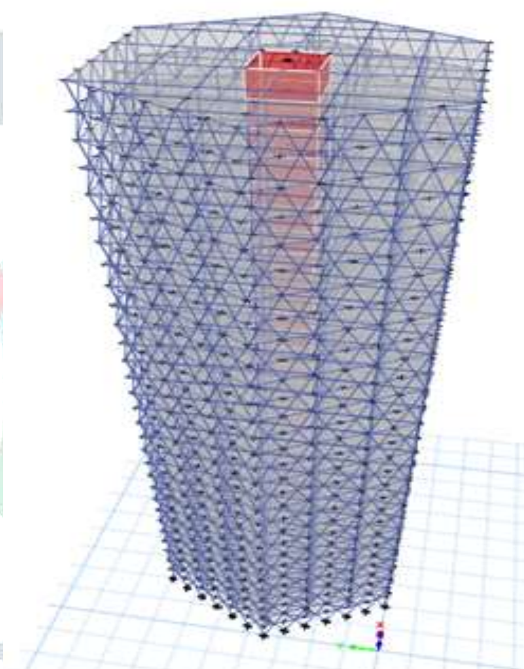

**Figure2:** 3D view of Hexagonal Building plan with central core portion

A 30 storey Hexagonal building with following geometric dimensions is considered to assess the efficiency of Diagrid structural system. Input data required for modeling of structure. The overall Description of Structural Member is as shown in **Table 1**

**Table1:** overall Description Structural Member of Hexagonal Building

| Sr. No. | Description | values |
|---|---|---|
| 1 | No of story | 30 |
| 2 | Plan size | 40 m (Dia) |
| 3 | Story height | 3.5 |
| 4 | Structure type | Steel frame |
| 5 | Dead load | 3 kN/m2 |

| | | |
|---|---|---|
| 6 | Live load | 2 kN/m2 |
| 7 | Location and Seismic zone | Guwahati and zone V |
| 8 | Diagrid angle | 65 degree |
| 9 | Diagrid member | Pipe section ( ISNB 200M) |
| 10 | Beams<br>A) Ring Beam<br>B) Tie Beam | <br>ISMB 500<br>ISWB 550 |
| 11 | Columns | ISWB 600-2 |
| 12 | Module geometry | triangle |
| 13 | Building shape | HEXAGONAL |

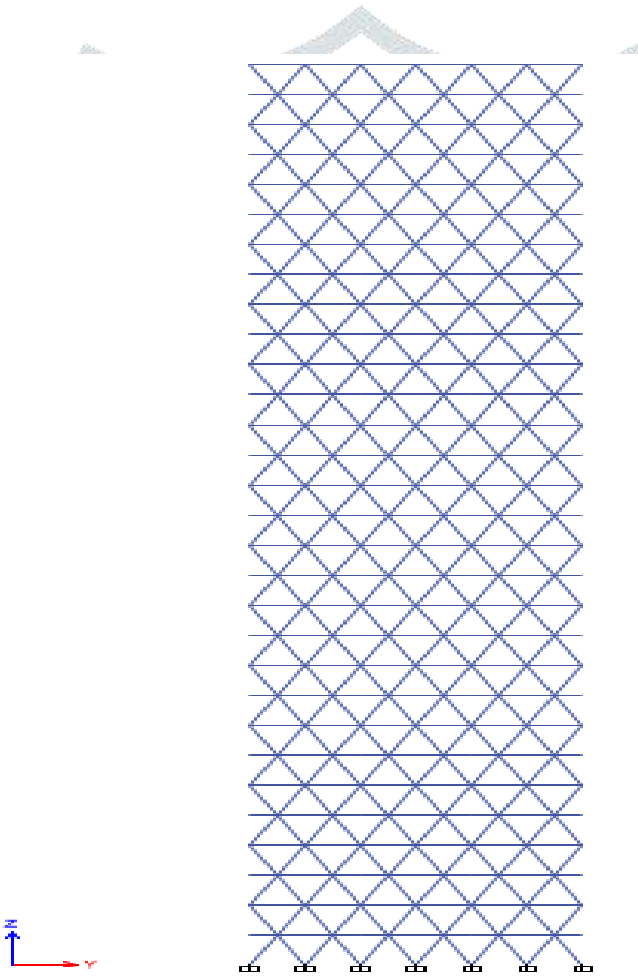

**Figure 3. Diagrid angle at 65˚**

IV. OCTAGONAL BUILDING PLAN AND ANALYSIS

Octagonal plan with straight beamis considered. Plan is shown in Figure view of 30 storied cyoctagonal diagrid structures with diagonal columns inclined at 65 as shown in Figure 4. Diameter of the structure is 52.26m. Floor height is 3.5m and slab thickness is 110 mm. Live loads applied are 2 kN/$m^2$. Diagonal columns are provided along the perimeter at angles of 65 °. Wind loads as provided assuming wind speed of 50 m/s and terrain category III. Seismic forces are provided for zone factor 0.36, importance factor 1 and response reduction factor 5. The structure is analysed in ETABS 16 software. Along dynamic wind loads are computed as per IS 875-III (2015).

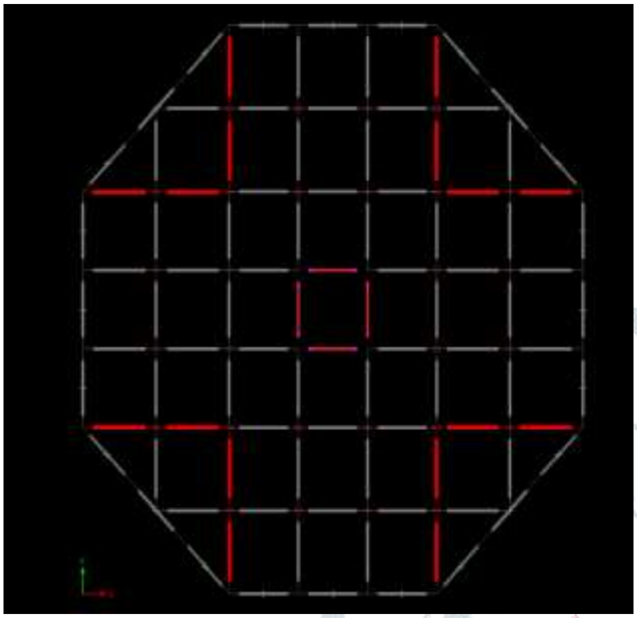

**Figure4 :** Octagonal Building Configuration

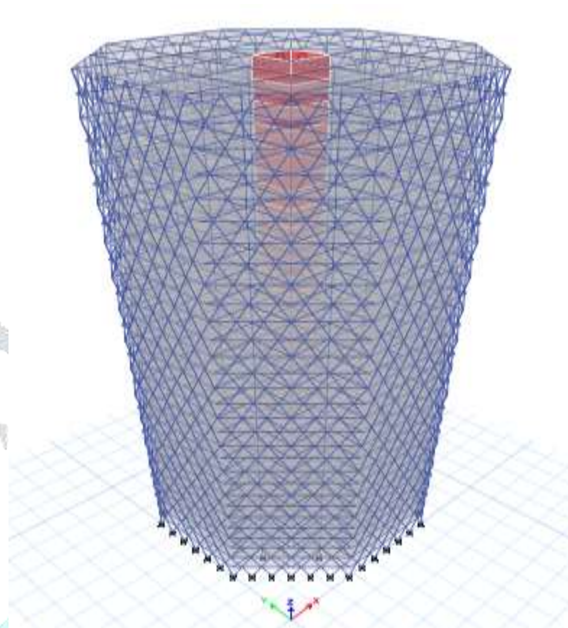

**Figure5: 3D view of** Octagonal Building plan with central core portion

A 30 storey Hexagonal building with following geometric dimensions is considered to assess the efficiency of Diagrid structural system. Input data required for modeling of structure. The overall Description of Structural Member is as shown in **Table 2**

**Table 2:** overall Description Structural Member of octagonal Building

| Sr. No. | Description | Values |
|---|---|---|
| 1 | No of story | 30 |
| 2 | Plan size | 52.26m (Dia) |
| 3 | Story height | 3.5 |
| 4 | Structure type | Steel frame |
| 5 | Dead load | 3 kN/m2 |
| 6 | Live load | 2 kN/m2 |
| 7 | Location and Seismic zone | Guwahati and zone V |
| 8 | Diagrid angle | 65 degree |
| 9 | Diagrid member | Pipe section ( ISNB 200M) |
| 10 | Beams<br>A) Ring Beam<br>B) Tie Beam | <br>ISMB 500<br>ISWB 550 |
| 11 | columns | ISWB 600-2 |
| 12 | Module geometry | Triangle |

| | | |
|---|---|---|
| 13 | Building shape | OCTAGONAL |

V. ANALYSIS RESULT FO HEXAGONAL BUILDING MODEL

The displacement of 30 storey square diagrid structure is shown in Fig . 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 storey square diagrid structure is shown in Fig. It is observed that inter-storey drift in x-direction and y-direction due to dynamic wind load is higher compared to earthquake load

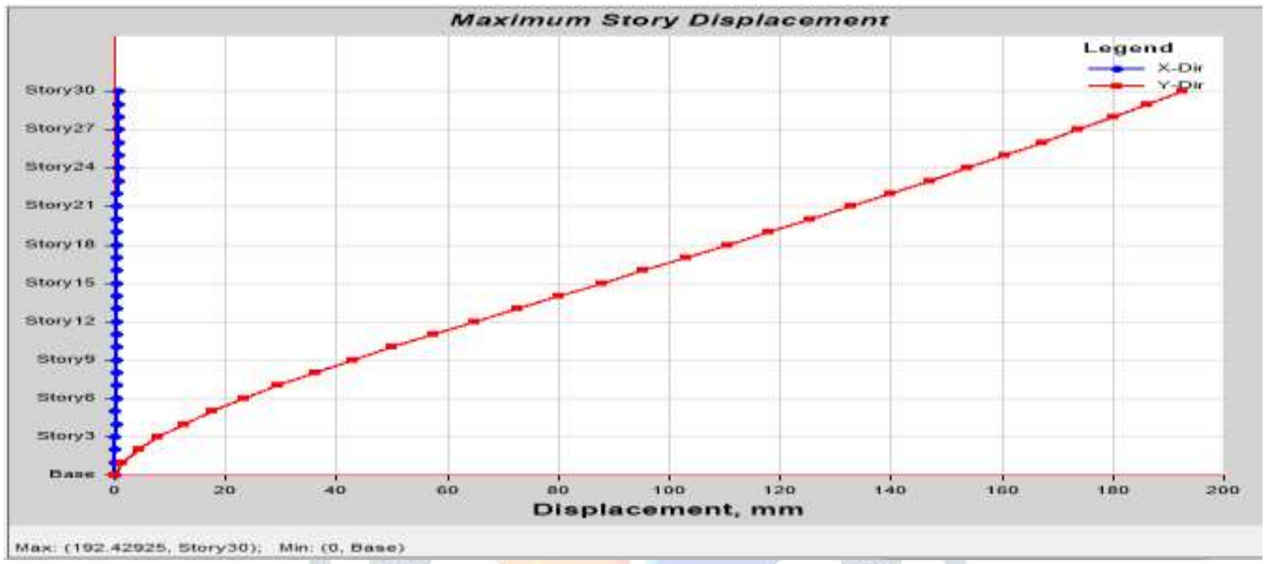


**Figure6:** Maximum displacement at $65^{0}$ Diagrid angle

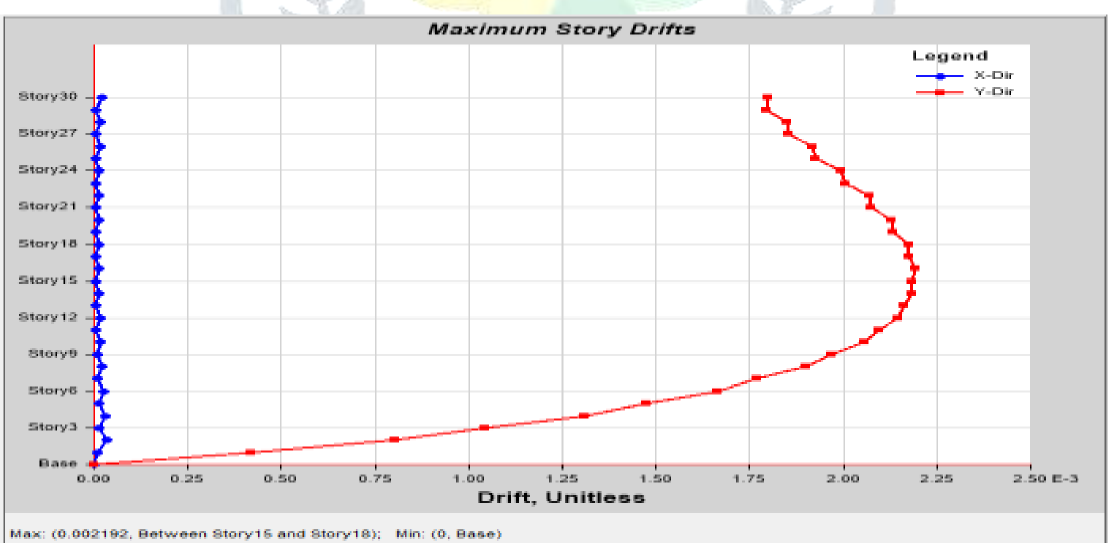


**Figure7:** Inter-story at $65^{o}$ Diagrid angle

VI. ANALYSIS RESULT FOR OCTAGONAL MODEL

The displacement of $3^{O}$ storey square diagrid structure is shown in Fig8. 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 storey square diagrid structure is shown in Fig9. It is observed that inter-storey drift in x-direction and y-direction due to dynamic wind load is higher compared to earthquake load

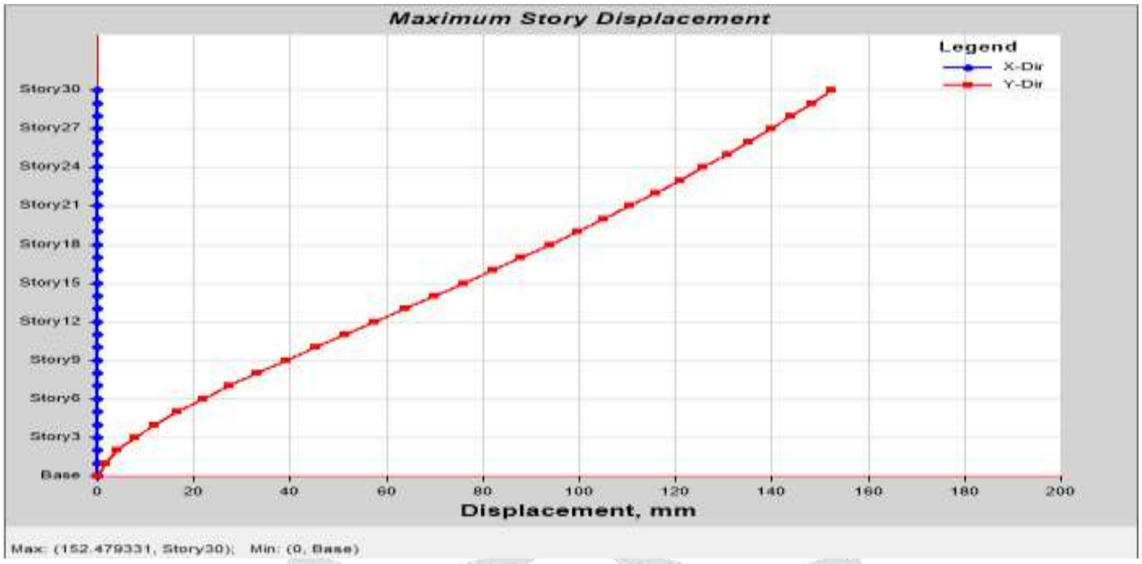


**Figure8**: Maximum displacement at 65$^{O}$

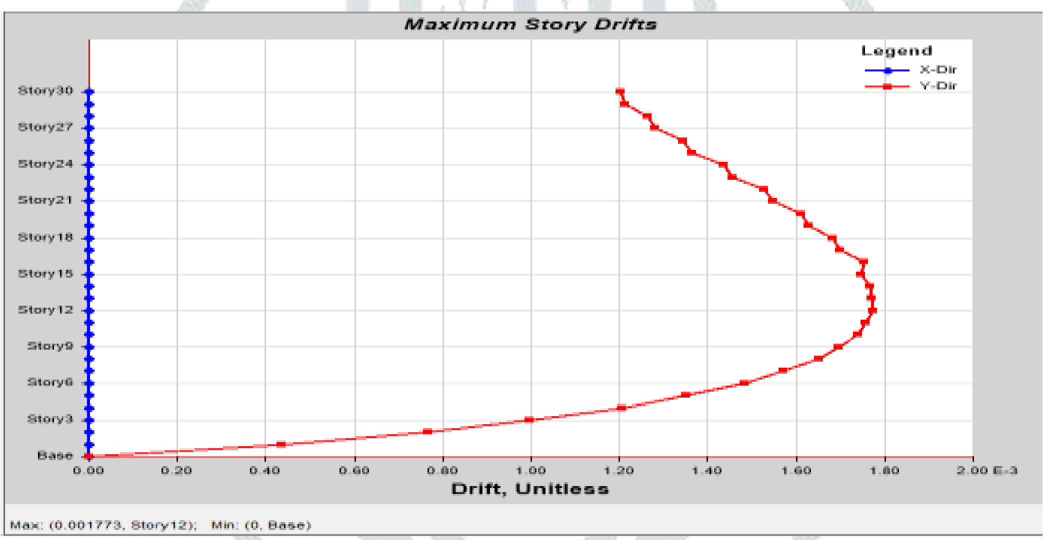


**Figure9**: Inter-story at 65$^{0}$ Diagrid angle

VII. COMPARISONS OF RESULTS

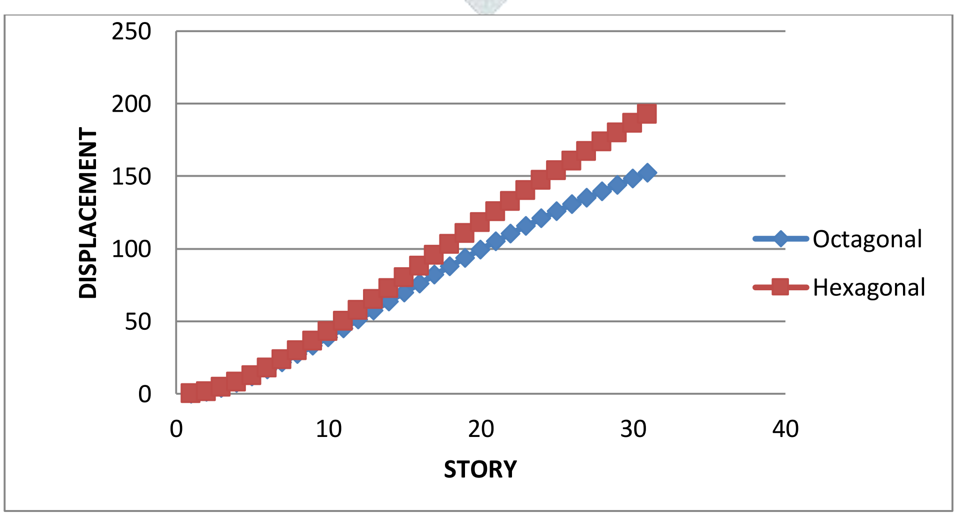

**Figure10**: Displacement between Hexagonal and Octagonal Building at diagrid angle 65˚

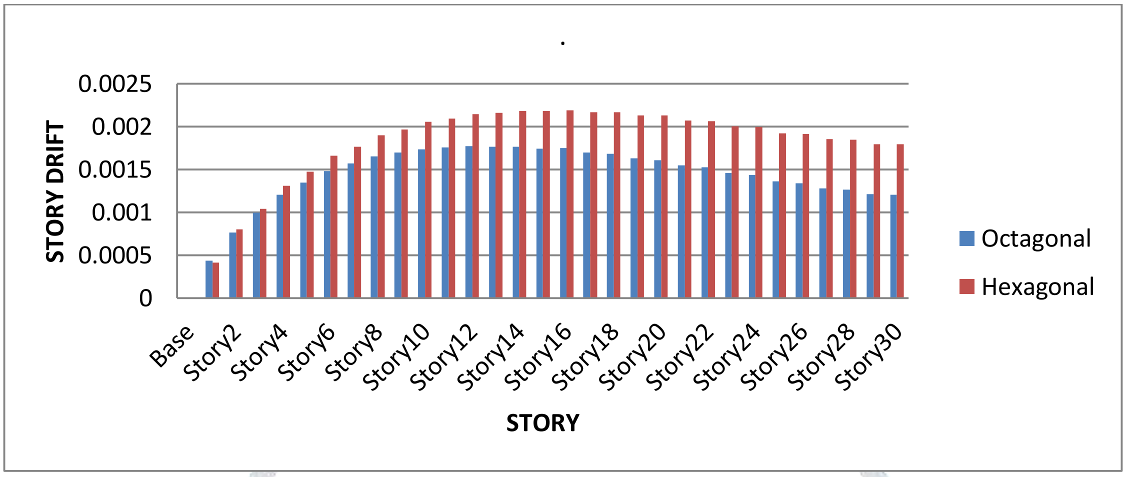


**Figure11**: Drift between Hexagonal and Octagonal Building at diagrid angle 65˚

**Table 3:** Interpreted Result of Hexagonal Diagrid building

| | HEXAGONAL BUILDING | | |
|---|---|---|---|
| DIAGRID ANGLE | DISPLACEMENT | DRIFT | TIME PERIOD |
| 47˚ | 211.89 | 0.00242 | 2.866 |
| 65˚ | 192.42 | 0.002192 | 2.775 |
| 73˚ | 223.011 | 0.002579 | 2.976 |
| 80˚ | 289.59 | 0.003373 | 3.386 |

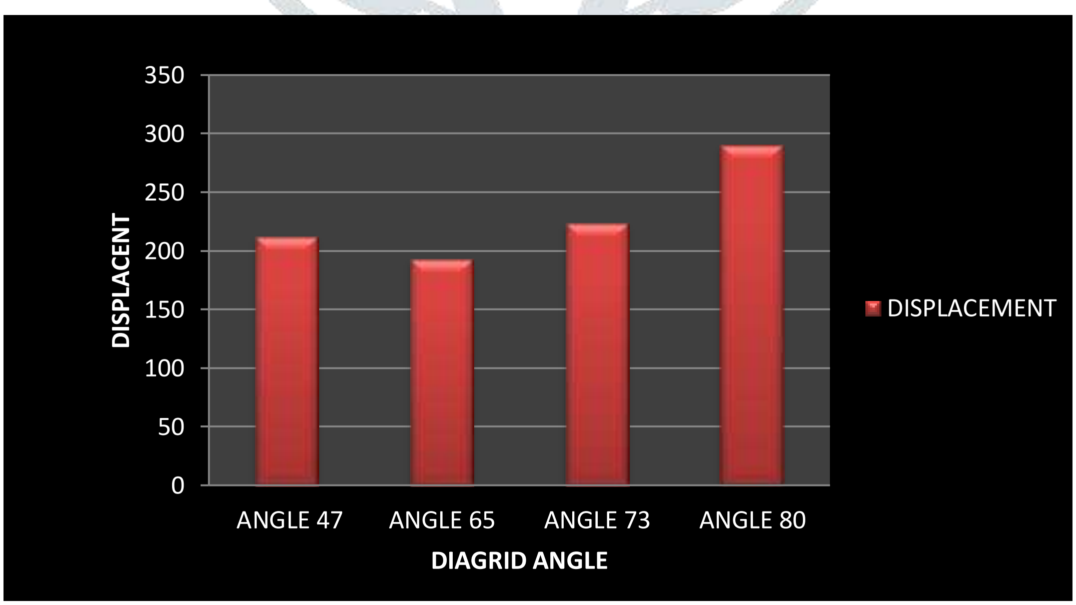


**Figure 12:** Displacement of Hexagonal Building at various angles

**Table 4:** Interpreted Result of Octagonal Diagrid building

| | OCTAGONAL BUILDING | | |
|---|---|---|---|
| DIAGRID ANGLE | DISPLACEMENT | DRIFT | TIME PERIOD |
| 47˚ | 162.75 | 0.001858 | 3.014 |
| 65˚ | 152.47 | 0.001773 | 2.968 |
| 73˚ | 189.47 | 0.002289 | 3.328 |
| 80˚ | 276.74 | 0.00335 | 4.007 |

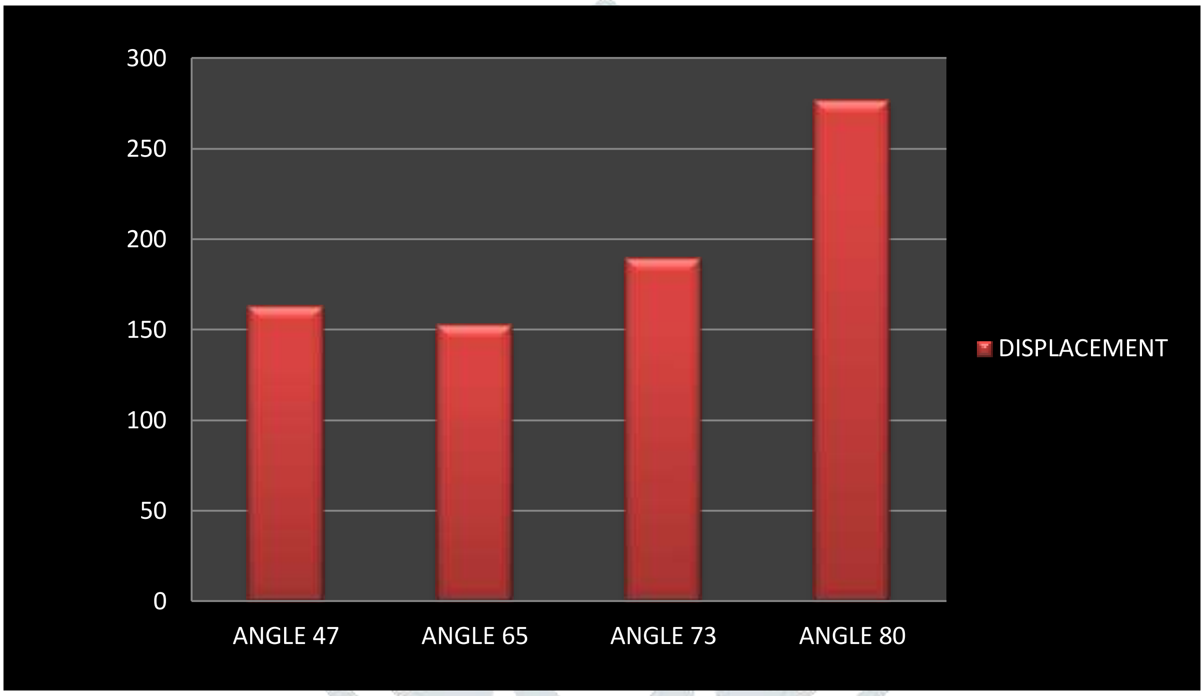


**Figure 13:** Displacement of Hexagonal Building at various building

VIII.CONCLUSION

In this paper, analysis and design of 30 storey diagrid steel building with shear wall core is presented in detail. ETABS 2016 software is used for modeling of structure in Wind analysis and responses pectrum analysis. All structural members are designed using IS 800:2007 considering all load combinations. Load distribution in diagrid system is also studied for 30 storey building. The storey response time period, storey displacement, inters storey drift and total storey displacement is obtained from response spectrum analysis, gives the lesser values when compared to static analysis. The shear wall is provided more stability to the structure to resist the seismic loads and along wind speed. The total load acting on the each storey due to lateral and gravity loads are calculated.

- **General conclusions**

1. Wind loading governs the structural response than earthquake loading, for the tall buildings.

2. In octagonal building top displacement is less as compare to Hexagonal building.

3. Time period of Hexagonal building is less as compare to Octagonal building.

4. Inter story drift is seen to increase considerably. It can be due to less shear rigidity as the diagonal columns tend to be vertical

5. as the angle of diagrid increases axial rigidity of the diagonal columns decreases. Hence lateral load resisted by diagrid decreases.

- **Optimum angle for building**

7. Amongst different Hexagonal diagrid angle in this study i.e. 47˚,65˚,73˚,80˚ at 65˚ diagrid angle structure gives optimum result.(maximum displacement, interstory drift).

8. Amongst different Octagonal diagrid angle in this study i.e 47˚,65˚,73˚,80˚, at 60˚ to 65˚ diagrid angle structure gives optimum result. (Maximum displacement, inter-story drift).

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