A Comparative Study between Dia grid and Hexagrid Structural System in Tall Buildings

Nujed Ali Khan[1], BR Narayan[2], Dr. N S Kumar[3]

[1]M. Tech, Structural Engineering, Ghousia College of Engineering, Ramanagara, Karnataka, India
[2]Assistant Professor, Dept. of Civil Engineering, Ghousia College of Engineering, Ramanagara, Karnataka, India
[3]Prof. & HOD, former Director (R & D), Dept. of Civil Engineering, Ghousia College of Engineering, Ramanagara

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Abstract - The growth of urban population and the pressure on the limited space in the urban area led to the vertical growth of buildings. As the height of the building increases the lateral loads acting on the building increases. So, it is important to take care of the lateral load resisting systems in the building which is more important than the structural system that resists the gravitational loads that is dead load and live load. It is very important to select a structural system that the structural elements are utilized effectively and should satisfying design requirements.

The aim of the current thesis work is to study seismic responses (store displacements, storey drift. Fundamental time period and base shear) of Diagrid and Hexagrid building located in different seismic zones (for Zone II, III, and IV) as per IS 1893-2016

All the three models were checked for displacement, story drift, time period and base shear for zone II, zone III and zone IV. With the help of accurate data the same model can be subjected to time history analysis in the future and the behaviour of all the models can be re-evaluated Different angles can be used for diagrid and for hexagrid systems. To find out optimum angle for the building.

***Key Words*: lateral load, Diagrid and Hexagrid building , store displacements, storey drift**

1.INTRODUCTION

High-rise structures are commonly offices or residential structures (apartments, hotels), and in most of the cases it is the combination of both. They generally include parking, basements, and garages. Studies done on structural systems are appropriate to specific structures, and the results obtained are not sufficient to favour an exact structural system even in acutely similar conditions. Today there are so many structural steel systems that are being used for the lateral bracing of tall buildings. There are different lateral load resisting structural systems that are currently being used in the design of tall steel buildings and are broadly divided into the following categories, braced frame structures, rigid frame structures, Shear wall structures, infilled frame structures, wall frame structures, braced tube system, outrigger system, tubular system, space structures, and hybrid structures.

1.1 Diagrid System

Diagrids are involved both in gravity and lateral load resistance of buildings. These are perimeter structural configurations characterized by a narrow grid of diagonal members. Enhanced interest and more use of diagrid as reference to the large span and high rise buildings, particularly when they are featured by complex geometries and curved shapes, sometimes they are completely free forms.

The diagrid structural system can be defined as a diagonal members framed as a framework made by the intersection of different materials like metals, concrete or wooden beams which is used in the construction of buildings and roofs. Diagrid structures of the steel members are productive in giving solution in terms of quality, strength and stiffness. Be that as it may, these days a boundless application of diagrid is utilizes in the large span and high rise buildings, especially when they are having a complex geometries and curved shapes.

1.2 Hexagrid system

A major point of this design approach is to introduce a new structural system for Tall building. The hexagonal and diamonds were located along the entire exterior perimeter surfaces of the building in order to maximize their structural effectiveness and capitalize on the aesthetic innovation. This strategy is much more effective than confining diagonals to narrower building cores. In the hexagrid structure system, almost all the conventional vertical columns are eliminated and to define a unique structural system for Tall building in order to minimize additional system for lateral loads (lateral system). In this system (Beehive), members in hexagrid structural systems can carry gravity loads as well as lateral forces due to their hexagonized configuration in a distributive and uniform manner. Compared with other systems in Tall buildings, hexagrid structures are much more effective in minimizing shear deformation because they carry shear by axial action of the diagonal members, while other structures carry shear by the bending of the vertical columns and horizontal spandrels.

2. Methodology

Three models modeled in etabs and their responses are noted down and compared to evaluate the results and conclusion

Conventional Model 1.

Conventional model consists of a rectangular geometry of length 24.02m and breadth 19.17 metres each and height of each storey 3.2m, B+G+24 floors respectively. With 5 bays in both the directions for podium at basement and ground level. With 3 bays in both the directions at typical floor levels is analysed for seismic zones II, III, and IV and the results and noted down.

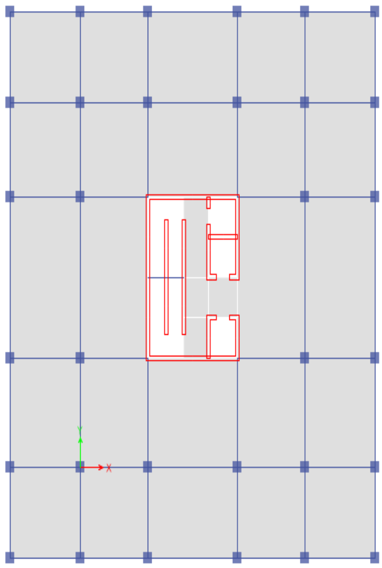


Fig -1: Ground floor plan

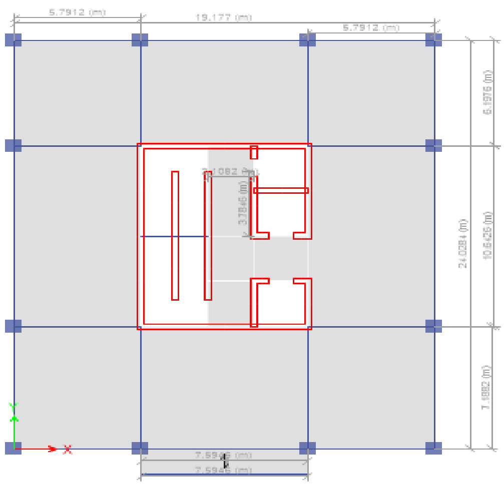


Fig -1a: Typical floor plan

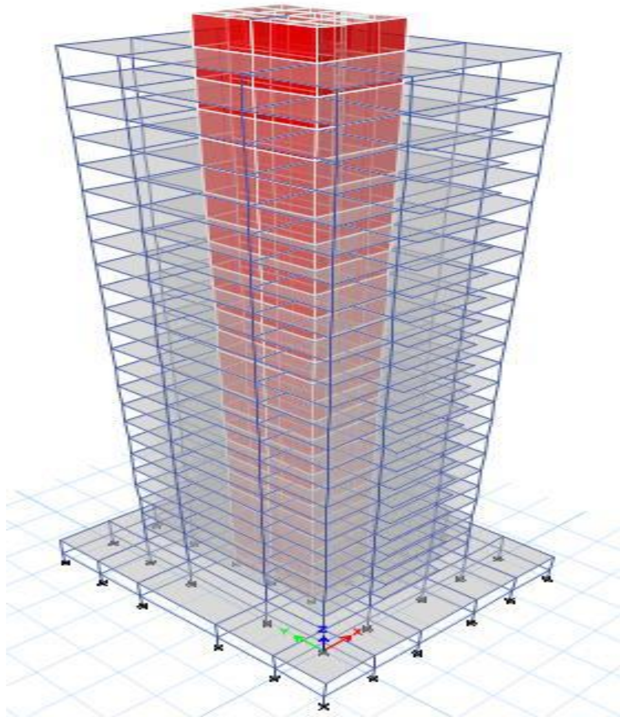


Fig -1b: **3D View**

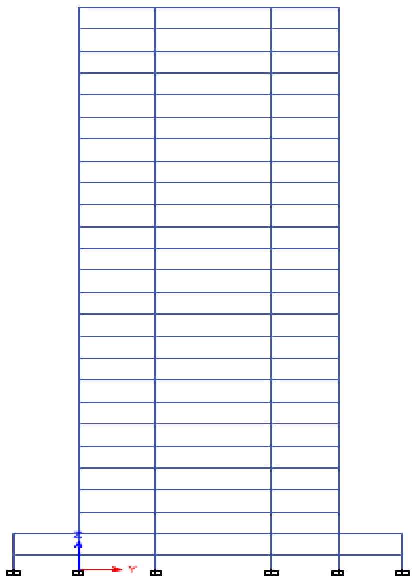


Fig -1c: **Elevation**

Fig 1: Conventional System

Diagrid Model 2.

The model is made to scale in ETABS and it is subjected to gravity loads. As per IS1893-2016 the seismic response of the building in zone II, zone III and zone IV are noted.

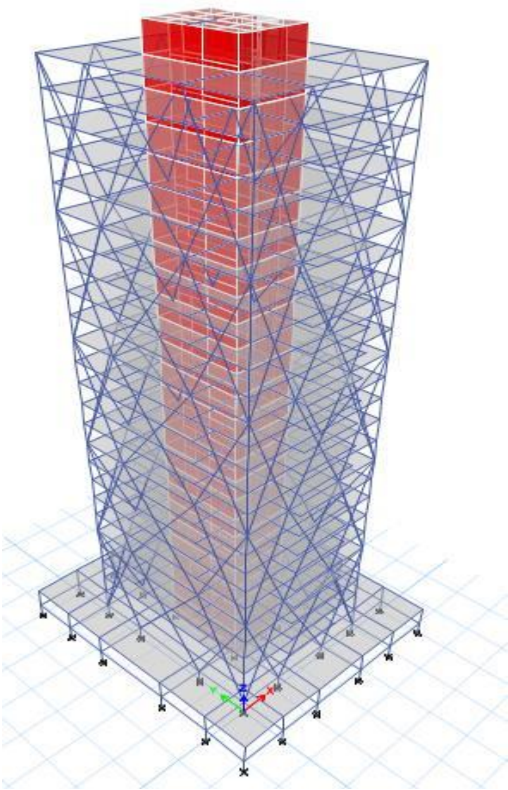


Fig -2: 3D View

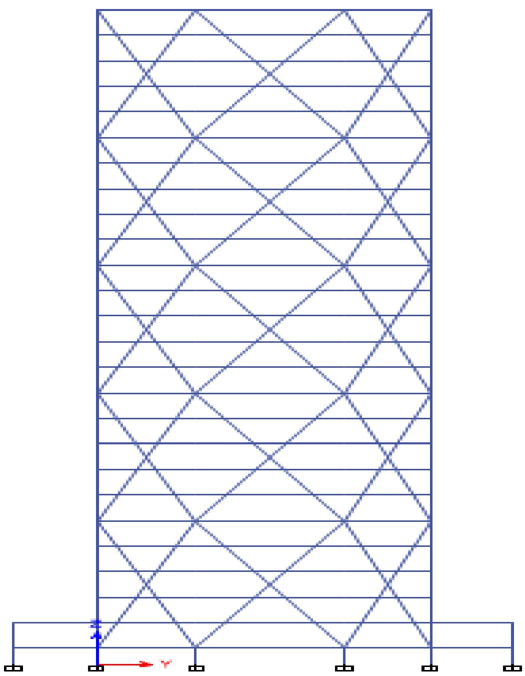


Fig -2a: Elevation

Fig -2: Diaagrid System

Hexagrid Model 3.

The model is made to scale in ETABS and it is subjected to gravity loads. As per IS1893- 2016 the seismic response of the building in zone II, zone III and zone IV are noted.

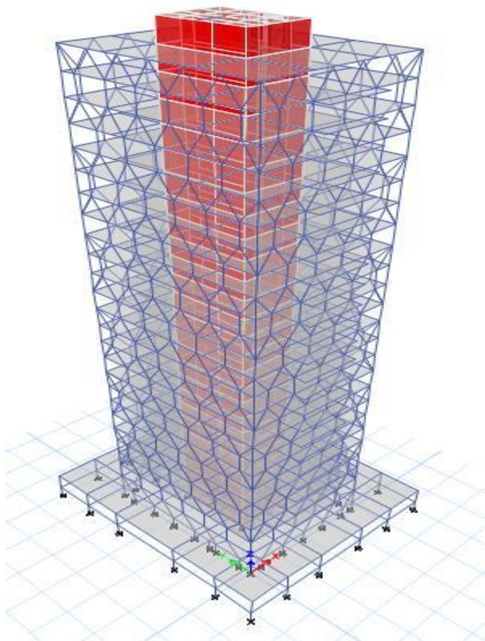


Fig -3:3D View

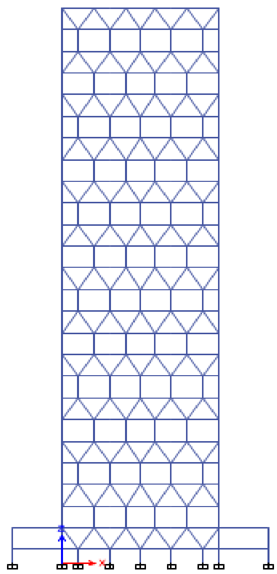


Fig -3a:Elevation

Fig -3: Hexagrid System

3. RESULT AND DISCUSSION

This chapter presents results of seismic analysis of all the models considered as per the model analysis which was discussed in chapter 4. The results and discussions given are considered in detail with reference to required tables and figures.

3.1 Displacement

The maximum values of displacements are tabulated by comparing X and Y directions. The values of displacement of different models are obtained by subjecting the models to response spectrum analysis and time history analysis (linear) shows max displacement.

Table 1: Max Displacement (Response spectrum X direction)

SL NO	ZONES	MAX DISPLACEMENT Conventional (mm) SPECX	MAX DISPLACEMENT Diagrid (mm) SPECX	MAX DISPLACEMENT Hexa-grid (mm) SPECX
1	ZONE II	17.22	7.57	9.787
2	ZONE III	27.552	12.112	15.66
3	ZONE IV	41.328	18.168	23.49

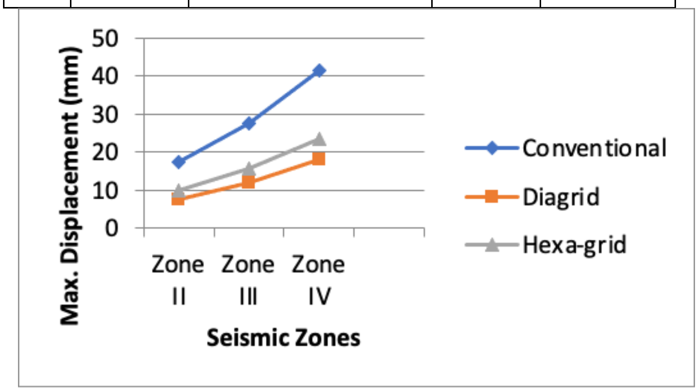


Fig 3.1:**Graph of displacement variation**

Table 2: Max Displacement values (Response spectrum Y direction)

SL NO	ZONES	MAX DISPLACEMENT Conventional (mm) SPECY	MAX DISPLACEMENT Diagrid (mm) SPECY	MAX DISPLACEMENT Hexa-grid (mm) SPECY
1	ZONE II	25.012	5.967	9.1
2	ZONE III	40.018	9.548	14.561
3	ZONE IV	60.028	14.321	21.841

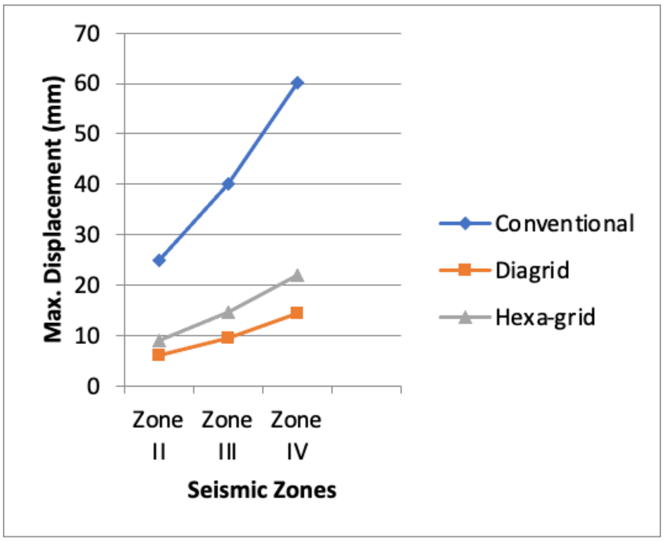


Fig 3.2: **Graph of displacement variation**

Table 3: **Max Displacement values (Time history X direction)**

SL NO	ZONES	MAX DISPLACEMENT Conventional (mm) THX	MAX DISPLACEMENT Diagrid (mm) THX	MAX DISPLACEMENT Hexa-grid (mm) THX
1	ZONE II	21.332	7.406	7.067
2	ZONE III	34.132	11.849	11.308
3	ZONE IV	51.195	17.772	16.961

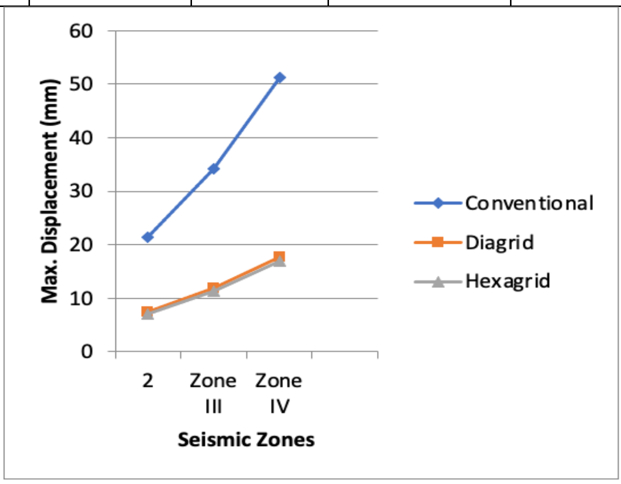


Fig 3.3: Graph of displacement variation

Table 4: Max Displacement values (Time history Y direction)

SL NO	ZONES	MAX DISPLACEMENT Conventional (mm) THY	MAX DISPLACEMENT Diagrid (mm) THY	MAX DISPLACEMENT Hexa-grid (mm) THY
1	ZONE II	33.73	6.361	8.746
2	ZONE III	53.968	10.178	13.994
3	ZONE IV	80.947	15.269	20.993

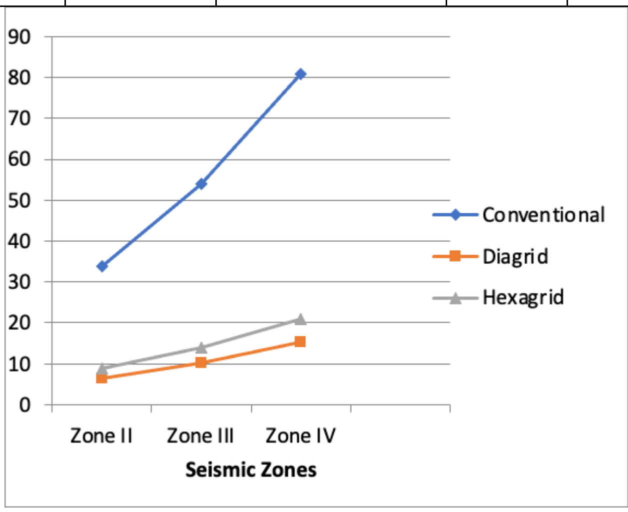
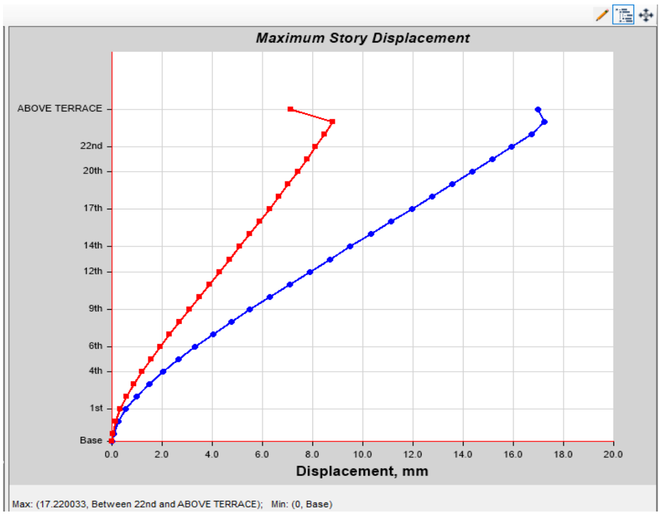
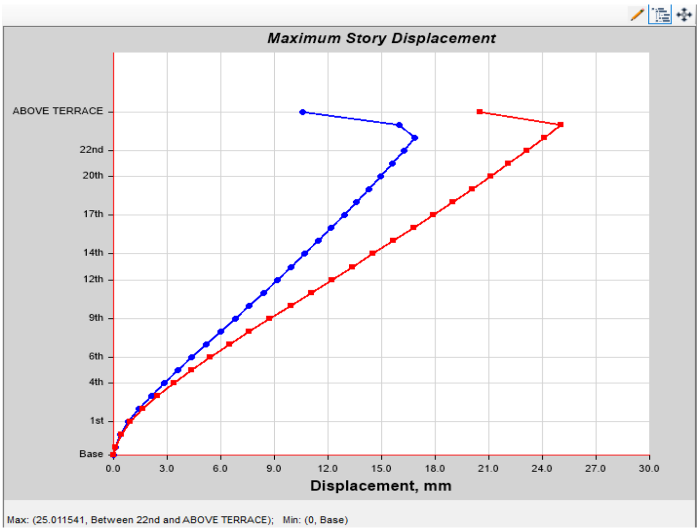


Fig 3.4: Graph of displacement variation

Maximum story displacement for Conventional model at zone II, III and IV

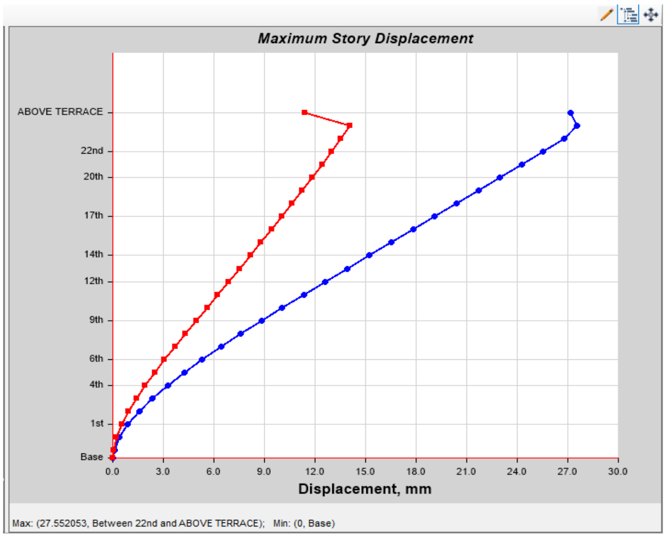


a) Displacement X direction.

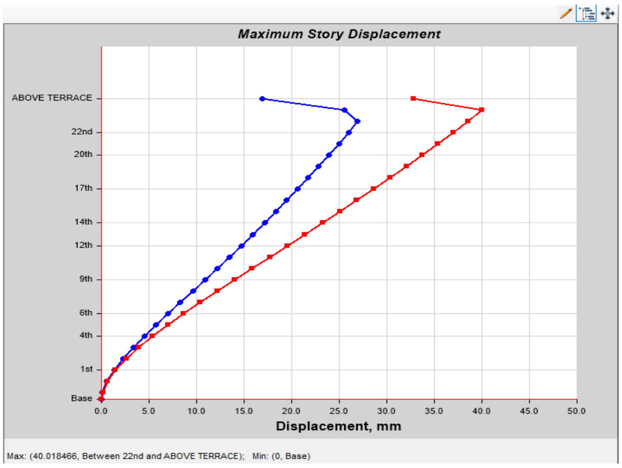


(b) Displacement Y direction

Fig 3.5 Maximum story displacement for zone II conventional model

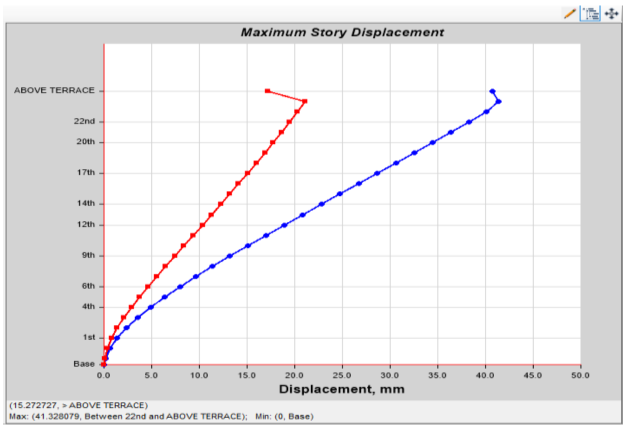


(a) Displacement X direction

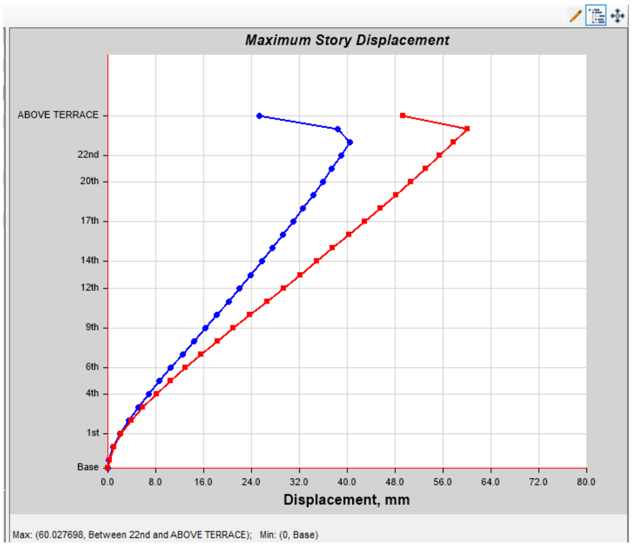


(b) Displacement Y direction

Fig 3.6: Maximum story displacement for zone III conventional model



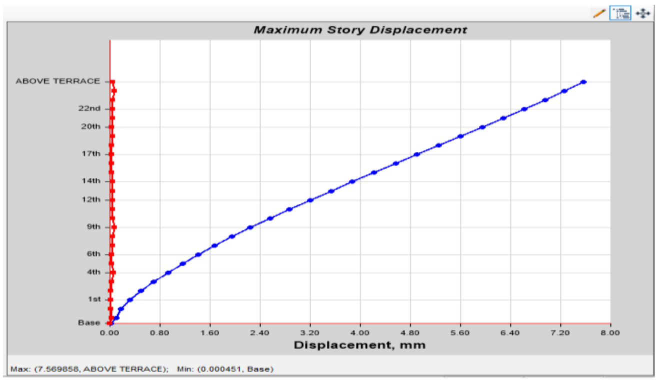
(a) Displacement X direction



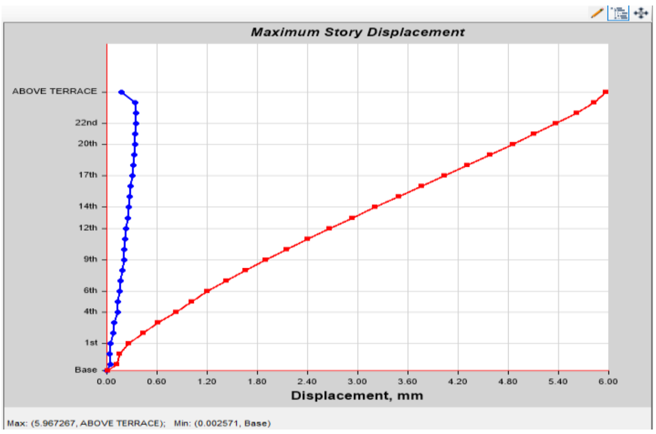
(b) Displacement Y direction

Fig 3.7 Maximum story displacement for zone IV conventional model

Maximum story displacement for Diagrid system

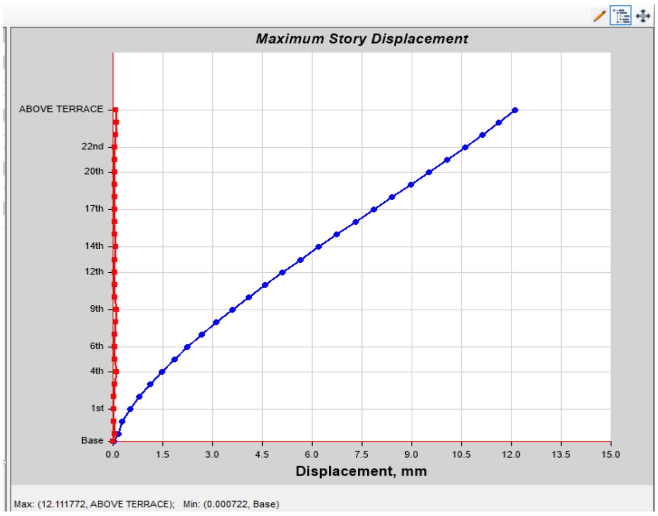


(a) Displacement X direction

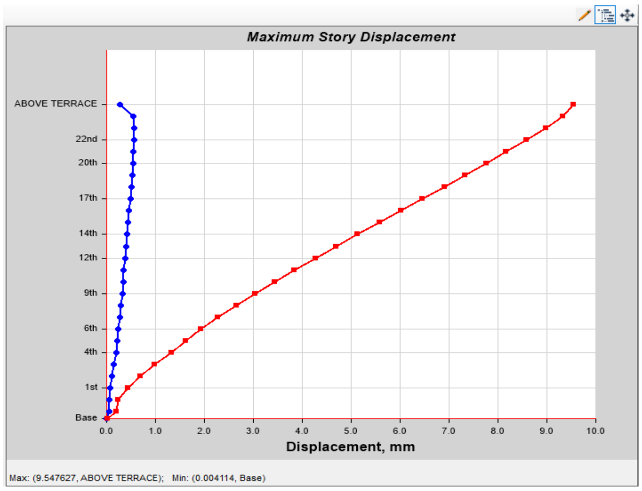


(c) Displacement Y direction

Figure 3.8: Maximum story displacement for zone II Diagrid model

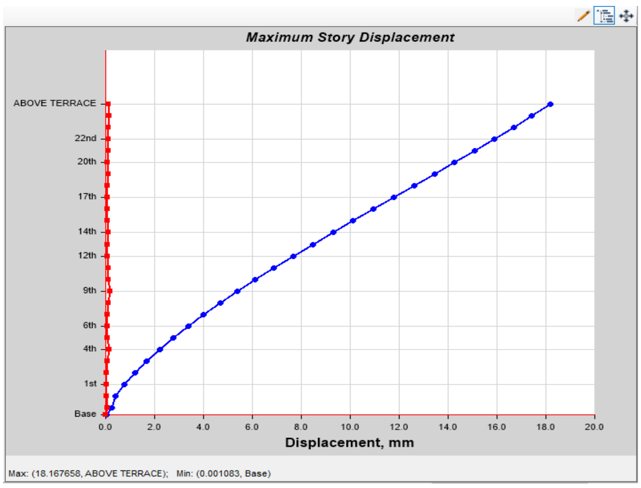


(a) Displacement X direction

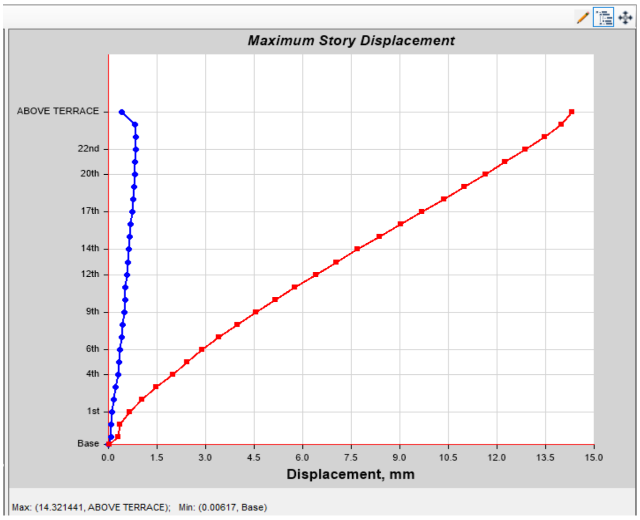


(a) Displacement Y direction

Fig 3.9 : Maximum story displacement for zone III Diagrid model



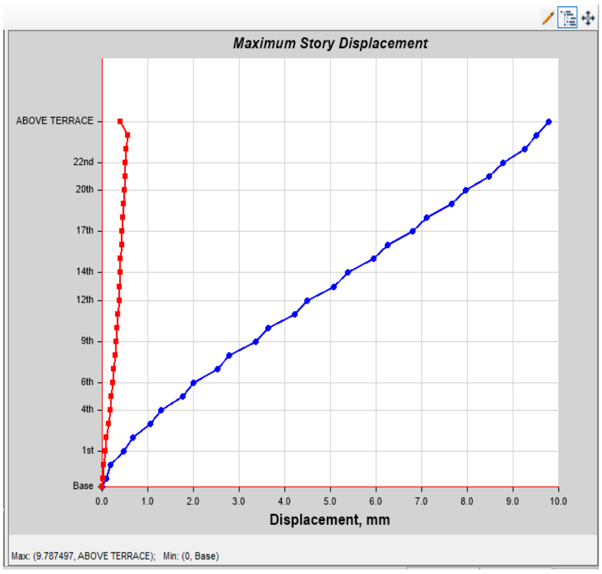
(a) Displacement X direction



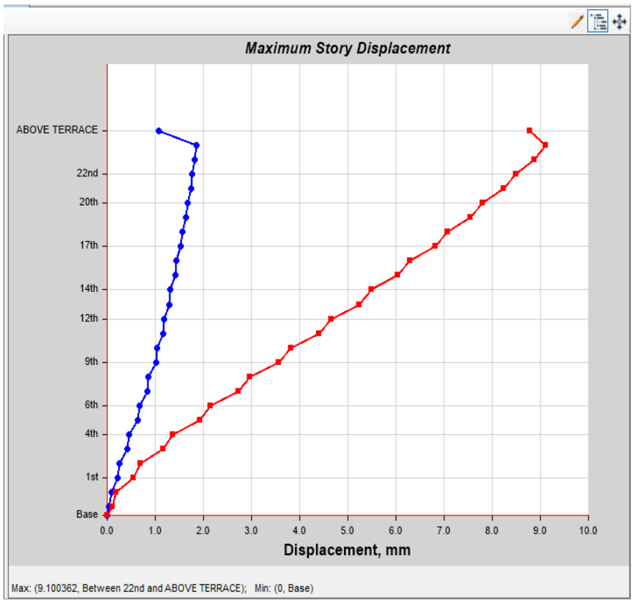
(b) Displacement Y direction

Fig 3.10 Maximum story displacement for zone IV Diagrid model

Maximum story displacement for Hexagrid model

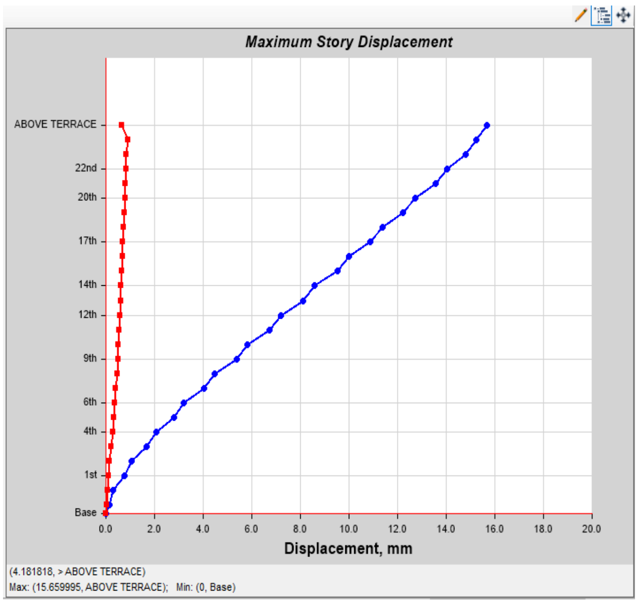


a)Displacement X direction

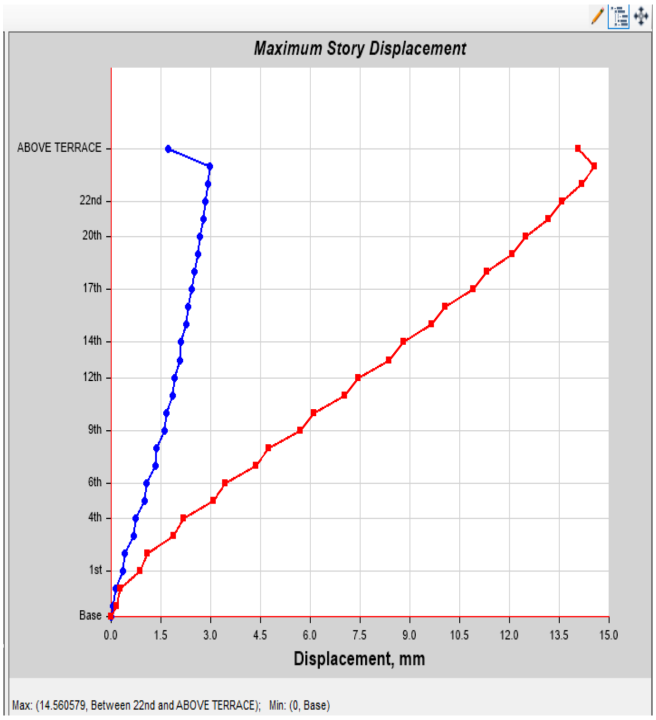


(b) Displacement Y direction

Figure 3.11: Maximum story displacement for zone II Hexagrid model

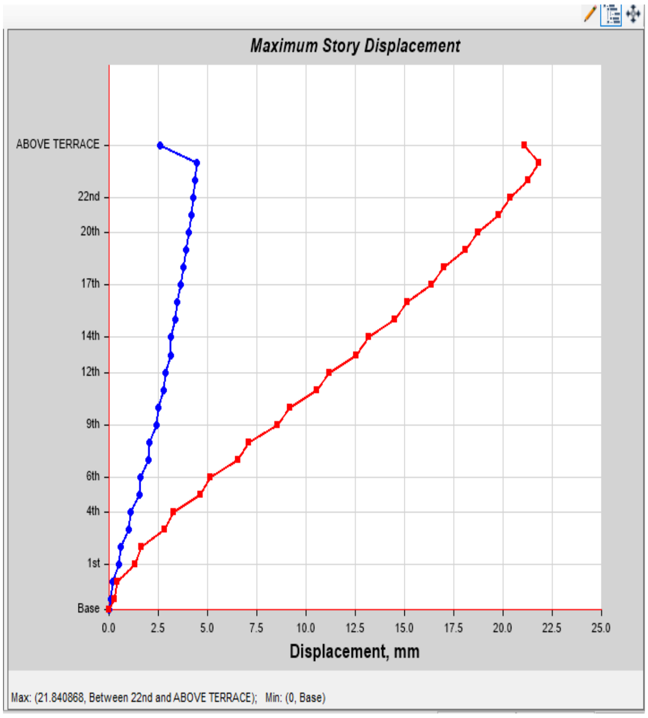


(a) Displacement X direction



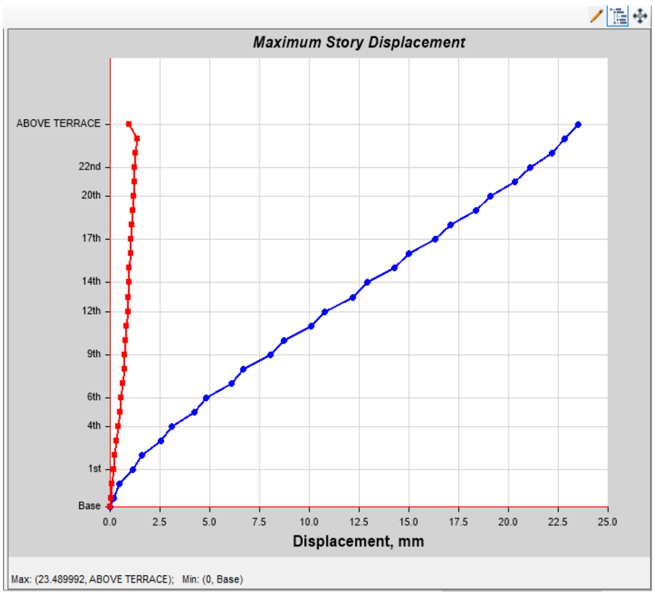
(a) Displacement Y direction

Fig 3.12 Maximum story displacement for zone III Hexagrid model



(b) Displacement Y direction

Fig 3.13 Maximum story displacement for zone IV Hexagrid model



(a) Displacement X direction

3.1.2 Story drift ratio

Table 5: Max Story Drift values (Response spectrum X direction)

SL NO	ZONE	MAX STORY DRIFT Conventional SPECX	MAX STORY DRIFT Diagrid SPECX	MAX STORY DRIFT Hexa-grid SPECX
1	Zone II	0.000268	0.000116	0.000184
2	Zone III	0.000428	0.000185	0.000261
3	Zone IV	0.000643	0.000278	0.000392

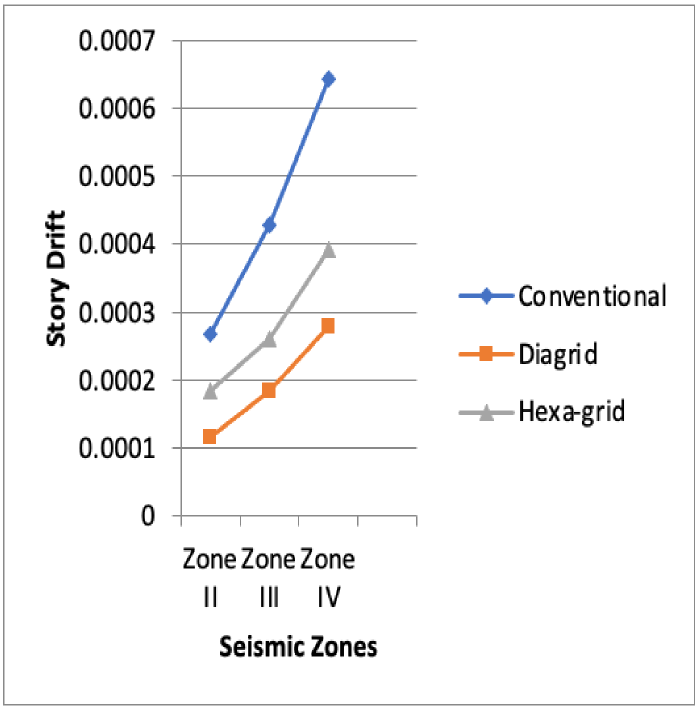


Fig 3.14 Graph of Story drift variation

Table 6: Max Story Drift values (Response spectrum Y direction)

SL NO	ZONE	MAX STORY DRIFT Conventional SPECY	MAX STORY DRIFT Diagrid SPECY	MAX STORY DRIFT Hexa-grid SPECY
1	Zone II	0.000383	9.5E-05	0.000189
2	Zone III	0.000613	0.000152	0.000272
3	Zone IV	0.00092	0.000229	0.000407

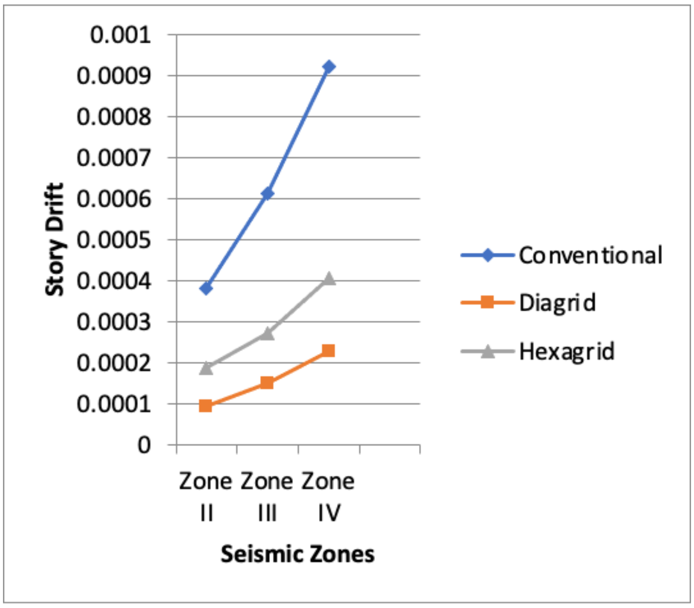


Fig 3.15 : **Graph of Story drift variation**

Table 7: Max Story Drift values (Time History X direction)

SL NO	ZONE	MAX STORY DRIFT Conventional THX	MAX STORY DRIFT Diagrid THX	MAX STORY DRIFT Hexa-grid THX
1	Zone II	0.000327	0.00011	0.000144
2	Zone III	0.000523	0.000175	0.00021
3	Zone IV	0.000784	0.000263	0.000314

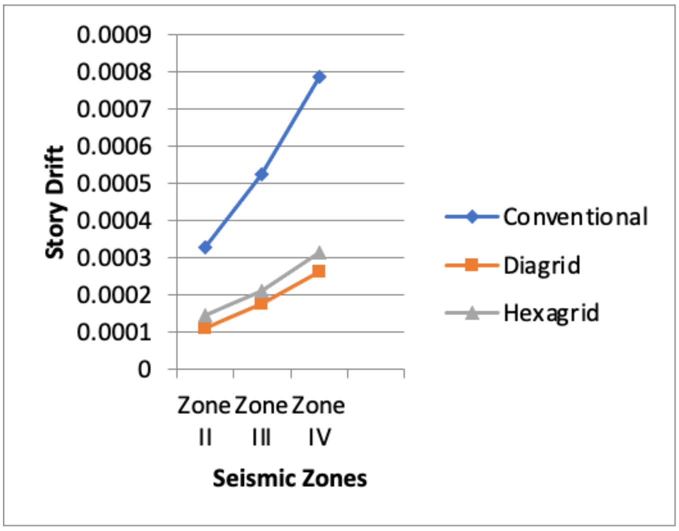


Fig 3.16: **Graph of Story drift variation**

Table 8: Max Story Drift values (Time History Y direction)

SL NO	ZONE	MAX STORY DRIFT Conventional THX	MAX STORY DRIFT Diagrid THX	MAX STORY DRIFT Hexa-grid THX
1	Zone II	0.000327	0.00011	0.000144
2	Zone III	0.000523	0.000175	0.00021
3	Zone IV	0.000784	0.000263	0.000314

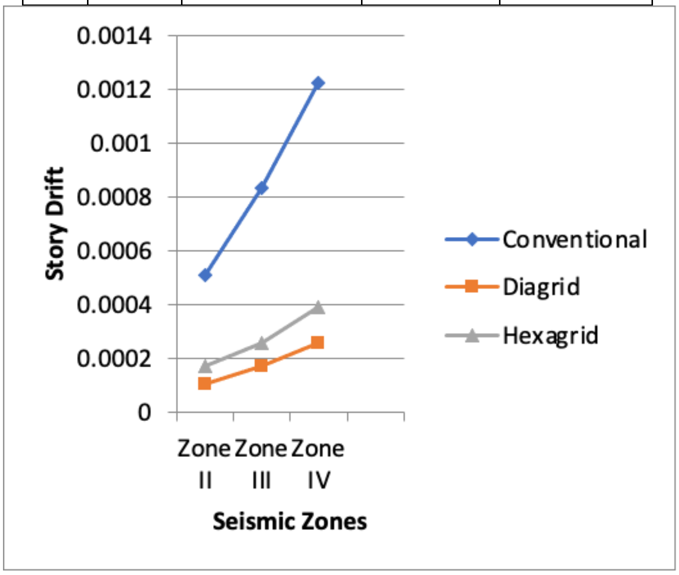
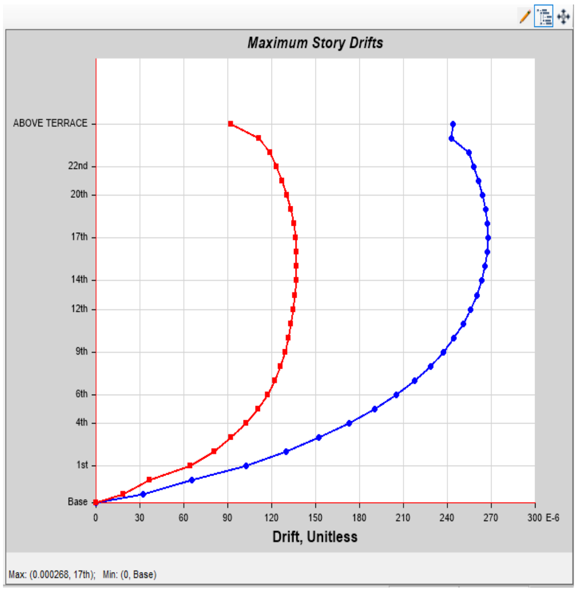
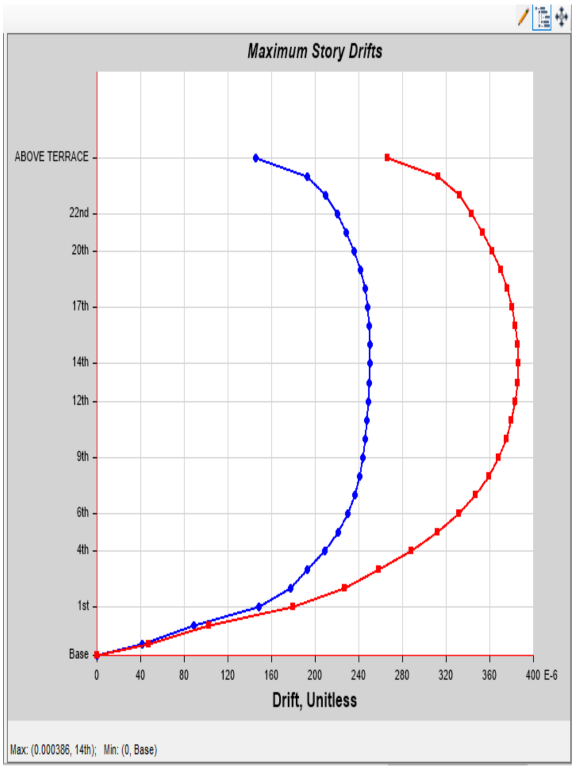


Fig 3.17 : Graph of Story drift variation

Maximum story drift for Conventional model

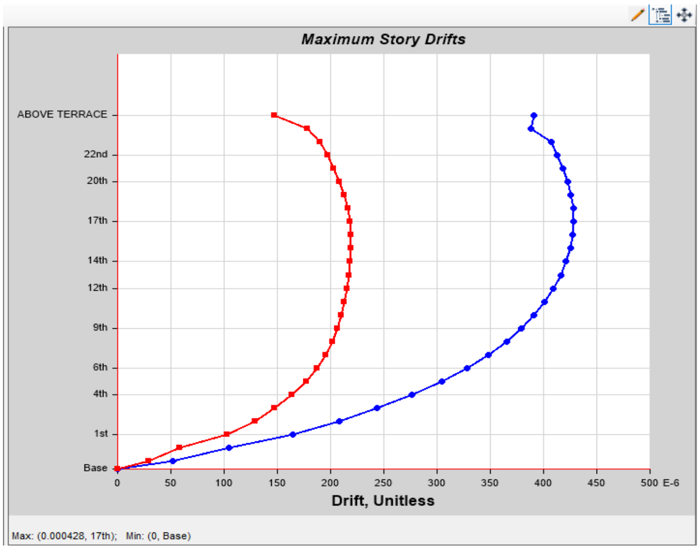


(a) Story Drift X direction

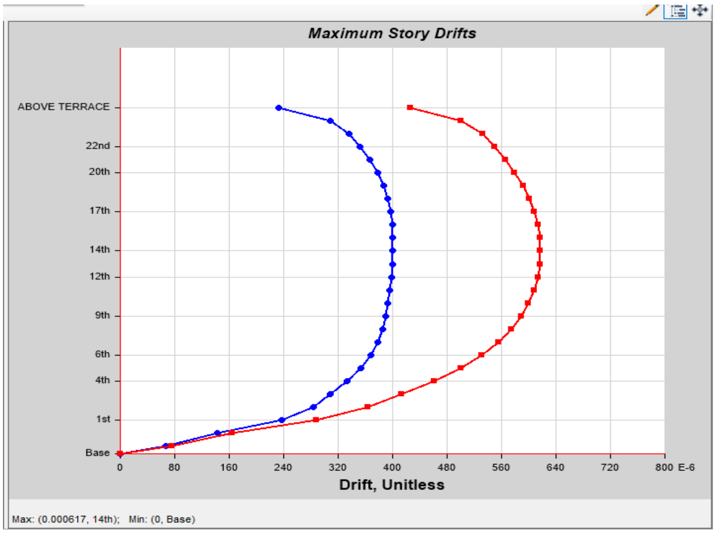


(b) Story Drift Y direction

Fig 3.18 Maximum story drift for zone II Conventional model

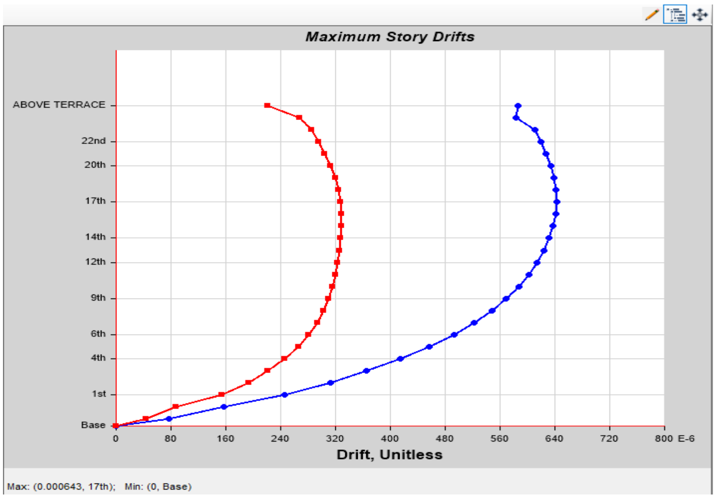


(a) Story Drift X direction

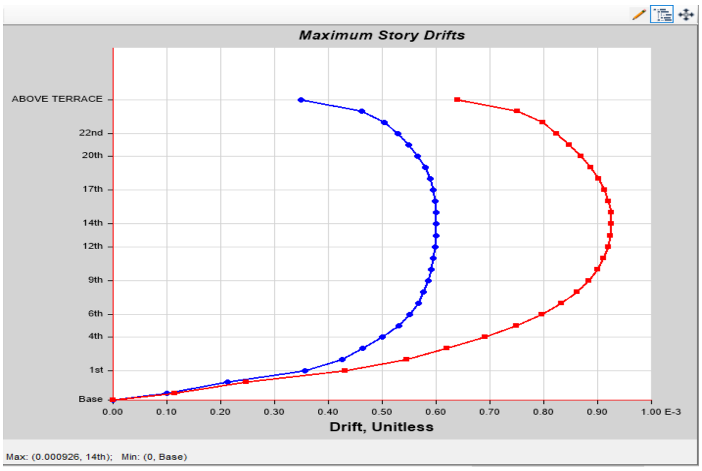


(c) Story Drift Y direction

Fig 3.19 Maximum story drift for zone III Conventional model



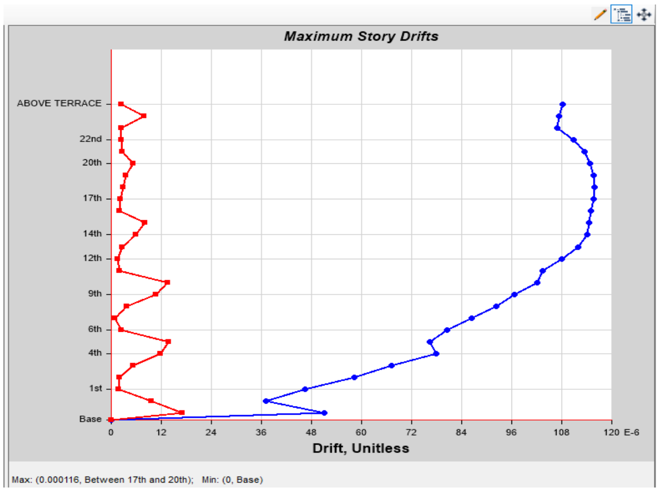
(a) Story Drift X direction



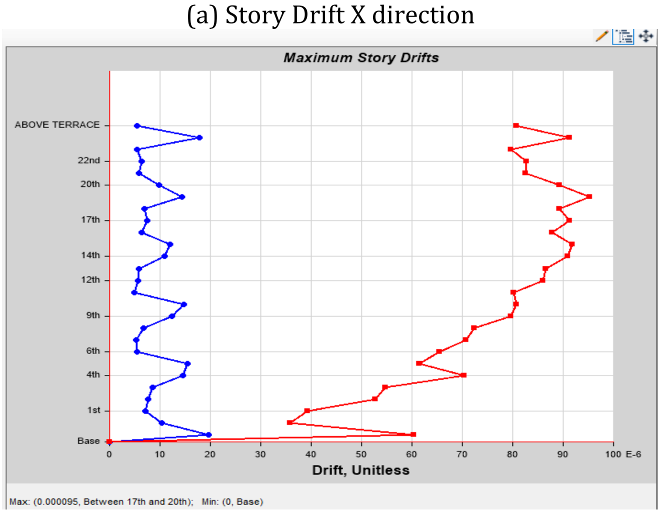
b) Story Drift Y direction

Fig 3.20 Maximum story drift for zone IV Conventional model

Maximum story drift for Diagrid mode

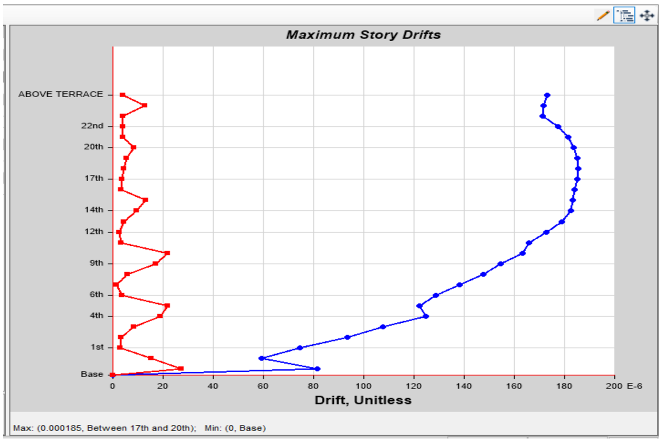


(a) Story Drift X direction

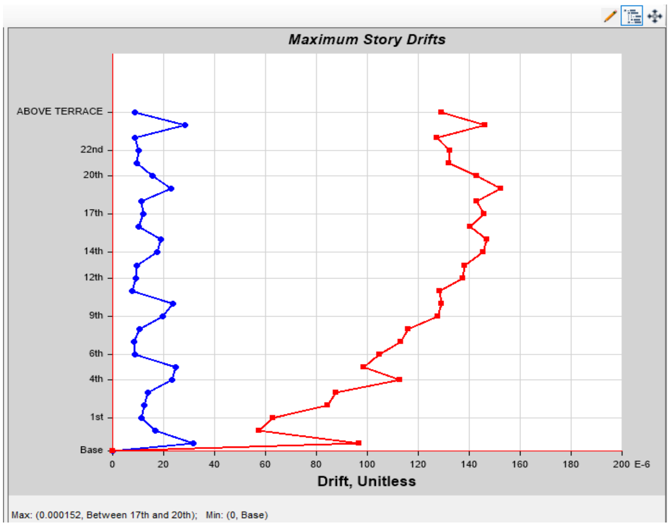


(b) Story Drift Y direction

Fig 3.21 Maximum story drift for zone II Outrigger model

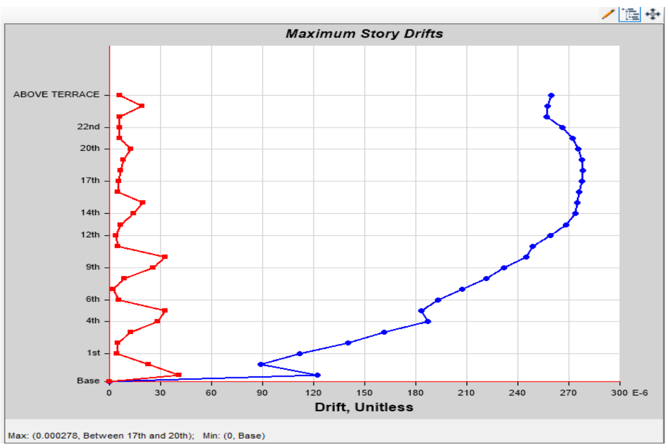


(a) Story Drift X direction

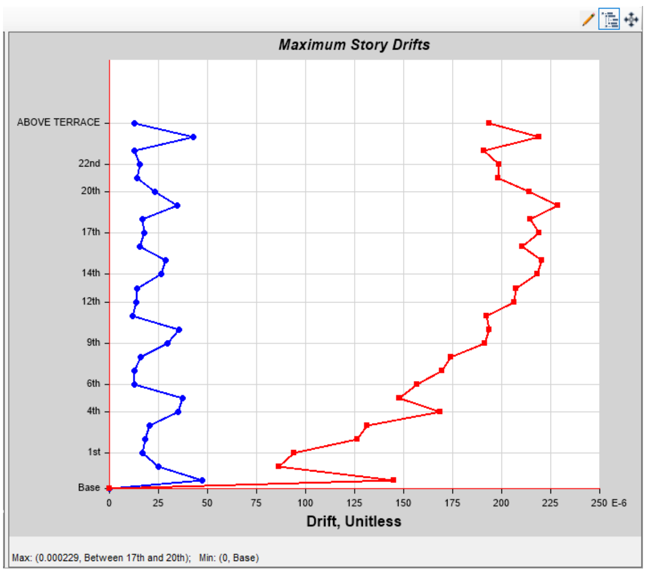


(b) Story Drift Y direction

Fig 3.22 Maximum story drift for zone III Diagrid model



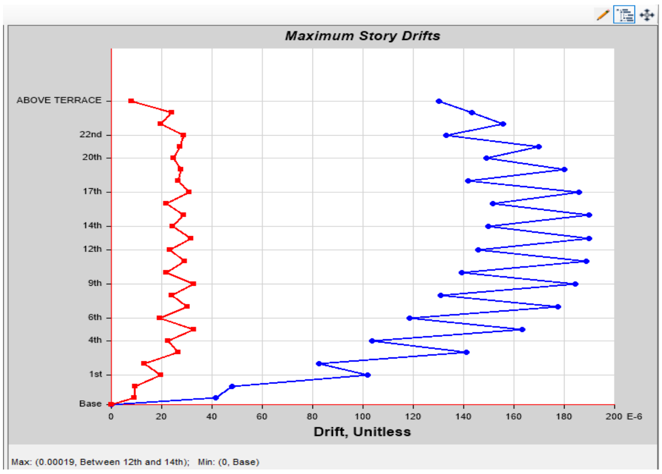
a)Story Drift X direction



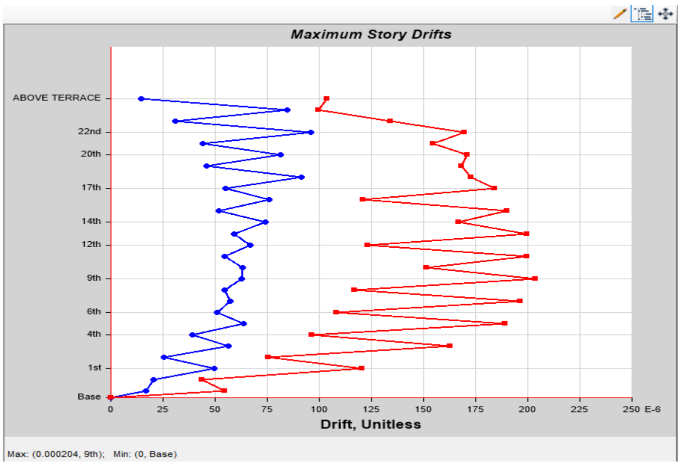
b) Story Drift Y direction

Fig 3.23 Maximum story drift for zone IV Diagrid model

Maximum story drift for Hexagrid model

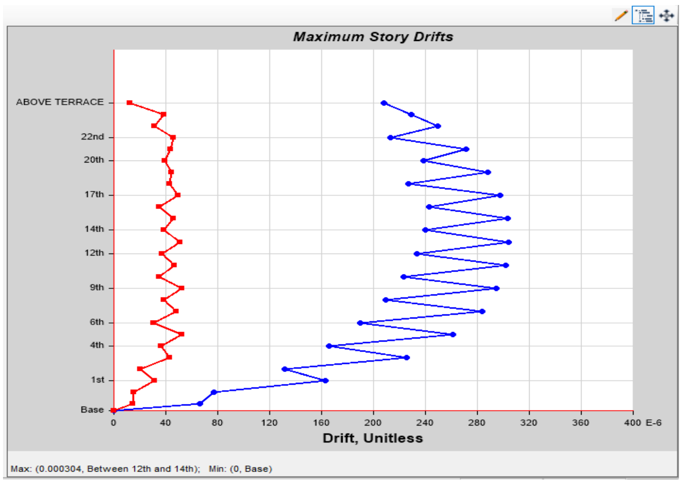


(a) Story Drift X direction

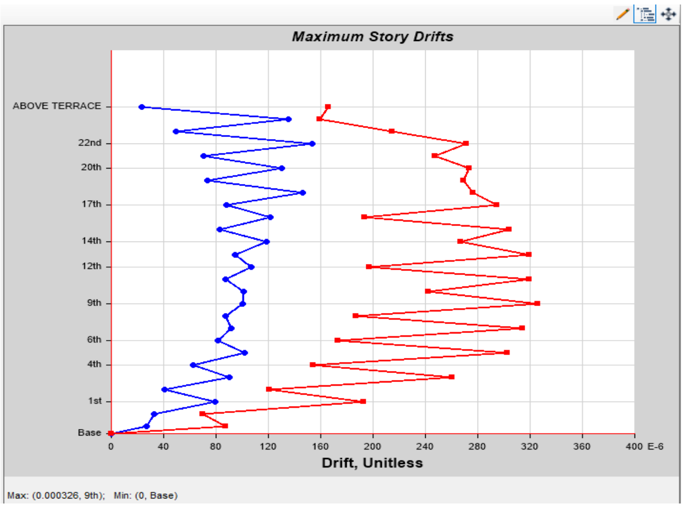


(b) Story Drift Y direction

Fig 3.24: Maximum story drift for zone II Hexagrid model

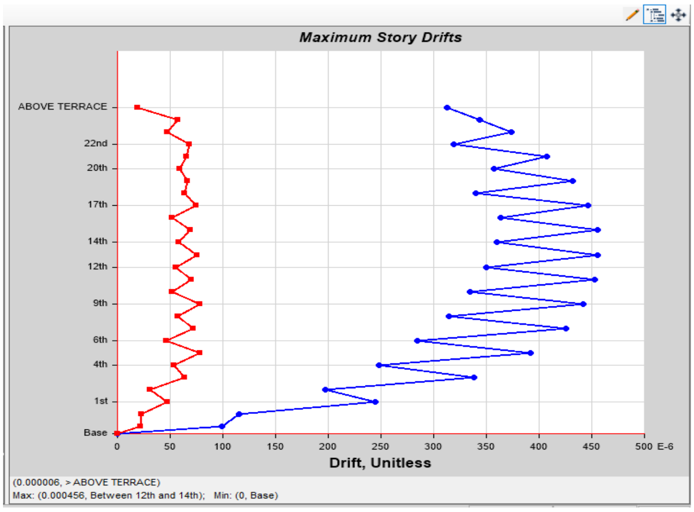


(a) Story Drift X direction

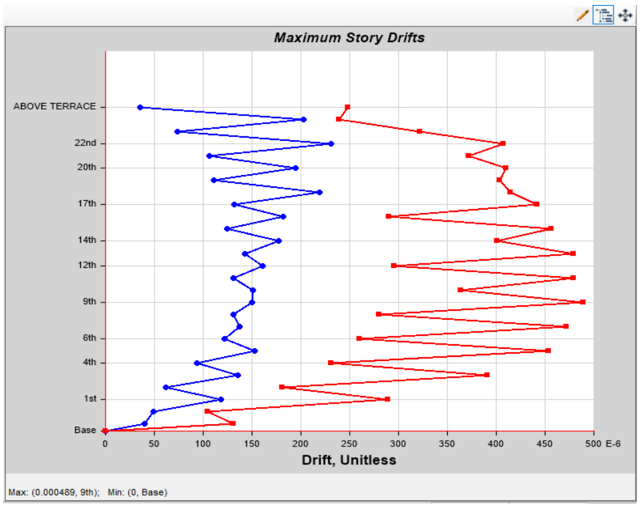


(b) Story Drift Y direction

Fig 3.24 Maximum story drift for zone III Hexagrid model



(a) Story Drift X direction



(b) Story Drift Y direction

Fig 3.24 :Maximum story drift for zone IV Hexagrid model

3.1.3 Time period

Table 9: Time period values for different Models

SL NO	ZONES	MAX TIME PERIOD Conventional Secon	MAX TIME PERIOD Diagrid Seconds	MAX TIME PERIOD Hexagrid Seconds
1	Zone II	2.547	1.47	1.683
2	Zone III	2.547	1.47	1.683
3	Zone IV	2.547	1.47	1.683

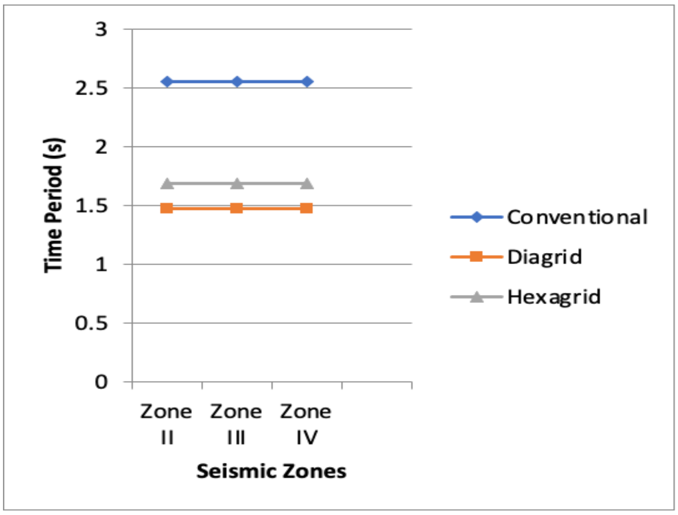


Fig 3.25 Graph of variation in time period.

1) 3.1.4 Base shear

Calculation of base shear rely on upon, soil conditions at the site, concurrence to potential sources of seismic activities. The base shear values are obtained and tabulated in the below table 3.

Table 10: Base shear values

SL NO	ZONES	MAX BASE SHEAR Conventional kN SPECX	MAX BASE SHEAR Diagrid kNSPECX	MAX BASE SHEAR Hexagrid kNSPECX
1	Zone II	1441.3217	1554.2779	1600.6662
2	Zone III	2306.1148	2486.8446	2561.0659
3	Zone IV	3459.1722	3730.2669	3841.5988

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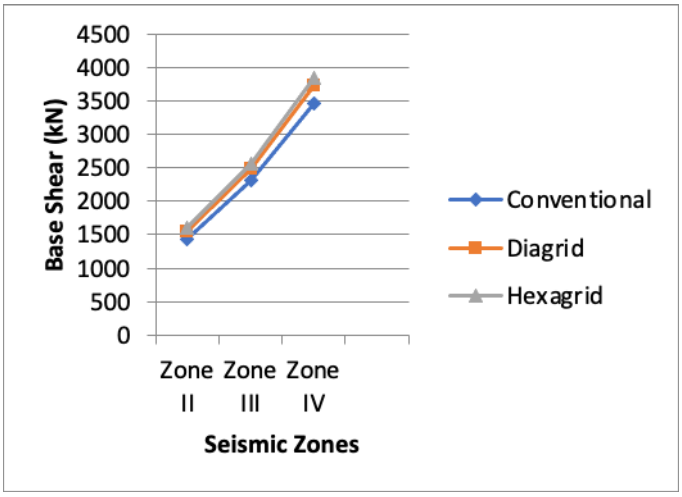


Fig 3.26 Graph of variation in base shear.

Table 11: Base shear values

SL NO	ZONES	MAX BASE SHEAR Conventional kN SPECY	MAX BASE SHEAR Diagrid kN SPECY	MAX BASE SHEAR Hexagrid kN SPECY
1	Zone II	1613.0537	1739.4684	1791.3838
2	Zone III	2580.8859	2783.1495	2866.2141
3	Zone IV	3871.3289	4174.7242	4299.3212

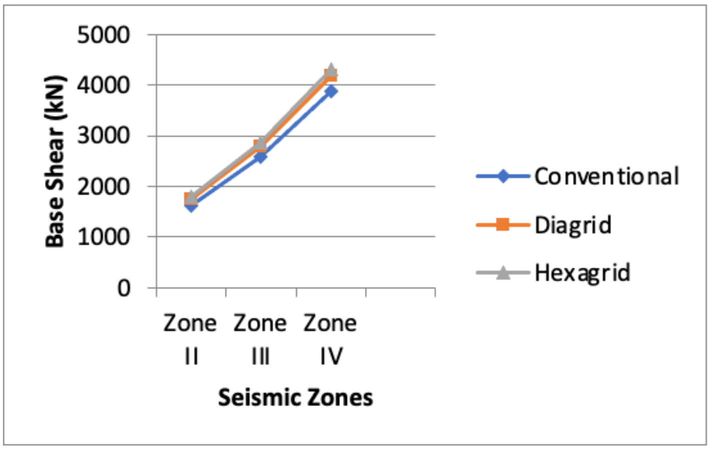
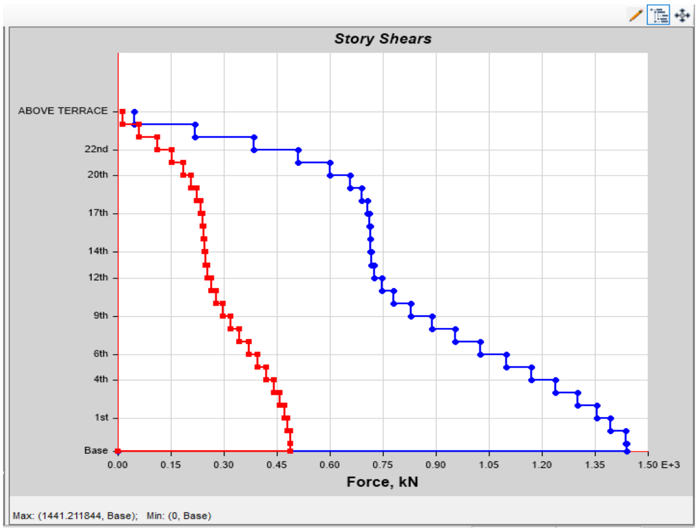
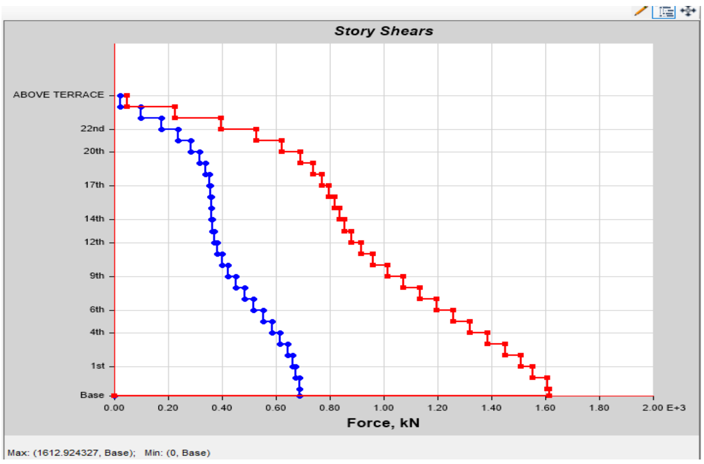


Fig 3.27 **Graph of variation in base shear.**

Story shear for Conventional model

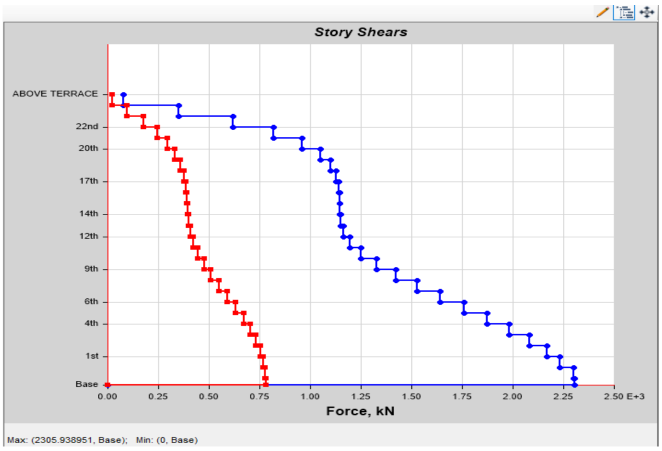


a) Story Shear X direction

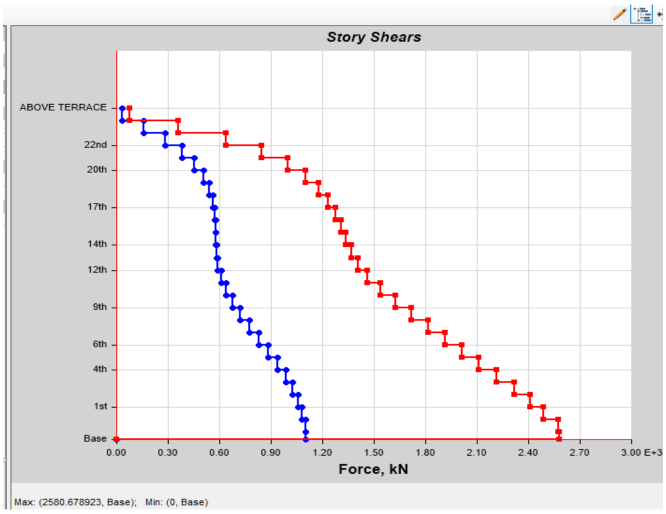


(b)Story Shear Y direction

Fig 3.27 Story Shear for zone II Conventional model

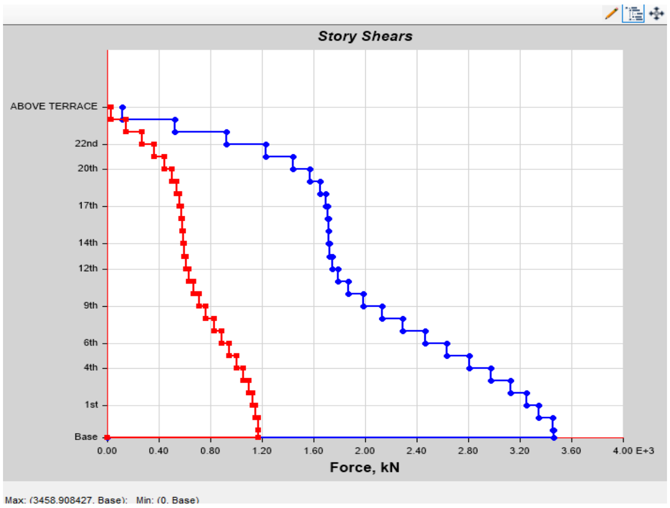


a) Story Shear X direction

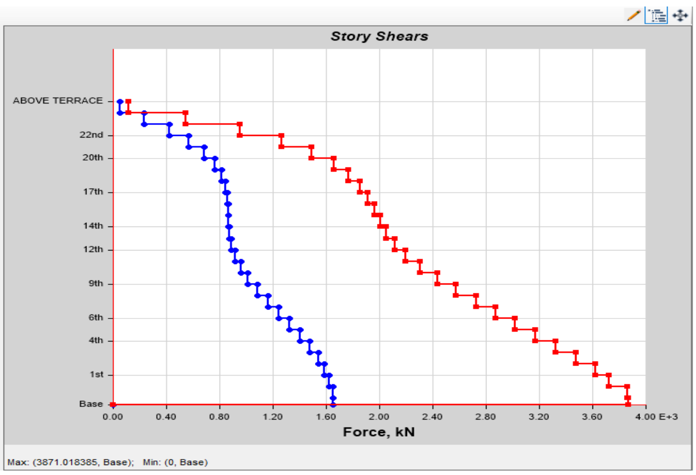


(b) Story Shear Y direction

Fig 3.28 Story Shear for zone III Conventional model



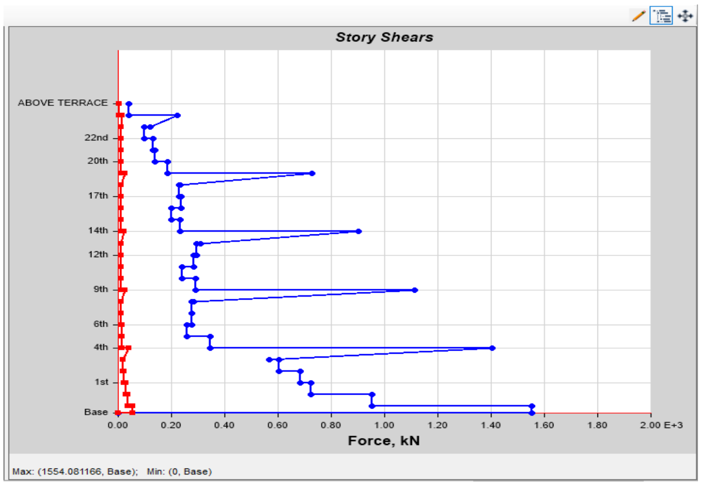
a) Story Shear X direction



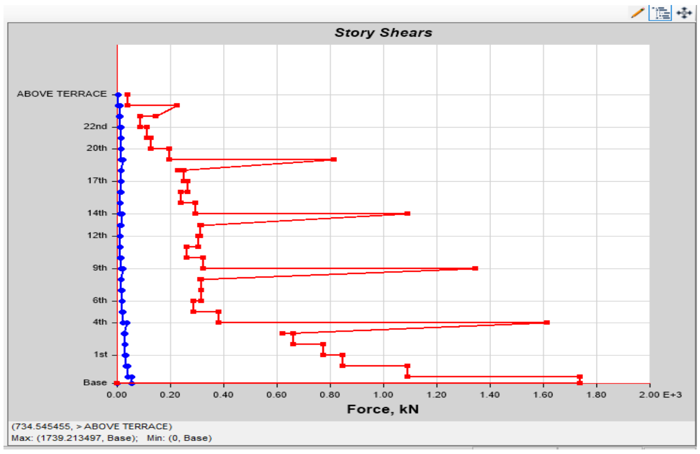
(b) Story Shear Y direction

Fig 3.29 Story Shear for zone IV Conventional model

Story shear for Diagrid model

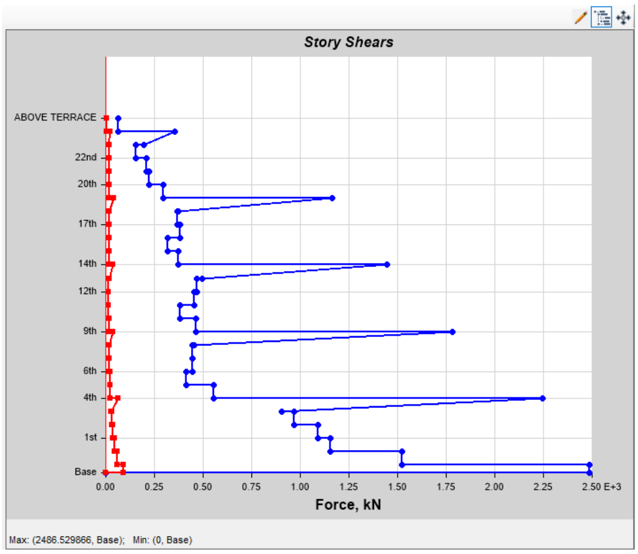


a) Story Shear X direction

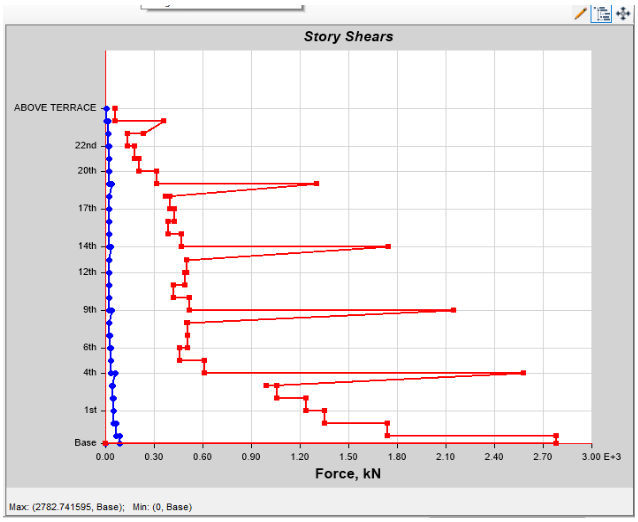


b)Story Shear Y direction

Fig 3.30 Story Shear for zone II Diagrid model

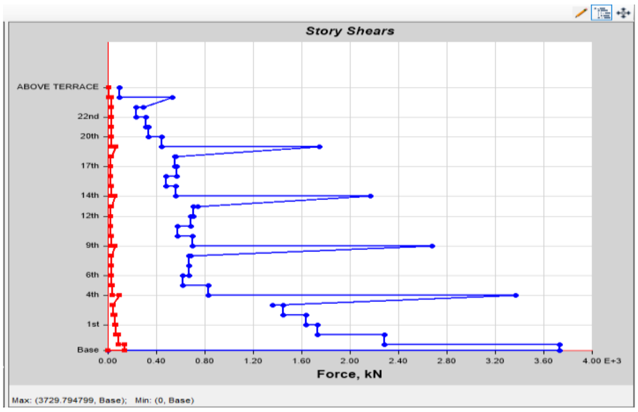


a) Story Shear X direction

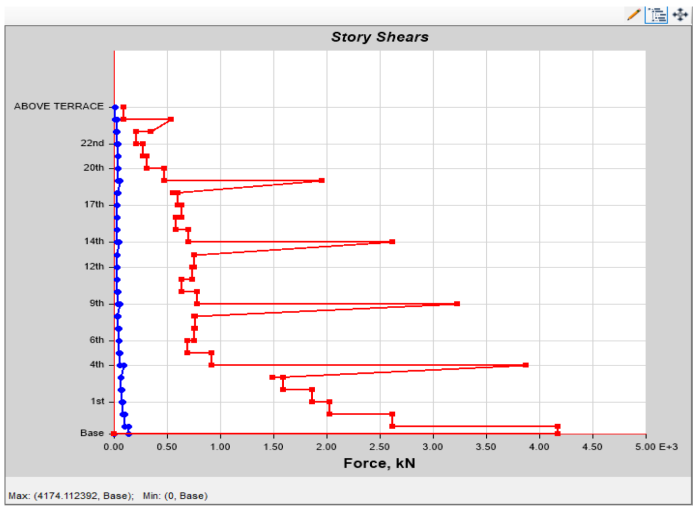


(b) Story Shear Y direction

Fig 3.31 Story Shear for zone III Diagrid model



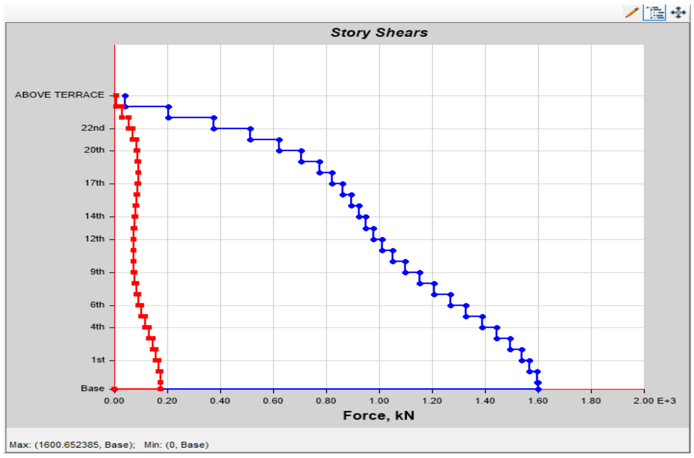
a) Story Shear X direction



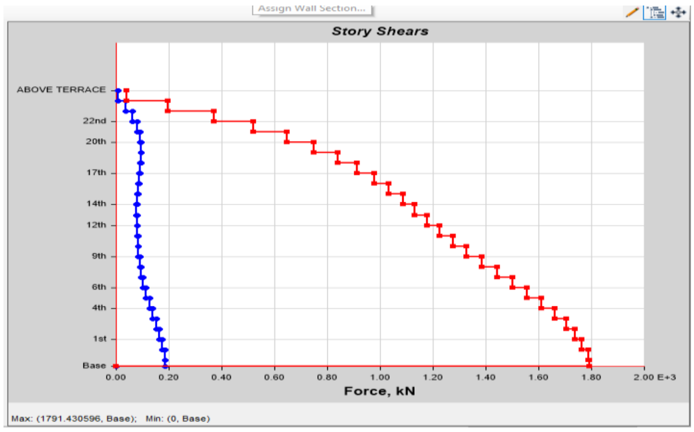
b)Story Shear Y dire

Fig 3.32 Story Shear for zone IV Diagrid model

Story shear for Hexagrid model

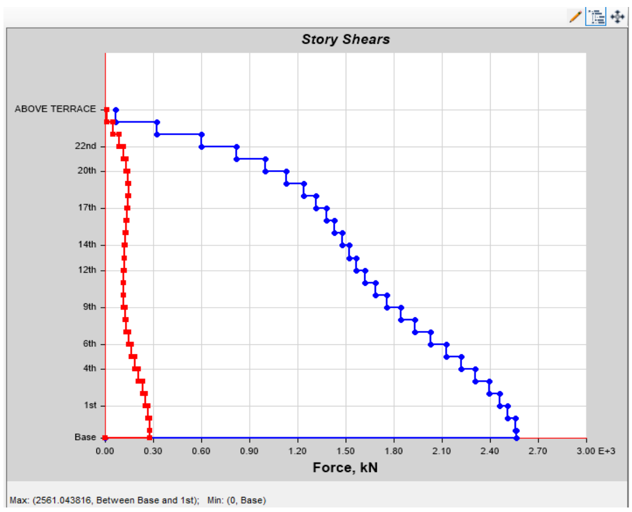


a) Story Shear X direction

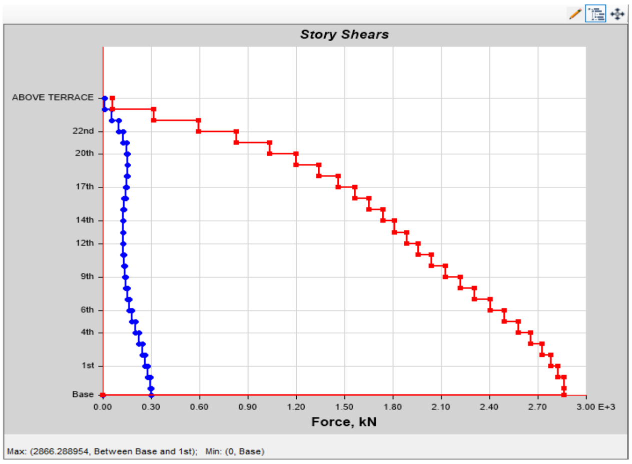


(b) Story Shear Y direction

Fig 3.33 Story Shear for zone II Hexagrid model

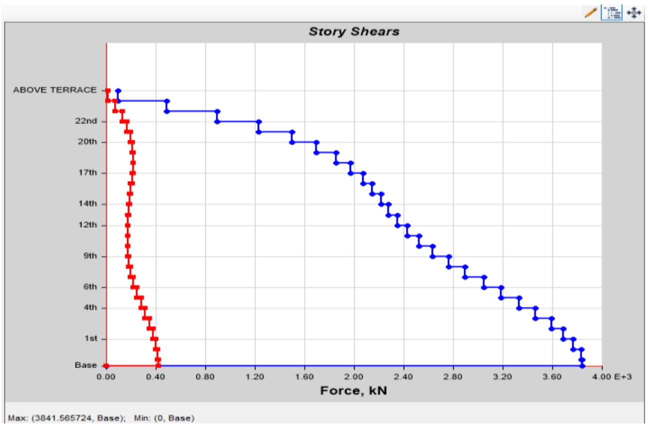


a) Story Shear X direction

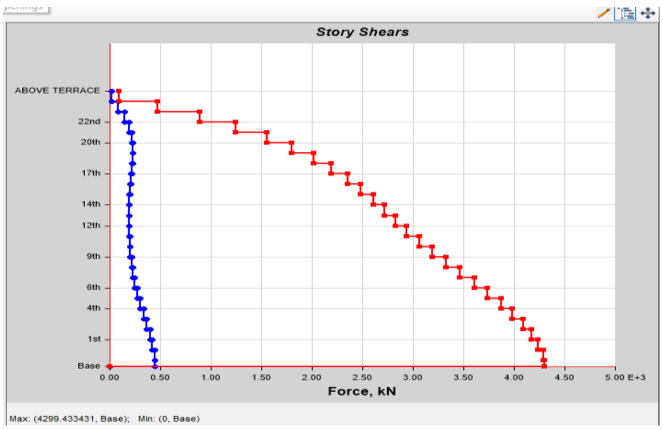


(b) Story Shear Y direction

Fig 3.34 Story Shear for zone III Hexagrid model



a) Story Shear X direction



b)Story Shear Y direction

Fig 3.34 Story Shear for zone IV Hexagrid model

3.2 Discussion of result

In this study a B+G+ 24 structure was analysed.

- Conventional model includes dead load, live load and dynamic (Response spectrum and Time history analysis) earthquake loading.
- Diagrid model includes dead load, live load and (Response spectrum and Time history analysis) dynamic earthquake loading.
- Hexagrid model includes dead load, live load and (Response spectrum and Time history analysis) dynamic earthquake loading.

All the above three models were checked for displacement, story drift, time period and base shear for zone II, zone III and zone IV. The comparison between them was drawn and following results were obtained.

A. Displacement

From the results of displacement, it is noted that the maximum reduction in lateral displacement for response spectrum is seen in Diagrid model for 56.03% in X direction and 76.14% in Y direction. For linear Time history analysis Diagrid model and Hexagrid model shows a reduction in lateral displacement by 65.28% and 66.86% in X direction. For linear Time history analysis, the Diagrid model shows a reduction in lateral displacement by 81.113% in Y direction and Hexagrid model shows a reduction in lateral displacement by 74.06% in Y direction. By considering both the X and Y directions it is concluded that Diagrid model gives the best results for reducing the displacement for response spectrum and Time History Analysis.

B. Story drift

From the results of drift, it is noted that the maximum reduction in lateral drift for response spectrum seen in Diagrid model for 56.76 % in X direction and 75.10 % in Y direction. For linear Time history analysis, the Diagrid model shows a reduction in drift by about 66.45% in X direction and 78.98% in Y direction.

From the results of drift, it is noted that the reduction in lateral drift for response spectrum seen in Hexagrid model for 39.03 % in X direction and 55.76 % in Y direction. For linear Time history analysis, the Hexagrid model shows a reduction in drift by about 59.94% in X direction and 68.19% in Y direction.

C. Time period

From the graphs and tables of time period in the results section it is clearly observed that the Diagrid model has reduced the maximum amount of time period. It is noted that in Diagrid model the time period of the building was reduced by about 42.28% and for Hexagrid system the time time period of the building is reduced by 33.92%. Hence Diagrid model is most effective in handling the lateral loads and reducing the time period of the building.

D. Base shear

Since base shear value directly proportional to weight of the building, the regular model is having fewer loads compared to other models. It is observed from the graphs and tables that the results of analysis the Diagrid and Hexagrid model showed a slight increase in the base shear in all zones. The increase in the base shear of Diagrid model is 7.267% and 9.954% for Hexagrid model along X direction and Y direction.

4. CONCLUSIONS

By considering all the models and their behaviour in dynamic earthquake loading. It is concluded that Diagrid gives the most suitable results. As it tends to reduce the lateral displacement and story drift in both X and Y direction by a good margin.

Scope for future works

- In this study a B+G+24 structure was considered and the same study can be carried out in high rise building.
- In response spectrum, Three zones were considered and soil type as II. Other soil types can be taken and a future study can be carried out.
- With the help of accurate data the same model can be subjected to time history analysis in the future and the behaviour of all the models can be re-evaluated.
- Different angles can be used for diagrid and for hexagrid systems. To find out optimum angle for the building.

REFERENCES

1. Kiran Kamath, Sachin Hirannaiah, Jose Camilo Karl Barbosa, "An analytical study on performance of a diagrid structure using nonlinear static pushover analysis" ELSEVIER , perspectives in science(2016) PISC-166, 7 April 2016.
2. YongJae Lee, Jintak Oh, Hussam Hassan Abdu, and Young K. Ju, "Finite Element Analysis of Optimized Brace Angle for the Diagrid Structural System" International journal of steel structure 16(4): 1355-1365 (2016).
3. Jagadeesh B N, Dr. Prakash M R, "Seismic Response of Steel Structure With Mega Bracing System" International Journal of Engineering Sciences & Research Technology, 5(9): September, 2016, ISSN: 2277-9655
   Impact Factor: 4.116
4. Raghunath .D. Deshpande, Sadanand M. Patil, Subramanya Ratan, "Analysis and Comparison of Diagrid and Conventional Structural System" International Research Journal of Engineering and Technology, volume: 02 issues: 03, june-2015.

BIOGRAPHIES

Nujed Ali Khan, Completed Bachelor degree in Civil Engineering from Ghousia College of Engineering, Ramanagara, Karnataka under VTU in the year 2019, Presently pursuing M. tech in Structural Engineering in Ghousia College of Engineering, Ramanagara, Karnataka, Under VTU.

Narayana BR, Working as Associate prof. in the Department of Civil Engineering, Ghousia College of Engineering, Ramanagaram.

Dr. N S Kumar, Graduated in the year 1985 from Mysore University, M.E. in Structural Engineering., in the year 1988 from Bangalore University and earned his PhD from Bangalore University during the year 2006 under the guidance of Dr. N Munirudrappa, the then Chairman and Prof. UVCE, Faculty of Civil Engineering, Bangalore University. Presently, working as Prof. & HoD, Department of Civil Engineering, Ghousia College of Engineering, Ramanagaram and completed 31 years of teaching. He is involved in the Research field related to the behaviour of Composite Steel Columns and Nano Materials for a decade. To his credit, over 150 publications, and travelled abroad for his research presentations including world conferences too. Also, more than 3PhD's completed and ongoing 5 are working under his guidance. Also, authored more than 8books to his credit.