PERFORMANCE OF DIFFERENT DIAGRID SHAPE IN HIGH RISE STEEL BUILDINGS WITH MASS ECCENTRICITY

Nihal Mohammed[1], Shajil N[2]

Abstract— Therapid increase in population and constraint land space have influenced the growth of high rise buildings. Diagrid –'Diagonal Grid' is a structural system used commonly for high rise structures and has more structural efficiency, aesthetic potential and can save up to 20% of the steel weight compared to the conventional structural system. The peripheral diagrid can withstand the lateral loads acting on the structure and has appreciable flexibility with the floor plan by avoiding interior and corner columns. In this paper analysis and design of 36 storey diagridstructure with mass eccentricity on circular and square shape diagrid is done and the analysis results are compared in terms of time period, top storey displacement, storey drift and torsional irregularity.

Index Terms— Diagrid, High rise buildings, Mass eccentricity, Top storey displacement, Time period, storey drift, Torsional irregularity.

1 Introduction

As a building's height increases, the required amount ofstructural material to resist lateral loads increases due to the premium for height. Thus for constructing tall building structural systems, use of minimum amount of structural material, is of significant importance to save available limited resources and contribute to constructing sustainable built environments.Recently seismic performance of the high rise structures are significantly affected by the geometric complexity and irregularity of building structures which have been rapidly increasing.

Today, however, many different design approaches are prevalent for tall buildings. This contemporary design trend has produced various building forms, such as twisted, tapered, tilted, and free forms. Among various structural systems developed for today's tall buildings, diagrid structure is been used in this paper. Due to their structural efficiency and architectural potential, diagrid structures have been used for many tall buildings worldwide.

Diagrid system has unique geometric configuration which consist of inclined columns on periphery of the buildings. This system is foundto be better at lateral load resisting when compared to other structural systems Diagrid structures are generally stiffer than equivalent tubular system and provide more efficient use of material. The triangulation configuration of diagrid on periphery provides increased stability and distributes the forces in much uniform manner.

The diagrid has an economical advantage as it does not require as much steel as the ordinary steel frame.Due to triangulated configuration in diagrid structureboth gravity and lateral load can be carried out by the system. The lateral shear can be carried by the diagonal members located on the periphery hence shear rigidity cores can be avoided.

In this paper analysis and design of 36 storey diagrid structure with mass eccentricity on circular and square diagrid structure is done and the analysis results are compared in terms of time period, top storey displacement, storey drift and torsional irregularity. ETABS software is used for modeling and analysis of structural members. All structural members are designed as per IS 800:2007

2 Literature Review

Various research works has been done to study the behaviour of diagrid and high rise structures. Some of notable contributions are mentioned here;

Khushbu Jani and Parvesh V. Patel (2013) Analysed and designed Diagrid Structural System for High Rise Steel Buildings.In this paper analysis and design of 36,50,60, 70 and 80 storey structures are carried out. It was found that the interior columns should be designed for vertical loads and the diagrid system can resist lateral loads.

Dhaval N Sorathiya, Jasmin Gadhiya, Abhishek Raturi(2017) studied on economical diagrid angles and found that the optimum angle is in the range of 65^0-75^0. Parameters like time period, top storey displacement, storey shear, storey drift and steel weight is compared with conventional structure.

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Conclusion was that time period, storey drift, storey displacement and steel mass is comparatively less in diagrid structure than conventional steel structure.

Chetan S.Pattar Prof. Smt. Varsha Gokak (2018) analysed and studied a 16-storey square plan structure along with C-Type and L-Type structure with the concept of plan irregularity. Comparing C-Type, L-Type structure has good results in sway, stiffness and is more efficient.

3 Models

In this study two models are considered, circular and square shaped diagrid structures.

3.1 Building configuration

The 36 storey high rise building with 36 m × 36 m plan dimension of storey height is 3.6 m is considered. Pair of braces ie. diagrid is located on the outer periphery of the building. The angle of inclination is 74.5^0 which is been kept uniform throughout the height. At six meter spacing horizontally diagrids are fixed. The interior frame of the diagrid structures is designed only for gravity load. The design dead load is 3.75 kN/m2and designed live loads on floor slab is 2.5 kN/m2. 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 design earthquake load is computed based on the zone factor of 0.16, medium soil, importance factor of 1 and response reduction factor of 5. Modeling, analysis and design of diagrid structures are carried out using ETABS software. The beams and columns is modeled by beam elements and braces are modeled by truss elements, support conditions are assumed as hinged. All structural members are designed using IS 800:2007.

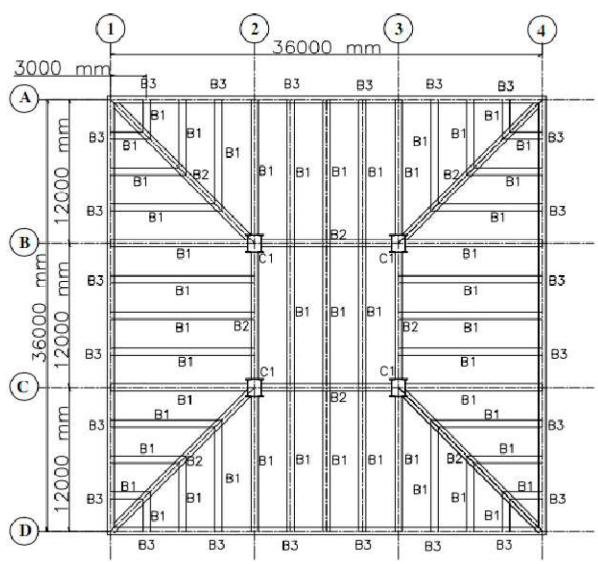


Fig 1- Floor plan of regualar diagrid structure.

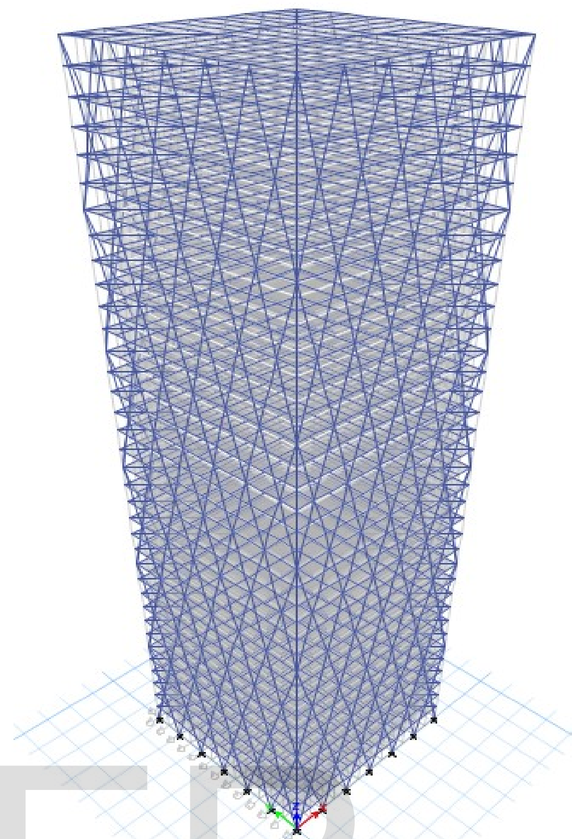


Fig 2- Isometric view of circular shaped diagrid structure.

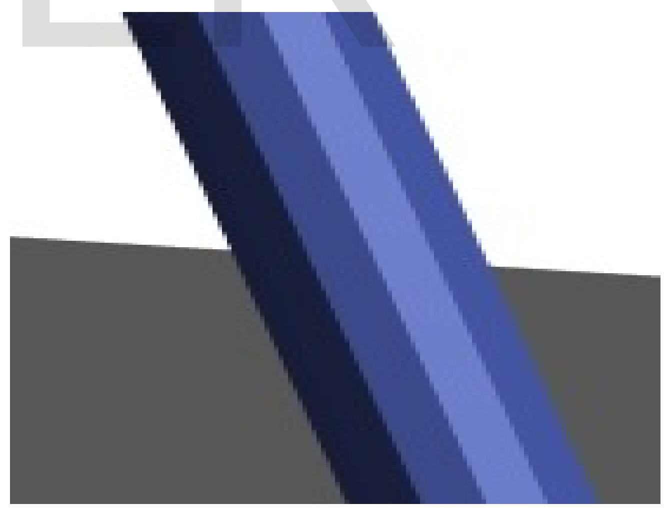


Fig 3- Rendered view of circular diagrid.

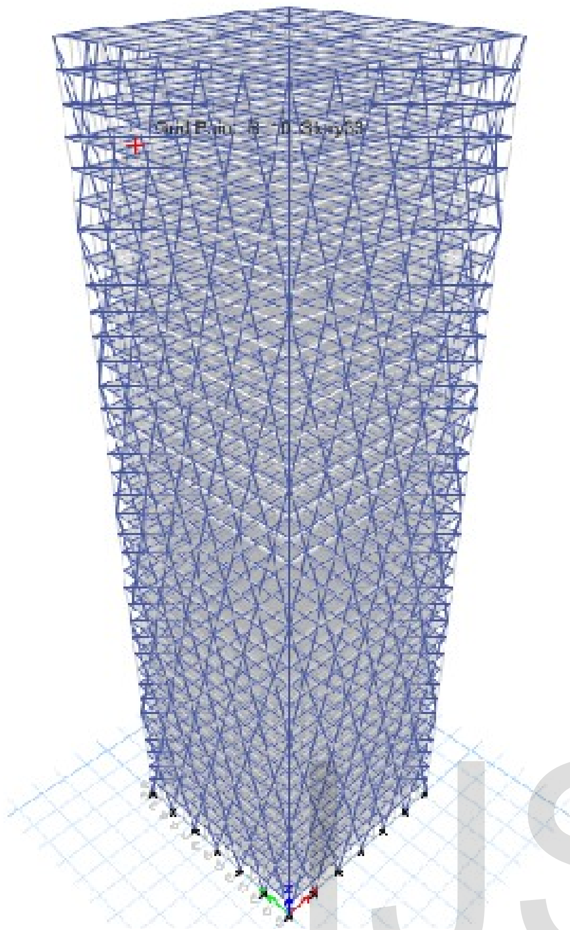


Fig 4- Isometric view of square shaped diagrid structure.

Fig 5- Rendered view of square diagrid.

3.2 Design details of structural members.

DESCRIPTION	VALUES
DIAGONAL COLUMNS	▪ 375mm pipe sections with 12mm thickness (19-36 storey). ▪ 450mm pipe sections with 25mm thickness (1-18 storey). ▪ 306mm x 306mm square section with 12mm thickness (19-36 storey). ▪ 378mm x 378mm square section with 25mm thickness (1-18 storey).
INTERIOR COLUMNS	▪ 1500mm x 1500mm
BEAMS	▪ B1=B3= ISMB550. ▪ B2=ISWB 600 with top and bottom cover plate of 220x50mm.
YIELD STRENGTH OF STEEL	▪ 250 N/mm².

Table 1- Size of typical members.

4 Analysis Results

4.1 Storey displacements of circular diagrid structure due to EQX.

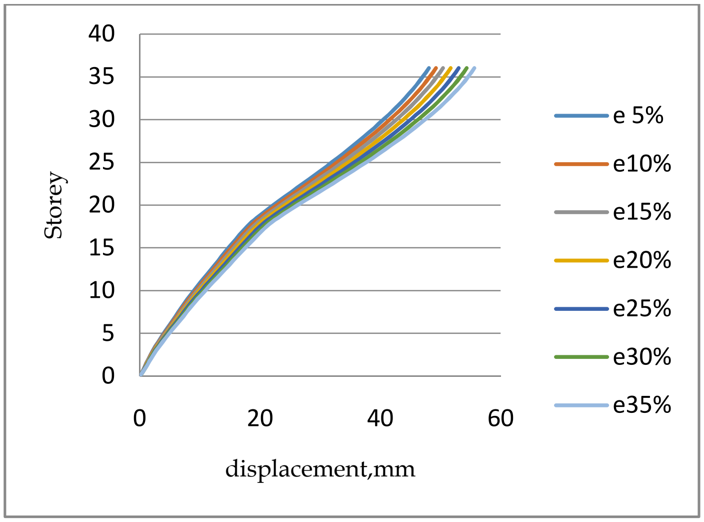


Fig 6- Storey displacement of circular diagrid at different eccentricities due to EQX.

4.2 Storey displacements of circular diagrid structure due to EQY.

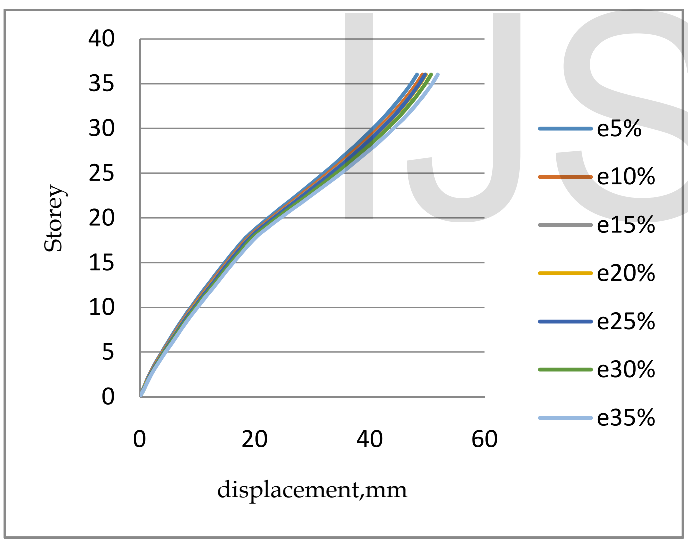


Fig 7- Storey displacement of circular diagrid at different eccentricities due to EQY.

4.3Storey drift of circular diagridstructure due to EQX.

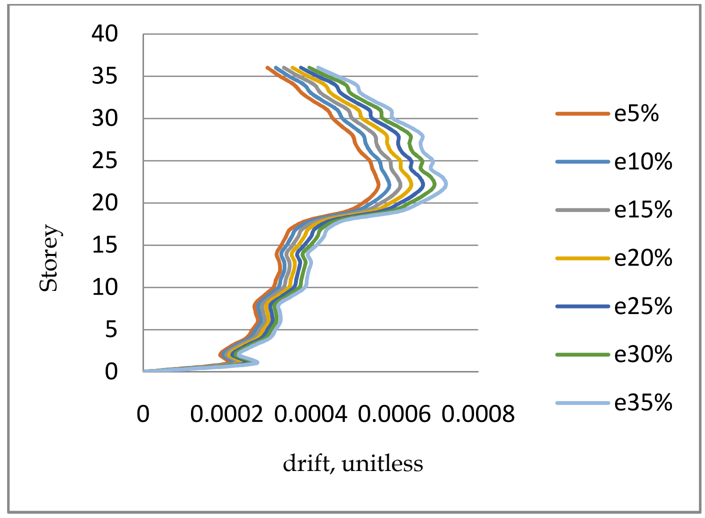


Fig 8- Storey drift of circular diagrid at different eccentricities due to EQX.

4.4 Storey drift of circular diagrid structure due to EQY.

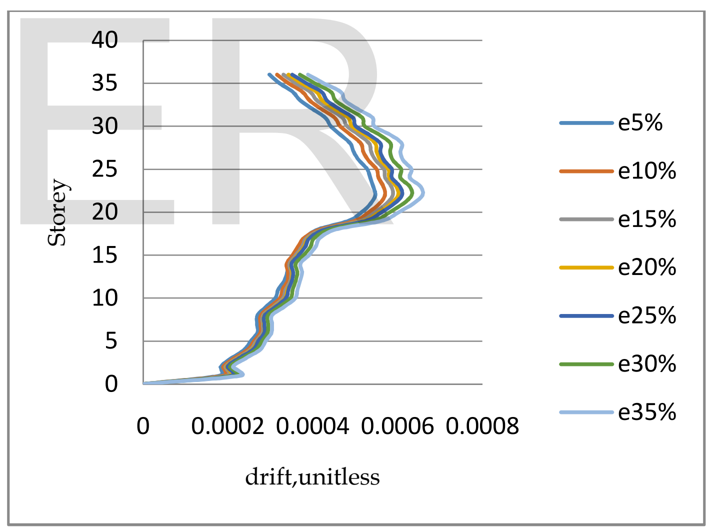


Fig 9- Storey drift of circular diagrid at different eccentricities due to EQY.

Storey displacement of the circular diagrid model are shown in Fig 6 and Fig 7. When the structure is having a mass eccentricity of 5% the top storey displacement is 48.084mm and the displacement is 55.637mm when the mass eccentricity is 35% due to earthquake load in X direction. When earthquake loading is in Y direction displacement is 48.217mm at 5% mass eccentricity and 51.828mm at 35% mass eccentricity

In Fig 8 and Fig 9 storey drift of the circular diagrid model are shown where 0.000297 is the drift of structure for 5% mass eccentricity and 0.000418 is the drift for 35% mass eccentricity when earthquake load is in X direction. The storey drift is

0.000298 and 0.000389 at 5% and 35% mass eccentricity respectively.

5 Comparison Of AnalysisResults

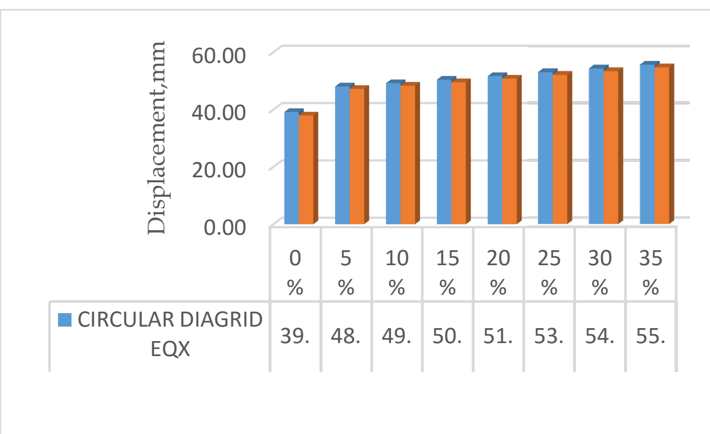
5.1 Time period of circular and square diagrid structures.

Eccentricity	Circular diagrid (sec)	Square diagrid (sec)
5%	3.323	3.247
10%	3.345	3.267
15%	3.499	3.325
20%	3.583	3.408
25%	3.791	3.608
30%	4.898	4.823
35%	4.991	4.924

Table 2- Time period of circular and square diagrid at different eccentricities.

As the mass eccentricity increases time period increases in both structures, comparatively time period is more in circular diagrid than square diagrid structure for same eccentricity.

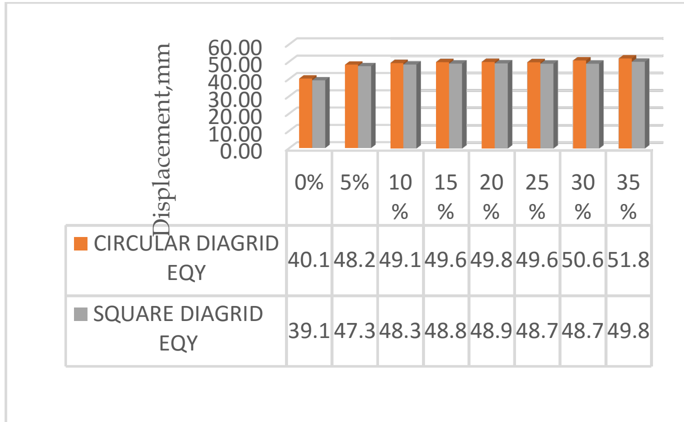
5.2 Top Storey displacement of circular and square diagrid due to EQX.



Comparison chart 1- Top storey displacement of circular and square diagrid due to EQX.

The maximum top storey displacement in circular diagrid is higher than the square diagrid due to earthquake load in X direction.

5.3 Top Storey displacement of circular and square diagrid due to EQY.



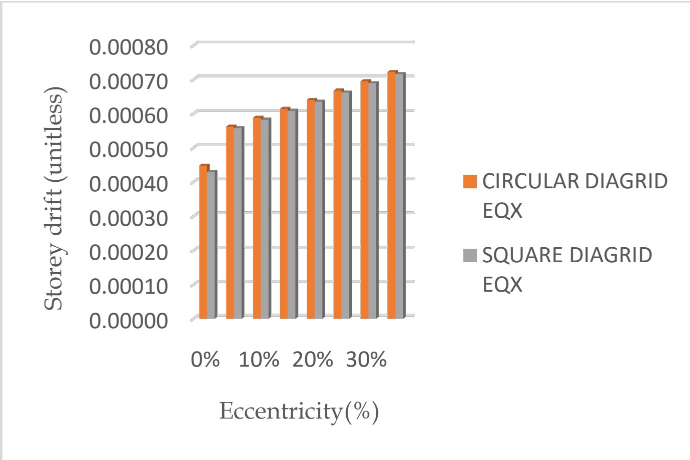
Comparison chart 2- Top storey displacement of circular and square diagrid due to EQY.

The maximum top storey displacement in circular diagrid is higher than the square diagrid due to earthquake load in Y direction.

5.4 Maximum storey drift of circular and square diagrid due to EQX.

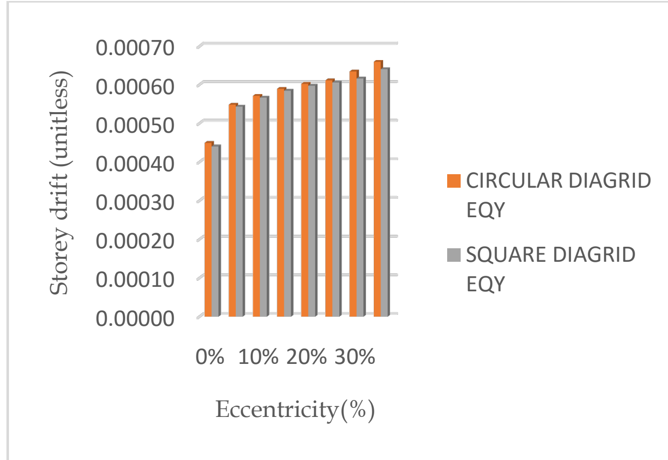
Eccentricity	Circular diagrid(unitless)	Square diagrid(unitless)
0%	0.00045	0.00043
5%	0.00056	0.00056
10%	0.00059	0.00058
15%	0.00061	0.00061
20%	0.00064	0.00063
25%	0.00067	0.00066
30%	0.00070	0.00069
35%	0.00072	0.00072

Table 3- Maximum storey drift of circular and square diagrid at different eccentricities due to EQX.



Comparison chart 3- Maximum storey drift of circular and square diagrid due to EQX.

The maximum storey drift in circular diagrid structure is higher than the square diagrid structure due to earthquake load in X direction.



Comparison chart 4- Maximum storey drift of circular and square diagrid due to EQY.

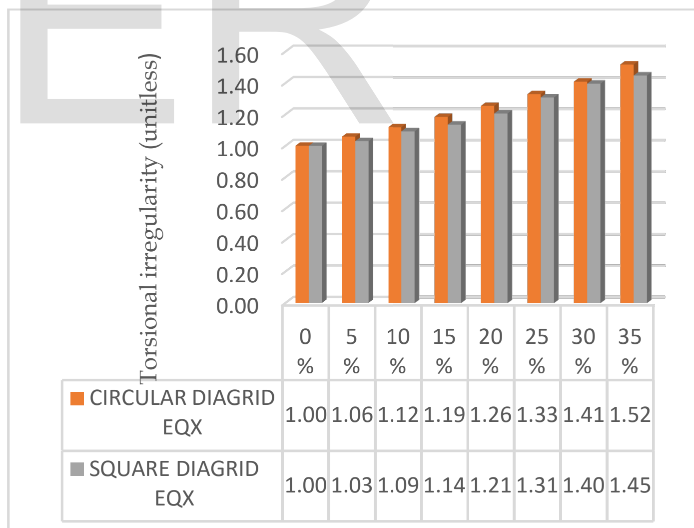
The maximum storey drift in circular diagrid structure is higher than the square diagrid structure due to earthquake load in Y direction.

5.5 Maximum storey drift of circular and square diagrid due to EQY.

Eccentricity	Circular diagrid(unitless)	Square diagrid(unitless)
0%	0.00045	0.00044
5%	0.00055	0.00054
10%	0.00057	0.00057
15%	0.00059	0.00058
20%	0.00060	0.00060
25%	0.00061	0.00061
30%	0.00063	0.00062
35%	0.00066	0.00064

Table 4- Maximum storey drift of circular and square diagrid at different eccentricities due to EQY.

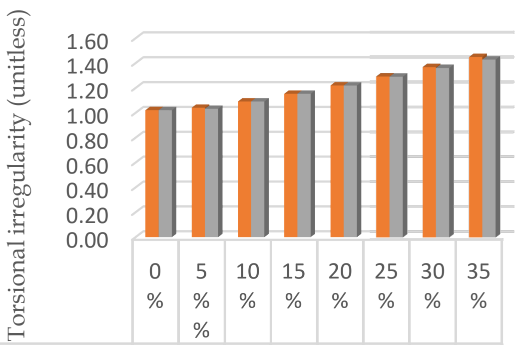
5.6 Torsional irregularity of circular and square diagrid due to EQX.



Comparison chart 5- Torsional irregularity of circular and square diagrid due to EQX.

The circular diagrid structure torsionally fails when the mass eccentricity is 35% but square diagrid structure can bear more than 35% mass eccentricity due to earthquake load in X direction. A building is said to be torsionally irregular when the maximum horizontal displacement of any floor in the direction of lateral force at one end of the floor is more than 1.5 times its minimum horizontal displacement at the far end of the same floor in that direction(as per IS 1893 (Part-1): 2016).

.5.7 Torsional irregularity of circular and square diagrid due to EQY.



	0 %	5 %	10 %	15 %	20 %	25 %	30 %	35 %
CIRCULAR DIAGRID EQY	1.02	1.04	1.09	1.15	1.22	1.29	1.37	1.45
SQUARE DIAGRID EQY	1.02	1.03	1.09	1.15	1.22	1.29	1.36	1.43

Comparison chart 6- Torsional irregularity of circular and square diagrid due to EQY.

The torsional irregularity in both the circular and square diagrid structure due to earthquake load in Y direction is less compared to earthquake load in X direction.

6 DISCUSSION & CONCLUSION

By providing mass eccentrically on both circular and square diagrid structurefeasibility of mass eccentricity in diagrid structure and validity of this concept under the parameters like time period,top storey displacement, storey drift and torsional irregularity will be known. Maintaining the same structural weight on both the models following conclusions are made;

i. The maximum storey displacement in circular diagrid structure is higher compared to square diagrid structure due to earthquake loading in both X and Y direction.
ii. The maximum storey drift on circular diagrid structure is high compared to square diagrid structure due to earthquake loading in X and Y direction.
iii. When mass eccentricity reaches 35% from the centre of super structure, circular diagrid structure torsionally fails whereas the square diagrid structure doesn't fail.
iv. Time period increases with increase in mass eccentricity in structure.

Hence with both the models, comparatively square diagrid structure has better stiffness,less sway and better torsional stability to earthquake loading.

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