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# Comparative Analysis of Seismic Performance of Diagrid Building with Different Types of Buildings. A Review

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**ABSTRACT:** The diagrid structure has emerged into an innovative method in the recent construction field and has led to the advancement of tall buildings and high-rise structures not only in the engineering field but also in the architectural field. It has also made the structure stiffer and lighter when compared to the normal conventional buildings. However, recent studies on system reported insufficient energy dissipation capacity and inadequate ductility. The limited ductility and energy dissipation capacity become critical under solid ground motion as diagrid elements carry both gravitational and lateral load. These diagrid members lose elasticity at certain deformations and start yielding leading to global collapse. In the present study reviews comparative seismic analysis between diagrid building, bare frame buildings and exterior brace buildings. The diagrid structures are modelled and analysed using ETABS, Staad pro and Sap2000 softwares. IS 1893: 2016 is considered for load combination of seismic analysis.

**KEYWORDS:** Diagrid buildings, Conventional building, Seismic analysis, Response Spectrum Analysis, ETABS.

## I. INTRODUCTION

The advancement in technology has made our life simpler and comfortable when compared to earlier times and has also led to the need for space for living for the growing population. According to the records, if we analyse our world population, it right now exceeds 8 billion, which mandates the need to fulfil the growing demands of the population. With the restricted land accessible, there is a need to develop tall structures.

The diagrid structure is one such method in which the vertical perimeter columns are eliminated, the frame carries the gravity load, as well as the lateral load and the usage of steel is also minimized when compared with the conventional building. Diagrid system consists of perimeter grid made up of a series of triangulated truss system. It is a structural system in which all perimeter columns are eliminated and consists of only inclined columns on the outer face of the building. Nearly 20% of structural steel is saved when compared to a conventional moment frame structure. The prominent force that influences the design of tall buildings is the lateral load, primarily due to earthquakes and wind.

## II. LITERATURE REVIEW

1. Khushbu Jania & Paresh V. Patel [1] (2012) have performed analysis and design of 36 storey diagrid steel building is presented in detail. A regular floor plan of 36 m × 36 m size is considered. ETABS software is used for modeling and analysis of structure. All structural members are designed using IS 800:2007 considering all load combinations. Load distribution in diagrid system is also studied for 36 storey building. Also, the analysis and design results of 50, 60, 70 and 80 storey diagrid structures are presented. From the study it is observed that most of the lateral load is resisted by diagrid columns on the periphery, while gravity load is resisted by both the internal columns and peripheral diagonal columns. Due to increase in lever arm of peripheral diagonal columns, diagrid structural system is more effective in lateral load resistance. Lateral and gravity load are resisted by axial force in diagonal members on periphery of structure, which make system more effective. Diagrid structural system provides more flexibility in planning interior space and facade of the building.

2. Nishith B. Panchal & Vinubhai R. Patel [2] (2014) have done comparative analysis and design of 20 storey diagrid structural system building and simple frame building is presented here. A regular floor plan of 18m x 18m size is considered. ETABS 9.7.4 software is used for modelling and analysis of structure. Analysis results like displacement, storey drift, storey shear are presented here. We conclude from the study that,

- As the lateral loads are resisted by diagonal columns, the top storey displacement is very much less in diagrid structure as compared to the simple frame building.
- The storey drift very much less for diagrid structural system.
- Diagrid structure system provides more economy in terms of consumption of steel and concrete as compared to simple frame building.

3. Nishith B. Panchal & Dr. V. R. Patel [3] (2014) have carried out analysis by considering the different angles of diagrid and also different storeys of the building. The plan of 36m x 36m is considered with four different types of angles of diagrid that is 50.2°, 67.4°, 74.5° and 82.1° and also by considering 24-storey, 36-storey, 48-storey and 60-storey building, a comparative study is carried out. We conclude from the study that,

- Diagrid angle in the region of 65° to 75° provides more stiffness to the diagrid structural system which reflects the less top storey displacement.
- The storey drift is very much lesser in the region of diagrid angle 65° to 75°.
- Diagrid angle in the region 65° to 75° provides more economy in terms of consumption of steel and concrete as compared to different angles of diagrid.
- When number of storey increases means height of building increases, diagrid angle in the region 65° to 75° gives better results in terms of top storey displacement, storey drift, storey shear and material consumptions.
- Diagrid structural system provides more economy and more benefits when no of storey is more than 40 with the diagrid angle in the region of 65° to 75°.
- Optimum angle of diagrid is observed in the region of 65° to 75°.

4. Ravish Khan & S.B. Shinde [4] (2015) have considered two structural models for this study, which is diagrid model and braced frame model. Following data are involved in the modelling of both the structures. 20-storey building with 18x18m plan dimension, having 72m of total height with 3.6m height of each storey is taken for both models. Size of diagrid is taken 350mm pipe section with 12mm thickness at an angle of 67.4°. For braced frame model, inverted V-type bracings are used which is long leg back to back double angle section of 180x180x15mm. The dead load is taken 5.5kN/m<sup>2</sup> on terrace level and 4kN/m<sup>2</sup> on floor level. The live load is taken 1.5kN/m<sup>2</sup> on terrace level and 4kN/m<sup>2</sup> on floor level of both the models. The earthquake load parameters are taken as zone factor 0.1, soil type II, Importance factor 1, Response Reduction 5 as per IS-1893-2002. Modelling, analysis and design is carried out on STAAD Pro V8i software and the design of columns are done by IS-456-2000 and that of beams, diagrids and bracings are done by IS 800- 2007. From the study, it is concluded that,

- The diagrid structure resists approximately the same amount of lateral loads as compared to the exterior braced structure, despite all the vertical columns being eliminated in the periphery of the diagrid structure
- The top storey drift of diagrid structure is less by 30.7% than in the exterior frame structure.
- The top storey displacement of diagrid structure is less by 46.7% than in the exterior frame structure.

5. Manthan I. Shah, Snehal V. Mevada, Vishal B. Patel [5] (2016) Statistical analysis of tall buildings in India is carried out and presented for buildings having height more than 150 m or 40 storeys. Parametric study and detailed comparison of diagrid structural system with respect to conventional frame is carried out for symmetrical buildings. In this study seven buildings of identical base area and loadings with different heights are designed for optimum sections for both structural systems diagrid and conventional frame in ETABS. The paper concludes that diagrid structure performs well than conventional frame structures and increase in steel weight with increase in height of building is considerably less in diagrid structures.



Based on the numerical study carried out in the present research work, following major conclusions can be drawn:

- Diagrid structural system has emerged as a better solution for lateral load resisting system in terms of lateral displacements, steel weight and stiffness. It is stiff enough to resist wind forces upto higher heights.
- The diagrid structure provides high efficiency in terms of steel weight along with the aesthetic appearance. For 24 storey building, weight of conventional frame is 100% more than diagrid building.
- Displacements on each storey and storey drifts are observed to be less in diagrid systems as compared to conventional frame.

6. Kiran Kamath & Sachin Hirannaiah [6] (2016) study the performance characteristics of diagrid structures using nonlinear static pushover analysis. The models studied are circular in plan with aspect ratio H/B (where H is total height and B is the base width of structure) varying from 2.67 to 4.26. The three different angles of external brace considered are 59°, 71° and 78°. The width of the base is kept constant at 12 m and height of the structure is varied accordingly. The nonlinear behaviour of the elements is modelled using plastic hinges based on moment curvature relationship as described in FEMA 356 guidelines. Seismic response of structure in terms of base shear and roof displacement corresponding to performance point were evaluated using nonlinear static analysis and the results are compared. The following are the observations drawn from the present analysis

- For all the brace angles considered 59° brace angle structures have lower base shear at performance for all the aspect ratios considered in the present study.
- The models with 71° brace angle has higher base shear at performance compared to any other brace angles considered in the study.
- The performance of the structure is influenced by brace angle and aspect ratio.

7. Dr. Gopisiddappa, M. Divyashree & Sindhuja G [7] (2017) have done analysis of 30 storey linear building and diagrid systems with different diagonal angles that is 45 degree, 63 degree, 73 degree, 75 degree, 78 degree, 81 degree. The comparison between linear building and diagrid building is carried out. ETABS software is used for modeling and analysis of structure. Analysis results like storey displacement, inter storey drift are presented here. Following are the conclusions inferred from the study. 1. Framing building without any load resisting system shows highest drift and displacement value as compared to diagrid system. 2. Top storey displacement is less for diagrid system with diagonal angle 63 degree. 3. Between the region 63 degree to 75degree (diagonal angle) diagrid system possess better stiffness, storey drift and storey displacement are less in this region.

8. Snehal S. Mali [8] (2017) has interpreted seismic response of diagrid building with conventional frame structure at seismic zone IV and soil type is hard. Model is of same parameter with diagrid and conventional frame. Position of diagrid in opposite face, three faces, and all faces in model are taken. Equivalent static analysis, Response spectrum analysis and wind analysis is done using ETABS software. Result is representing in term of displacement. It is concluded that at equivalent static analysis, response spectrum analysis of diagrid structure lateral displacement significantly less 45.48% and 41.71%, 45.92%, 42.17% in X, Y direction respectively as compared to conventional structure. At wind analysis lateral displacement significantly diagrid structure compared to conventional structure is less 45.34% in X and 41.59% in Y direction.

9. Mohammed Abdul Rafey and M. A. Azeem [9] (2018) investigated models of diagrid structures and conventional braced frame structures with different symmetric and asymmetric plan geometries. For the purpose of analysis, two symmetric and two asymmetric structures were modelled and analysed using linear static method for each of the two structural types. It was observed that the diagrid structures performance against the lateral loads was much better than that of the conventional braced frame structure and that the member stiffness in diagrid structures.

10. Amruta K. Podar [10] (2017) emphasized in comparison of the diagrid structure with the conventional building of G+20 storey and floor height of 3 m concerning storey drift, lateral displacement and, diagrid angle. Columns of

different angles of 45, 63, 71, 75 were considered in the diagrid model and conventional building vertical column of 90 was taken. The model was analysed and compared using ETABS software. The design parameters and load combination were assigned the same for both the building frames and the paper concluded that the diagrid angle of 63 gave optimum results for the G+20 storey building. The lateral displacement, storey drift, axial force and the shear force gradually reduced in the case of the diagrid structure. Hence it was concluded that the diagrid structure is more beneficial than the conventional building frame. 1. Diagrid building shows less lateral displacement and drift in comparison to conventional building. Axial load on internal column is less in diagrid building as compared to conventional building. Shear force of interior beam is less in diagrid as compared to conventional building. 2. For 20 storey diagrid structure, the optimal range of diagrid angle is from about 60° to 70°. 3. In comparison to conventional building, diagrid buildings are more aesthetic in look and it becomes important for high rise building. 4. Due to diagonal columns on its periphery, diagrid shows better resistance to lateral loads and due to this, inner columns get relaxed and carry only gravity loads. While in conventional building both inner and outer column are designed for both gravity and lateral loads.

11. Shith B. Panchal & Dr. V. R. Patel [11] (2020) have studied, seismic performance of 36storey diagrid structures with varying angles are evaluated using pushover and nonlinear time history analysis. Furthermore, in order to evaluate the effect of diagrid core on behaviour of structures, interior gravity frames are replaced with diagrid frames. The results of pushover analyses demonstrate that diagrid core can enhance the hardening behaviour of structures when the angles of perimeter panels are lower or equal than those of the core compared to the conventional diagrids. In addition, core diagrids provide safe margins between the damage states under lateral loading. Nonlinear time history analyses are then performed to assess inter story drift ratio, residual drift, energy dissipation and hinges distribution of structures. It is observed that most of the models perform well under rare ground motions and hinges are well spread throughout the height among different elements and diagrid structures are capable of undergoing large deformations under rare earthquakes Large portion of input energy are dissipated by diagonal members and as the slope of exterior diagonals exceed that of perimeter tube, diagrid core efficiently participates in dissipating energy Diagrids structures performed acceptable under earthquake motions and most of the mean deformations were within the allowable range. Deformations were spread throughout the height and addition of interior diagrid tube enhanced the distribution of forces towards upper levels especially in models with higher diagonal angles. The distribution of residual drifts also confirmed that diagrid system was well-behaved under rare earthquakes.

12. Aarthi Senthilkumar, R. Umamaheswari(2021) [12] comparative analysis of the structural performance of both conventional and diagrid structure using ETABS. The both building structure have same dimensions 30 storey building. Various parameters like storey drift, storey displacement, storey drift and storey stiffness are obtained. The paper concluded that diagrid structure has more efficiency in terms of lateral displacement under seismic loading. The diagrid structure is evidently more efficient than the conventional structure.

### III. RESULTS

The above literature review shows that comparison between diagrid structure models with conventional frame model, braced frame model. Various diagrid angles are considered with different irregularities in structure. Response spectrum, time history and pushover analysis is considered by using different softwares i.e Etabs, Staad pro, Sap2000 etc from the literature review it can be concluded that

1. Diagrid structure shows more stiffness than the simple conventional model
2. Diagrid structure resist greater lateral load than the braced framed structure.
3. Optimum angle changes with respect to the height of the diagrid structure.
4. Optimum angles lies in a range of 60° to 75° according to the height of the structure.

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