COMPARATIVE STUDY ON THE EFFECTIVENESS OF VARYING ANGLE DIAGRID STRUCTURAL SYSTEM IN HIGH RISE BUILDING

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Abstract – *The diagrid structural system has gained popularity recently in tall buildings because of its flexibility and structural efficiency. Each storey height's diagrid structure is planned with diagonals positioned at varying uniform angles and angles that progressively change as the building height increases. Due to the presence of inclined columns, the diagrid construction resists lateral loads more effectively than typical frame buildings with outside vertical columns. The slanted columns that are positioned at the outside edges of the structures in the diagrid system act axially to resist lateral loads because of their triangular shape, the diagonal members of diagrid structural systems are capable of supporting lateral forces and gravity loads. This study considers a thirty-storey high-rise building with different shapes of buildings, a different angle diagrid, and no diagrid structure. They are modelled for dead, live, seismic, and wind loads using ETABS software for zone 3 of medium soil. Scale factor is taken into consideration in both the X and Y directions according to IS code, and linear static and dynamic analysis has been performed. It is necessary to compare the structures with and without diagrids in order to compute the findings. It is anticipated that the diagrid system will improve the performance of lateral load and gravity load resistance for high-rise buildings.*

Key Words: High rise building, Angle diagrid system, Lateral load, seismic loads, ETABS software, varying angles.

1.INTRODUCTION

Structural engineers have come up with innovative designs throughout the history to decrease the lateral movement of high-rise buildings. The diagrid system is a structural and architectural marvel, known for its dual benefits of strength and aesthetics. It features a diagonal lattice of structural members that not only provide stability to tall buildings but also lend them a distinctive and iconic appearance. This system's unique design allows architects to create visually stunning structures with unconventional shapes and facades, setting them apart as urban landmarks. Beyond its visual appeal, the diagrid system enhances interior spaces by eliminating the need for numerous vertical columns or shear walls. The open layout provides flexibility for interior design and space utilization, making it especially advantageous for commercial and office buildings. Additionally, it efficiently distributes lateral forces like wind and seismic loads, reducing the need for excessive bracing and reinforcing materials, thereby enhancing both functionality and sustainability. In essence, the diagrid system represents a harmonious fusion of form and function, making it a preferred choice for architects and developers seeking to construct iconic, efficient, and structurally sound buildings in modern urban environments.

The principle underlying the diagrid structural system revolves around the utilization of diagonal members in place of traditional vertical columns or shear walls. This innovative approach capitalizes on the inherent strength of triangles, which are known for their stability and load-bearing capabilities. By strategically arranging these diagonal members in a grid-like pattern, the diagrid system effectively distributes the forces acting on a building, such as wind and seismic loads, in a more efficient and balanced manner. This results in enhanced structural stability and reduces the need for excessive bracing, allowing for greater design flexibility and open interior spaces. The principle of the diagrid system showcases the synergy between form and function, where architectural elegance merges seamlessly with structural integrity to create iconic and resilient buildings.

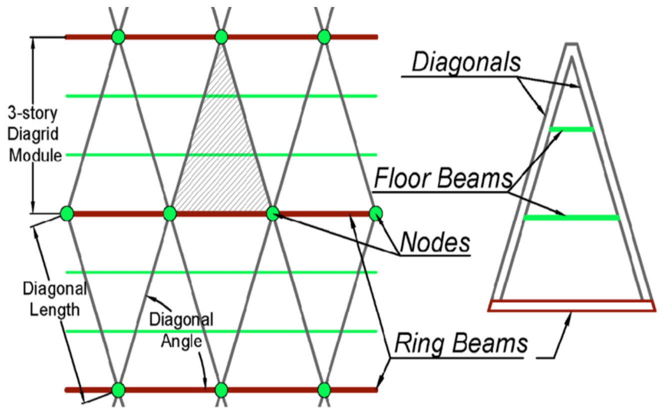


Fig-1: components of angle diagrid system

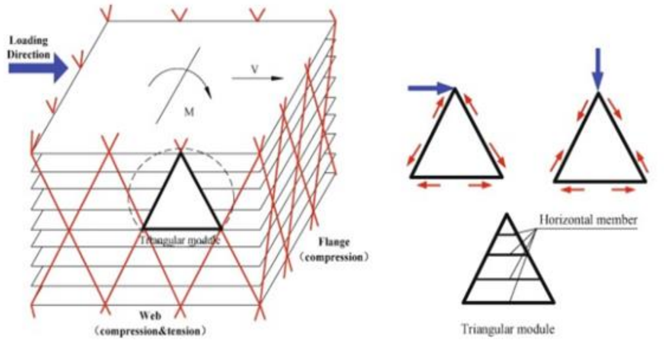


Fig-2: principle of diagrid structural system

2.LITERATURE REVIEW

The diagrid structural systems in tall buildings have been well studied in the literature, which provides in-depth information on their dimensional considerations, sustainability, and efficiency. Tripathi et al. (2016) carefully investigate how storey modules and diagrid angles affect structural behavior, taking into account factors like shear stresses, lateral displacement, and storey drift. In their thorough comparison of diagrid and conventional systems, Deshpande et al. (2015) highlight the benefits of the latter, particularly with regard to load distribution and material efficiency. These advantages can be translated into real benefits, such as cost savings and flexible interior layouts, particularly in buildings up to 50 meters wide by 100 meters high. To elaborate, Panchal et al. (2014) perform a thorough investigation over a wide range of building heights, from 24 to 60 storeys, with diagrid angles ranging from 50.2° to 82.1°, looking at important parameters including material consumption and top storey displacement. Furthermore, Jania et al. (2013) examines the particular measurements of a 36-storey diagrid steel skyscraper with a 36 x 36 m floor plan, focusing on the system's design flexibility and lateral load resistance. This study provides a sophisticated understanding of diagrid structural systems, offering insightful information and useful considerations for their use in tall structure design, especially with regard to dimensions and performance metrics.

2.1. Objective of study

Based on the literature review, from past few years, a conspicuous gap in the existing research landscape pertains to the limited exploration of alternative structural design strategies concerning angle-varying diagrid systems. While diagrid structures have garnered substantial attention, the majority of studies have predominantly focused on uniform diagrids with fixed angles. The potential benefits and structural implications of incorporating varying angles within diagrid systems, in the context of irregular structures, remain largely unexplored. An in-depth analysis of these alternative design approaches could yield valuable insights into their structural efficiency and performance characteristics. Since, very few researches have been conducted on Dynamic seismic analysis of Diagrid systems, this study mainly focuses on comparing the performance of conventional building and varying Diagrid systems under the effect of seismic loads using ETABS software.

3. MODEL DESCRIPTION

Determining the behavior of RCC structure by providing different angles of diagrid and different shapes of buildings analysis using ETABS software. A typical R.C design of 30 Storey is considered for the analysis having six bays in X direction with equivalent spacing of 3.5 m and six bays in Y direction with equivalent spacing of 3.5 m. The plan size is 21m x 21m. the floor-to-floor height is 3.5m and the total height of the building is 105m.

Table -1: Building details

Plan size	21m x 21m
Storey height	3.5 m
Total height	105 m
Number of stories	30
Grade of concrete	M40
Grade of steel	Fe415
Size of Beams	300mm x 600mm
Thickness of Slab	125mm
Size of diagrids	500mm x 500mm x 20mm
Size of Columns	Floor 0-9: 800mm x 500mm, Floor 10-19: 700mm x 450mm, Floor 20-30: 600mm x 400mm

MODELLING IN ETABS

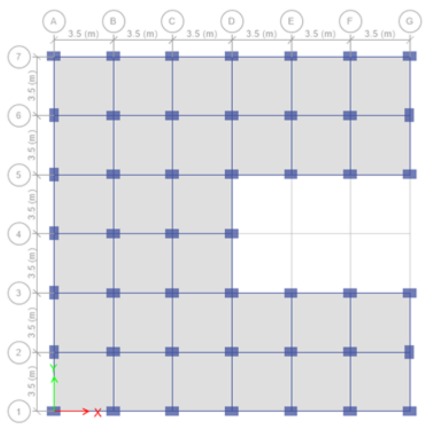


Fig – 2: Plan of C-shaped building

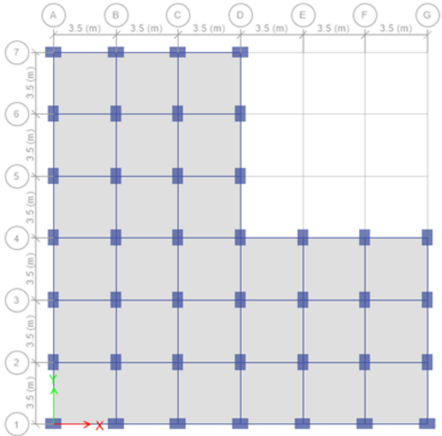
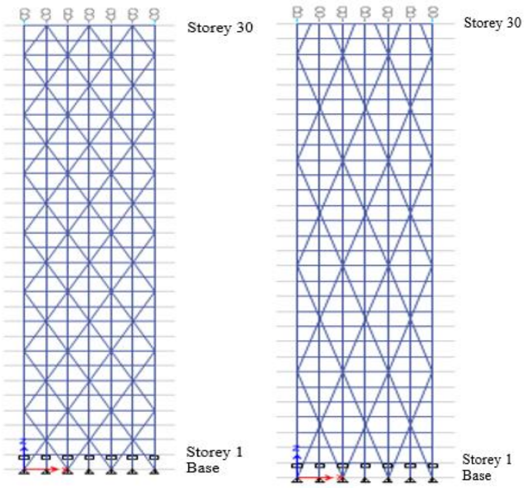
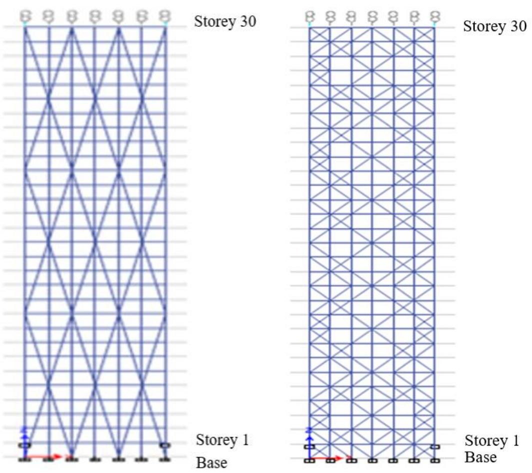


Fig – 3: Plan of L-Shaped building



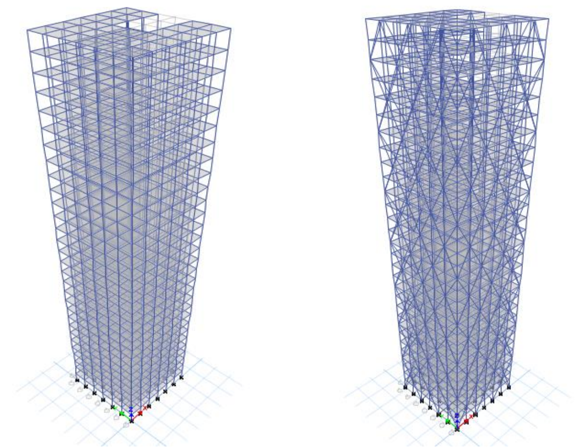
(a) (b)



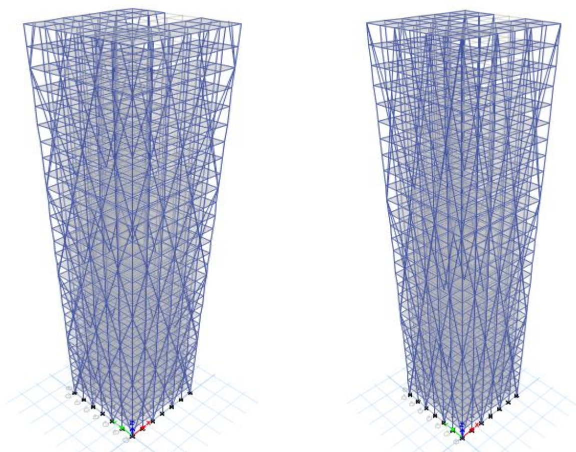
(c) (d)

Fig – 4: Typical floor plan, elevation of Diagrid system. Elevation of building at -
(a) 63.44° (b) 74.06° (c)78.60° (d) varying density

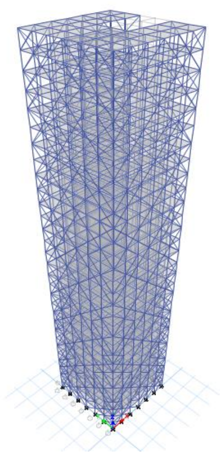
3D VIEW OF C- SHAPED BUILDING:



(a) (b)



(c) (d)



(e)

Fig- 4: 3D view of Diagrid system of C- shaped building.
(a) without diagrid system (A1), Diagrid at angle -
(b) 63.44° (A2), (c) 74.06° (A3), (d) 78.60° (A4), (e) Diagrids with varying density (A5).

3D VIEW OF L- SHAPED BUILDING:

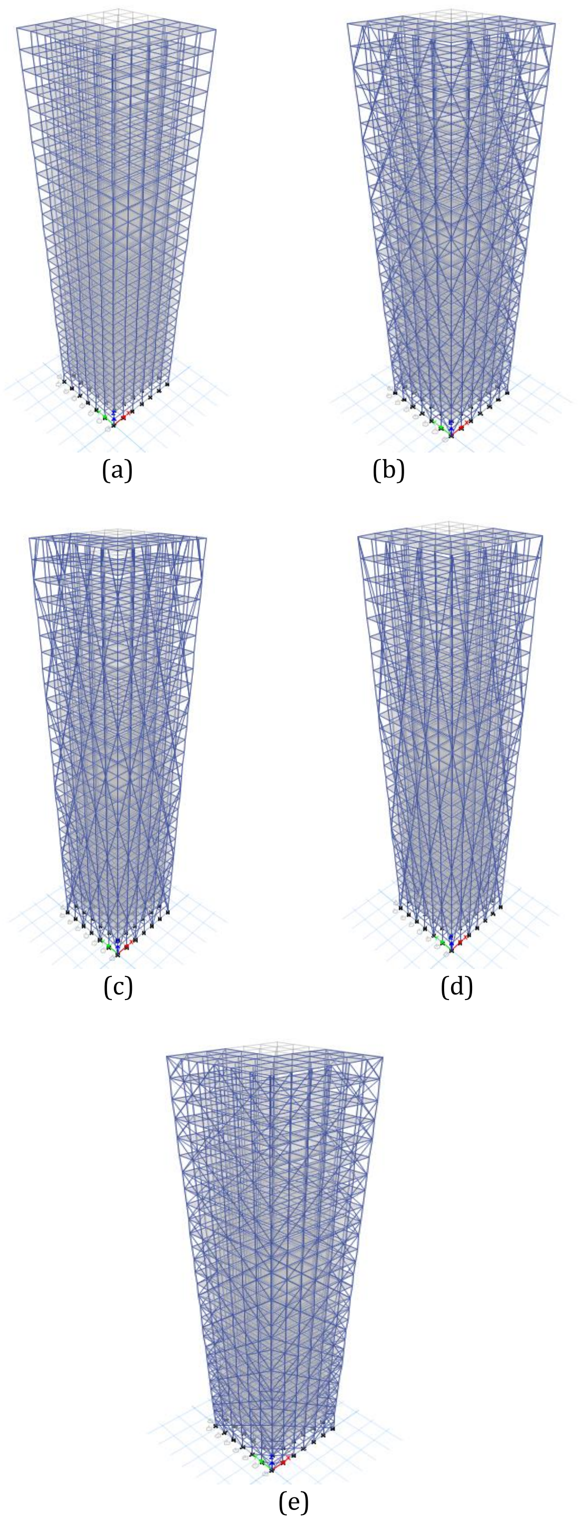


Fig- 5: 3D view of Diagrid system of L- shaped building. (a) without diagrid system (B1), Diagrid at angle - (b) 63.44°(B2), (c) 74.06°(B3), (d) 78.60°(B4), (e) Diagrids with varying density(B5).

3.1. Combination Of Loads for Analysis

Different types of loads have been considered and analyzed for the proposed building. The loads that are considered is self weight that is calculated by ETABS, floor finish of 1 kN/m^2 and live load of 3 kN/m^2.

DYNAMIC SEISMIC ANALYSIS:

According to IS 1893 (Part I): 2016, the following guideline used for seismic examination.

Importance Factor: 1.2 (Clause 7.2.3, Table-8)

Seismic Zone: IV

Zone Factor, Z: 0.24 (Table-3)

Soil type: Type II (Clause 6.4.2.1, Medium Soil)

Reduction Factor: 5 (Clause 7.2.6, Table-9, SMRF)

LOAD COMBINATIONS:

1.5(DL+SL)	1.5(DL+LL+SL)
1.2(DL+LL+SL+WX)	1.2(DL+LL+SL-WX)
1.2(DL+LL+SL+WY)	1.2(DL+LL+SL-WY)
1.5(DL+SL+WX)	1.5(DL+SL-WX)
1.5(DL+SL+WY)	1.5(DL+SL-WY)
0.9(DL+SL) + 1.5WX	0.9(DL+SL) – 1.5WX
0.9(DL+SL) + 1.5WY	0.9(DL+SL) – 1.5WY
1.2(DL+LL+SL+EQX)	1.2(DL+LL+SL-EQX)
1.2(DL+LL+SL+EQY)	1.2(DL+LL+SL-EQY)
1.5(DL+SL+EQX)	1.5(DL+SL-EQX)
1.5(DL+SL+EQY)	1.5(DL+SL-EQY)
0.9(DL+SL) + 1.5EQX	0.9(DL+SL) – 1.5EQX
0.9(DL+SL) + 1.5EQY	0.9(DL+SL) – 1.5EQY

Where,
DL – Dead Load
SL - Super Dead Load
LL – Live Load
WX – Wind Load in X direction
WY – Wind Load in Y direction
EQX – Earthquake Load in X direction
EQY – Earthquake Load in Y direction

4. RESULTS & DISCUSSION

4.1. MAXIMUM STOREY DISPLACEMENT OF C- SHAPED BUILDING

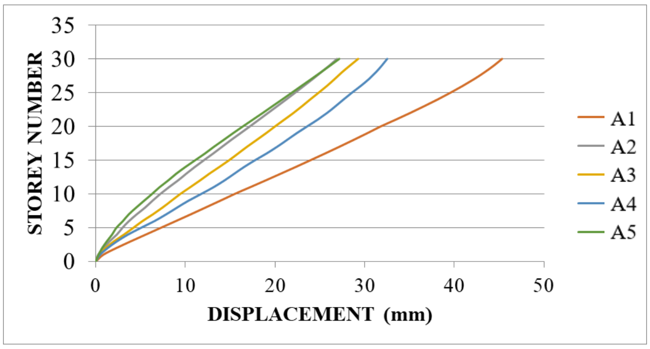


Chart -1: Storey Displacement C-shaped in X-direction

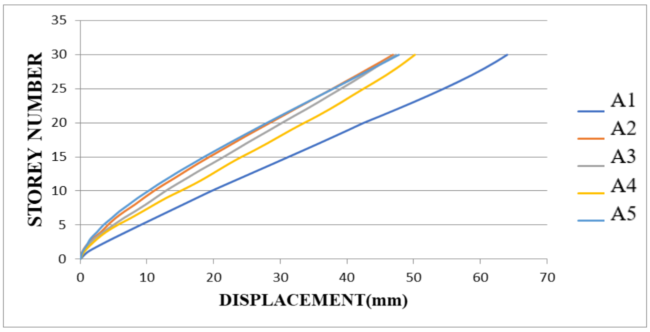


Chart -2: Storey Displacement C-shaped in Y-direction

4.3. MAXIMUM STOREY DRIFT FOR C-SHAPED BUILDING

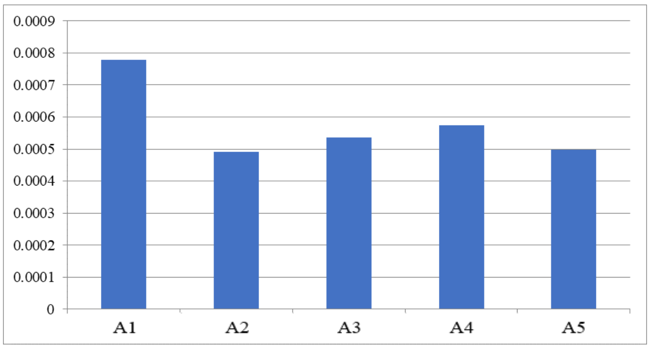


Chart -3: Storey Drift of C-shaped building in X-direction

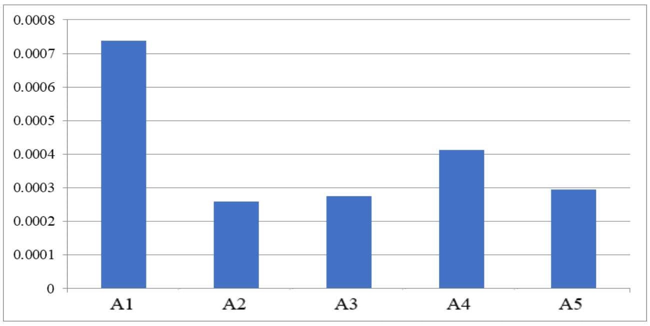


Chart -4: Storey Drift of C-shaped building in Y-direction

4.3. MAXIMUM STOREY DISPLACEMENT OF L- SHAPED BUILDING

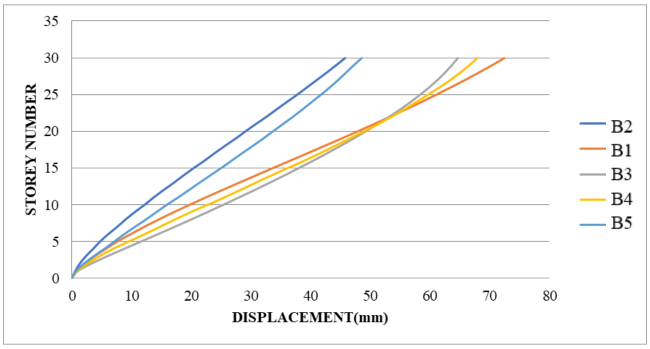


Chart -5: Storey Displacement C-shaped in X-direction

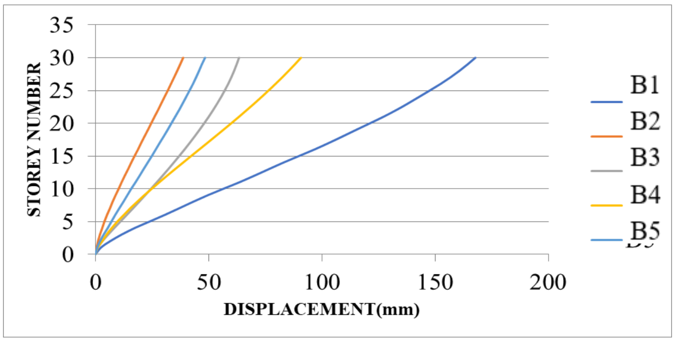


Chart -6: Storey Displacement C-shaped in Y-direction

4.4. MAXIMUM STOREY DRIFT FOR L-SHAPED BUILDING

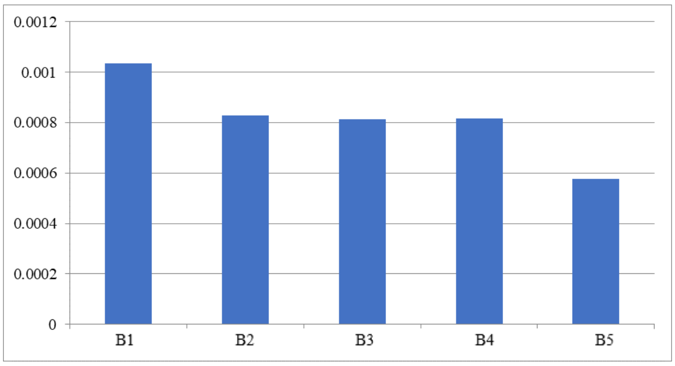


Chart -7: Storey Drift of C-shaped building in X-direction

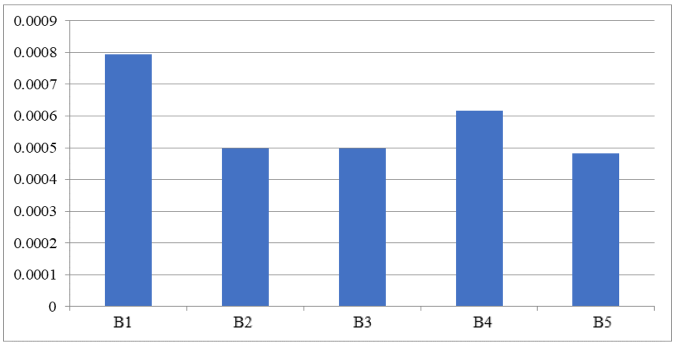


Chart -8: Storey Drift of C-shaped building in Y-direction

- From the charts i.e., chart-1,2,3 & 4. it can be observed that C-shaped buildings with Diagrid system was efficient in reducing storey displacement and storey drift in both the directions.
- In conclusion, for C-Shaped 30-storied building, the results indicate that the structural efficiency increases with diagrid angles of 78.60°(A4), 74.06°(A3), 63.44° (A2) and varying density (A5).
- From the charts i.e., chart-5,6,7 & 8, it can be observed that L-shaped buildings with Diagrid system was efficient in reducing storey displacement and storey drift in both the directions.
- In conclusion, for L-Shaped 30-storied building, the results indicate that the structural efficiency increases with diagrid angles of 78.60°(B4), 74.06°(B3), varying density (B5) and 63.44°(B2).

5. CONCLUSIONS

The current study evaluated the diagrid system's overall behavior for 30 storey irregular buildings. In order to compare conventional buildings with diagrid system buildings for storey displacement and storey drift in both X and Y directions, seismic analysis was done using ETABS software. The analysis's findings led to the following conclusions.

1.Buildings with angle diagrid system perform more efficiently than building without diagrid system.

2.In contrast to varying angle diagrid system it is inferred that the 4 storied diagrid angle of 63.44° is suitable for 30 storied building structure.

3.It could also be concluded that building structure with varying density also performs efficiently.

4.Buildings with diagrid system have less storey displacement and storey drift in contrast to buildings without diagrid system.

5. Considering everything mentioned before, it can be said that, though there was not a huge difference between diagrid systems with different angles, yet implementation of diagrid system would be advantageous, placing of Diagrid system causes architectural & functional constraints.

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