Dynamic Analysis of Diagrid Structure with Varying angles and Hybrid configurations under Lateral loads

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Abstract—**The rising demand for high-rise buildings necessitates efficient lateral load-resisting systems that combine structural stability with architectural appeal. This study presents a dynamic analysis of a G+20 RCC circular building diagrid structure, examining the effects of diagrid angles (55°–74°) and hybrid configurations on seismic performance. Various diagrid and conventional RCC frames are modeled in ETABS, and key parameters such as storey displacement, drift, shear,time period and stiffness are evaluated. Results show that diagrid structures significantly reduce lateral displacement and drift, with angles between 60° and 70° offering optimal strength, stiffness, and economy. Hybrid configurations further enhance deformation uniformity and energy dissipation. The study confirms that RCC diagrid systems are highly effective for high-rise buildings, providing improved seismic resistance, material efficiency, and design flexibility.**

I. INTRODUCTION

I.1 GENERAL

Rapid urbanization and rising land costs have limited horizontal city expansion, making vertical growth the preferred solution for modern urban areas. This trend has led to a surge in high-rise buildings, increasing demands on structural systems to resist both gravity and lateral loads efficiently. Traditional systems such as moment-resisting frames, braced frames, and shear walls often rely heavily on bending action, which becomes less effective with building height, resulting in higher material usage and reduced stiffness.

The diagrid (diagonal grid) structural system has emerged as a modern alternative, combining structural efficiency, material economy, and architectural flexibility. Its triangulated framework of diagonal members carries both gravity and lateral loads primarily through axial action, reducing bending in beams and columns, eliminating most vertical columns, and providing column-free interiors. Iconic structures such as The Gherkin (London), Hearst Tower (New York), and CCTV Headquarters (Beijing) illustrate the effectiveness of diagrids in high-rise design.The performance of diagrid systems depends strongly on the diagrid angle the inclination of diagonal members. Smaller angles enhance shear rigidity, while larger angles improve bending stiffness. Selecting an optimal angle is crucial to achieving the desired balance of strength, stiffness, and material efficiency.

1.2 HYBRID DIAGRID SYSTEM

Hybrid diagrid systems, where angles vary vertically or horizontally, further improve structural performance by optimizing stiffness distribution, reducing story drift, and enhancing energy dissipation under wind and seismic loads. Vertical variations provide higher axial capacity in lower stories and improved lateral resistance in upper stories, while horizontal variations address directional load asymmetry in circular or irregular structures. Hybrid configurations also allow material optimization, reducing weight in less critical zones and reinforcing high-demand areas.

II. LITERATURE REVIEW

Patel & Shah (2016) compared a G+30 steel diagrid with a conventional moment-resisting frame, reporting 15–20% steel savings, reduced storey drift, and lower lateral displacement due to axial action in diagonal members. They emphasized careful node design to capture axial-flexural interaction for constructability.

Madhavi & Naveen (2017) studied RCC diagrid frames under wind and seismic loads per Indian codes, showing ~30% reduction in top-storey displacement and improved lateral stiffness. The elimination of internal columns provided greater architectural flexibility, though detailing and constructability remained critical considerations.

Behera & Parhi (2023) conducted parametric studies of RCC diagrid buildings across Seismic Zones II and V, confirming lower storey drift, displacement, and bending stresses. They noted that module height and angle variations strongly influenced global stiffness.

Gorle & Gowardhan (2016) investigated diagrid angles (55°–75°) for a 36-storey steel building and found optimal performance between 65°–70°, balancing lateral stiffness and member axial demands.

Irkey & Kumar (2020) compared G+9, G+20, and G+30 diagrid buildings to conventional frames, showing higher stiffness and reduced base shear, while emphasizing the need for optimized geometry to avoid local stress concentrations.

Hossain et al. (2022) analyzed a 24-storey circular diagrid tower, reporting ~25% reduction in lateral displacement and improved torsional control due to wraparound perimeter diagrid members.

Yasin & Bhalchandra (2024) studied hybrid diagrid systems with varying angles by zone (e.g., 70° lower, 60° upper), showing improved deformation uniformity, energy dissipation, and optimized axial-lateral performance. Hybrid zoning enhances dynamic response but increases node complexity and fabrication challenges.

III. OBJECTIVES

1.To Perform dynamic analysis of circular high-rise buildings using hybrid diagrid systems with varying vertical and horizontal angles.

2.Evaluate key performance parameters including lateral displacement, storey drift, base shear, stiffness, and natural frequencies.

3. Identify the optimum hybrid diagrid angle combination that maximizes stiffness and minimizes displacement.

IV. SCOPE OF PROJECT

- To Analyze circular high-rise RCC buildings with hybrid diagrid systems under seismic and wind loads using ETABS.
- Investigate the effect of vertical and horizontal diagrid angle variations on structural performance.
- Compare hybrid diagrid configurations with uniform-angle diagrid systems to determine the most efficient design.

V. NEED OF PROJECT

- Efficiently utilize limited urban land by enabling taller buildings with superior lateral load resistance.
- Improve structural stability and seismic performance over conventional framed systems.
- Enable column-free floor plans for flexible, open, and aesthetically appealing architectural designs.

VI. METHODOLOGY

The present study evaluates the seismic performance of G+20 reinforced concrete buildings with steel diagrid systems using ETABS 2020. A circular plan building with fixed base supports and rigid floor diaphragms was modeled in AutoCAD and imported into ETABS for analysis. Material properties were assigned as per IS codes, with a 5% damping ratio for dynamic analysis. Eleven models were developed to study the effect of diagrid configurations: M0 represents the conventional moment-resisting frame, M1-M5 are uniform diagrid systems with angles of 55°, 60°, 65°, 70°, and 74°, respectively, M6-M8 are vertical hybrid models combining different angles along the height, and M9-M11 are horizontal hybrid models with varying angles around the plan perimeter. Dead, live, and seismic loads were applied according to IS 875 and IS 1893 (Part 1):2016. Response Spectrum Analysis was performed to evaluate natural frequencies, mode shapes, base shear, lateral displacement, and storey drift. Comparative analysis of all models revealed that hybrid diagrid configurations significantly improve stiffness, reduce inter-storey drift, and optimize material usage, while the conventional frame (M0) exhibited higher displacement and lower lateral resistance, confirming the efficiency of diagrid systems for seismic-resistant high-rise structures.The details of models are given as follows

- Plan dimension -91.4 x 91.4 m
- Storey height -3.5 m
- Number of storey -G+20
- Depth of foundation -3.6 m
- Beam -510 x 460 mm
- Column - 460 x 460 mm
- Thickness of Slab -150mm
- Foundation type -Mat foundation
- Surface plate -135 mm
- Grade of Concrete & steel-M_{40}& Fe_{550}
- Dead ,Live,floor load -5 KN/m^2, 4.5KN/m^2,2KN/m^2
- Sesismic zone -Zone II
- Zone Factor -0.10
- Rock and Soil type factor -2
- Response reduction factor -5
- Basic wind speed -39 m/s
- Terrain category -3
- Class of structure -Class B

Plan Elevation and 3D View of Different Models

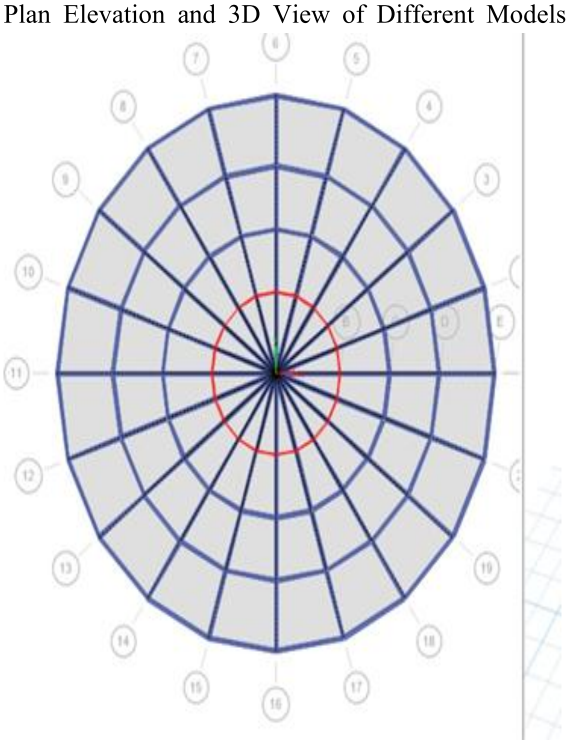
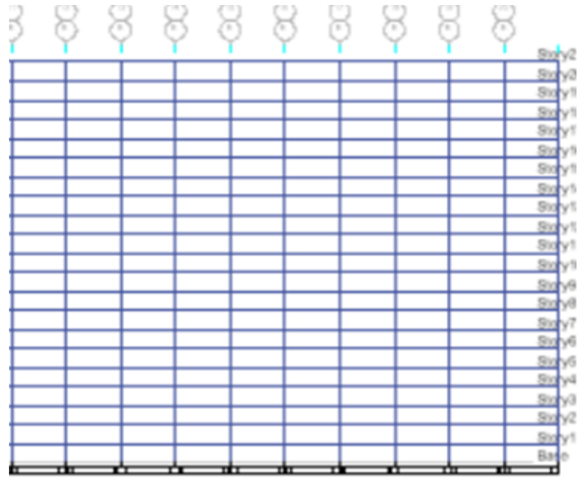


Figure Plan of bare frame Structure



FigureElevation view of M0

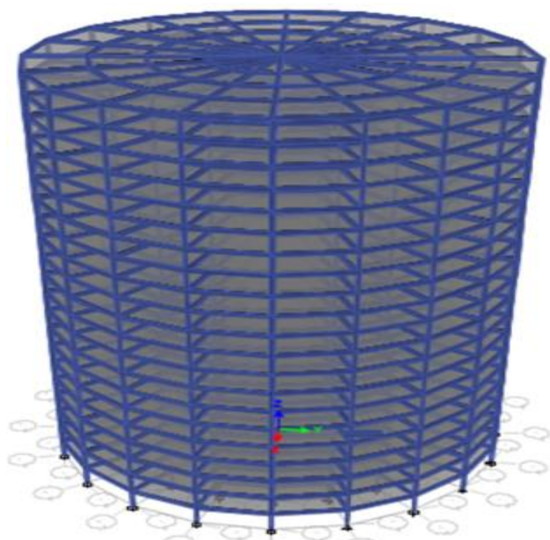


Figure 3D Rendering view of M0

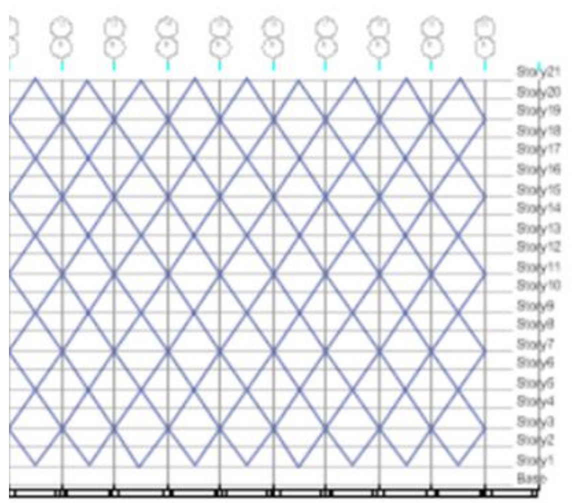


Figure Elevation view of M1

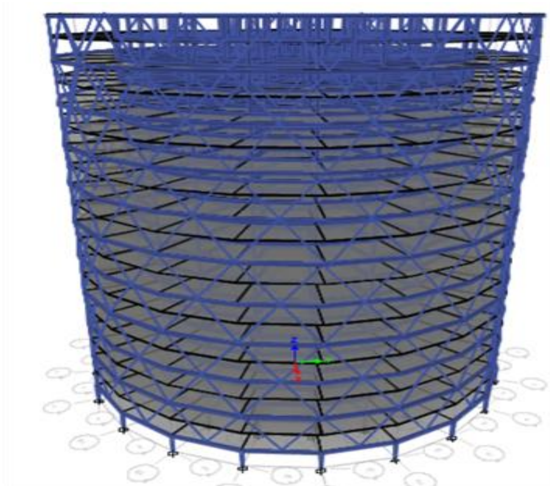


Figure 3D REndering view of M1

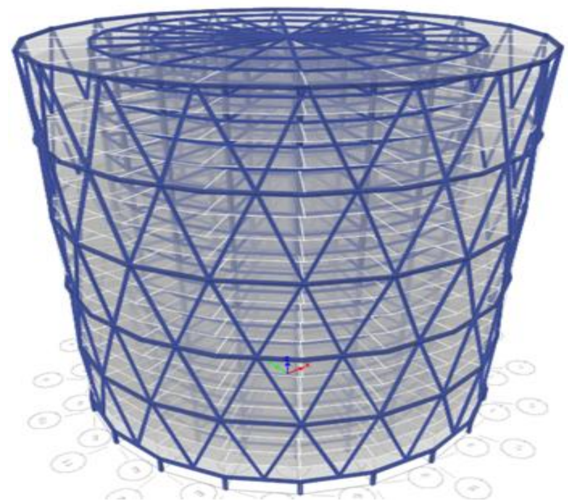


Figure 3D Rendering view of M4

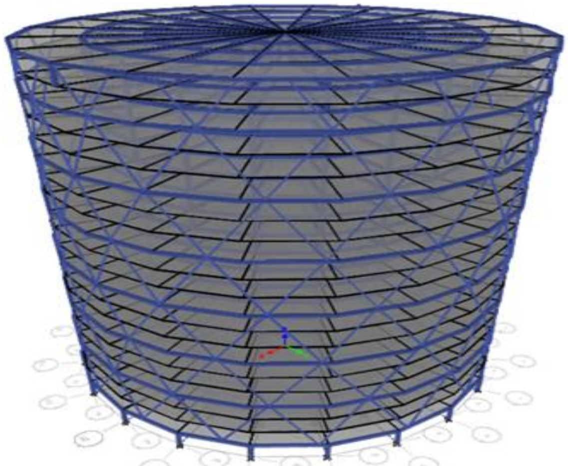


Figure 3D Rendering view of M2

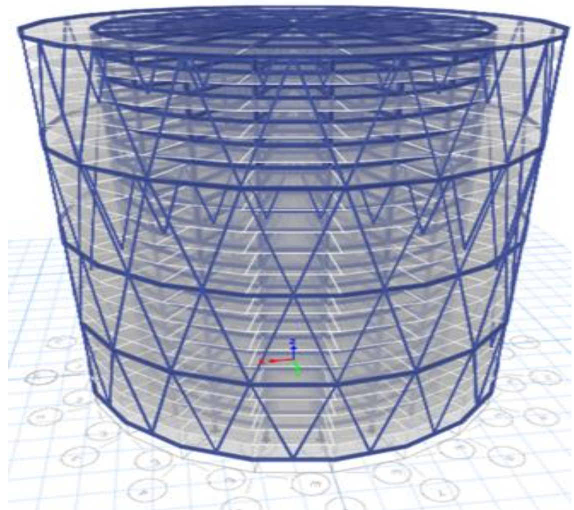


Figure 3D Rendering view of M5

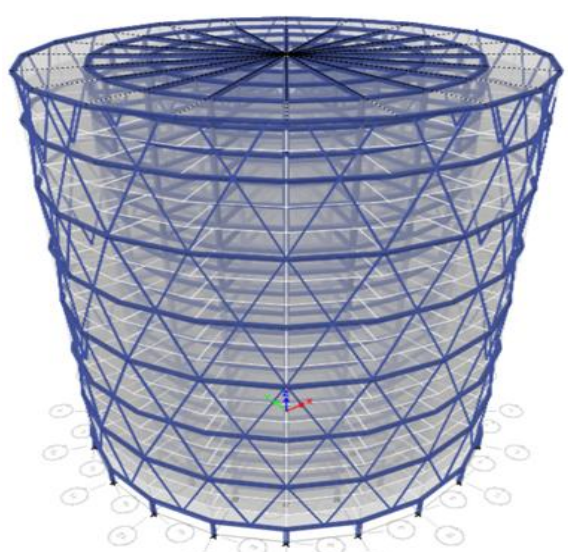


Figure 3D Rendering view of M3

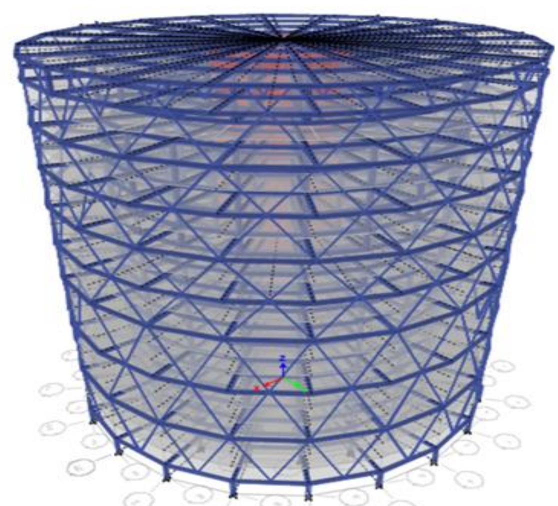


Figure 3D Rendering view ofM6(TOP55+BOT65)

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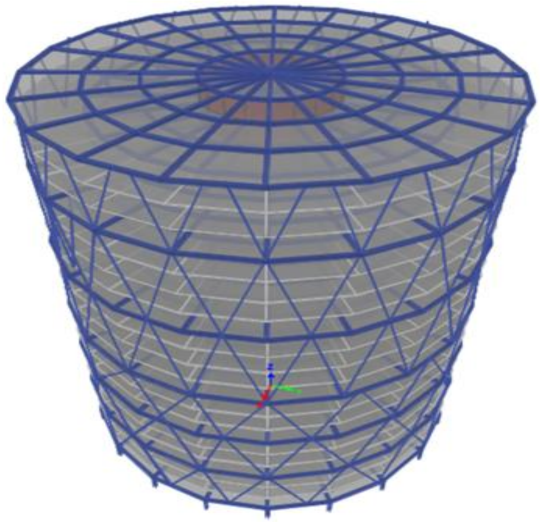


Figure 3D Rendering view ofM7(TOP60+BOT70)

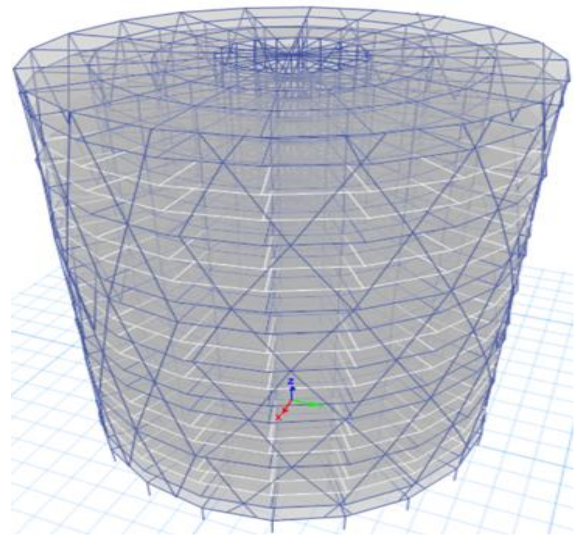


Figure 3D Rendering view ofM10(60+70)

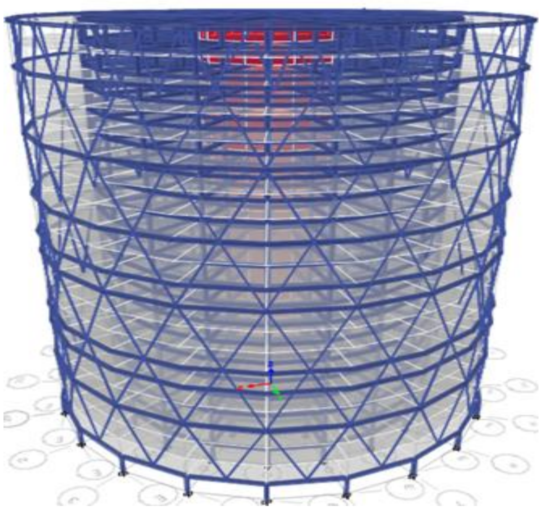


Figure 3D Rendering view ofM8(TOP65+BOT75)

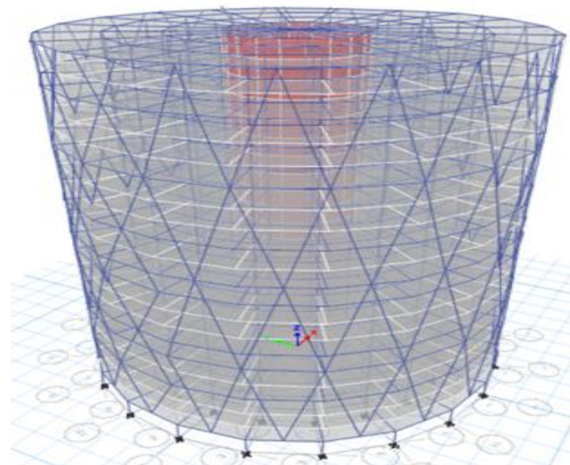


Figure 3D Rendering view ofM10(65+75)

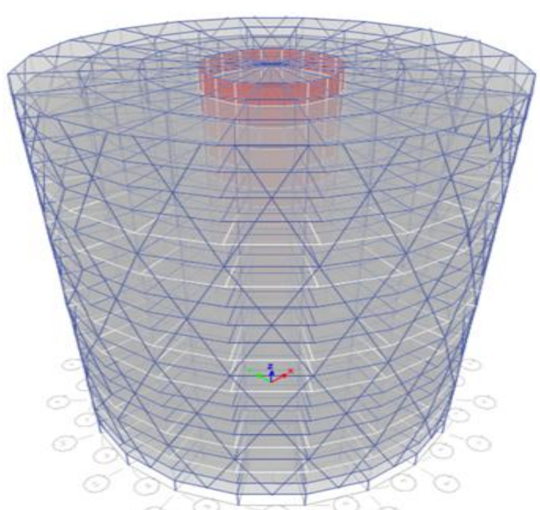


Figure 3D Rendering view ofM9(55+65)

VII. RESULTS AND DISCUSSIONS

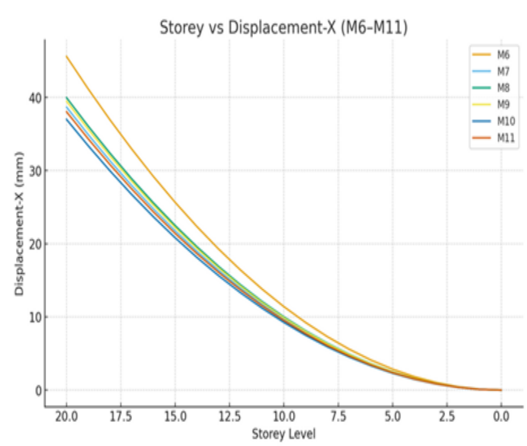


Figure StoreyVsDisplacement(M6-M11) in X

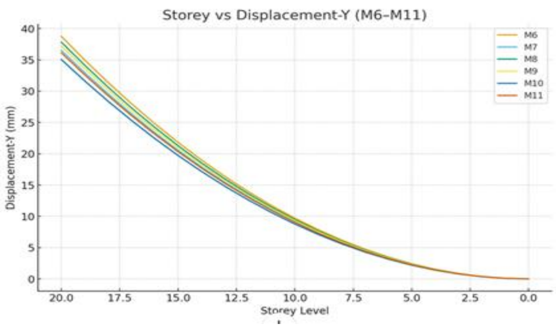
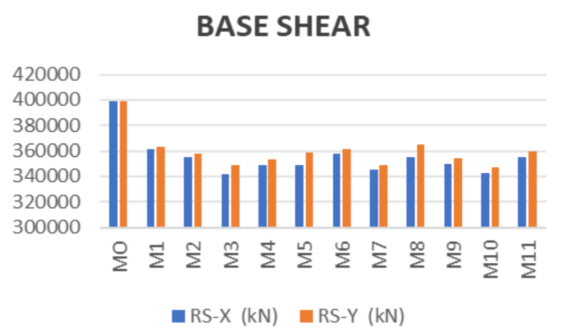


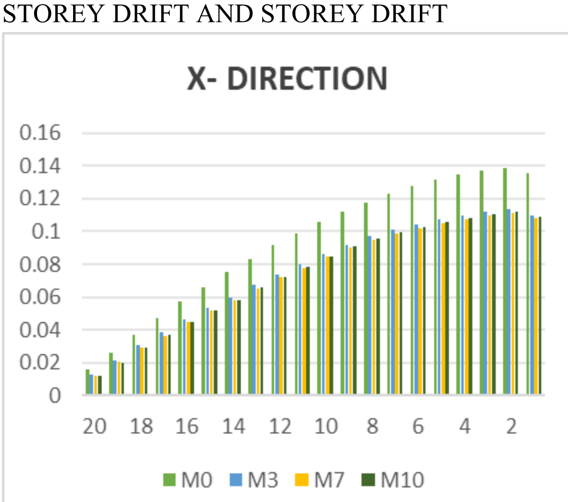
Figure StoreyVsDisplacement(M6-M11) in Y

Among all hybrid configurations, M7 (Vertical 60°+70°) and M10 (Horizontal 60°+70°) provide optimal displacement control, minimizing storey drift and outperforming uniform diagrids in lateral rigidity and serviceability.



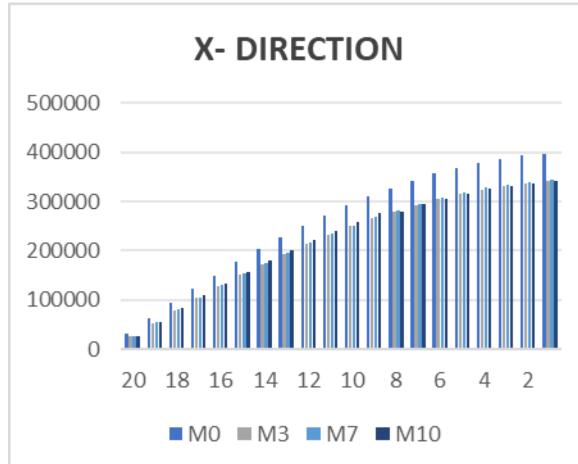
Hybrid diagrid models (M6–M11) show improved base shear, with M7 and M10 providing optimal lateral performance. Overall, diagrids outperform conventional frames, with the 65° uniform diagrid (M3) achieving the best balance of base shear, load distribution, and material efficiency.

STOREY DRIFT AND STOREY DRIFT



both uniform and hybrid, significantly reduce story drift compared to conventional framed buildings. Perfect models M3 for uniform diagrid, M7 for vertical hybrid, and M10 for horizontal hybrid offer maximum stiffness, better serviceability, and efficient lateral load distribution.

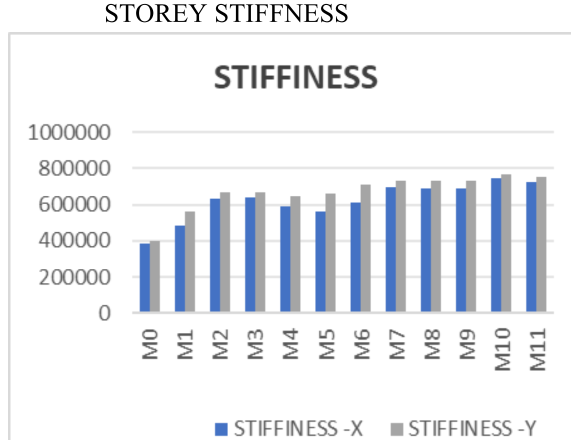
STOREY SHEAR



Among all, uniform 65° diagrid models (M7 and M10) achieve the lowest story shearand drift, ensuring efficient load transfer, minimized stress on interior columns, and reduced inter-storey drift. These results confirm that diagrid systems, particularly uniform configurations, enhance lateral load-resisting capacity and overall structural performance, while hybrid models offer intermediate benefits, and the conventional model is the least efficient in resisting lateral forces.

Hybrid diagrid models M7 (Vertical 60°+70°) and M10 (Horizontal 60°+70°) exhibit optimal performance, minimizing storey drift and base shear while outperforming uniform configurations in lateral stiffness and stability.

STOREY STIFFNESS



Stiffness results correlate with storey shear and displacement, confirming that hybrid diagrid configurations enhance rigidity, stability, and seismic performance of high-rise buildings compared to conventional frame.

VIII. CONCLUSION

Conventional RCC structures (M0) exhibit the highest top-storey displacement and drift, indicating lower efficiency in resisting lateral loads. Uniform diagrid systems (M1–M5) significantly improve lateral load performance, with M3 (65° diagrid) showing the best stiffness and displacement control among uniform configurations. Hybrid vertical diagrid models (M6–M8) enhance structural rigidity, with M7 (60°+70°) achieving the lowest lateral displacement and drift. Hybrid horizontal diagrid models (M9–M11) provide superior torsional and lateral stability, with M10 (60°+70°) performing optimally. Steeper diagrid angles (70°–74°) generally increase stiffness and reduce storey displacement. Base shear analysis confirms that hybrid diagrid systems distribute lateral forces more efficiently than conventional and uniform diagrid frames. Overall, hybrid diagrid arrangements outperform uniform and conventional systems, offering an optimal balance of stiffness, reduced displacement, and enhanced stability. The study demonstrates that diagrid structures are highly suitable for high-rise buildings under seismic loads, combining structural efficiency with architectural flexibility.

Scope for Further Study

- Investigate the performance of hybrid diagrid systems under progressive collapse and extreme loading scenarios such as blast or impact loads.
- Explore the use of advanced materials, including high-strength concrete and steel-composite diagrid members, to further optimize stiffness and reduce weight.
- Study the effect of varying diagrid angles along the height of the building for tailored stiffness and displacement control.
- Extend the research to irregular, circular, and super-tall buildings to evaluate hybrid diagrid efficiency in complex geometries.

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