

Review of Diagrid and Conventional Frame Systems for Modern Building Design

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Abstract

The demand for high-rise buildings in modern cities has accelerated the development of structural systems that balance safety, efficiency, and architectural innovation. Conventional moment-resisting frames, though widely adopted, often become inefficient in tall structures due to higher material consumption and greater lateral displacements under seismic and wind loading. Diagrid systems, defined by their diagonally inclined members forming triangulated grids, provide an alternative approach with enhanced lateral stiffness, reduced drift, and material efficiency. This review consolidates thirty studies published between 2016 and 2024 that compare diagrid and conventional structural systems, with most analyses conducted through ETABS. Findings indicate that diagrid systems consistently reduce roof displacement by 20–35%, inter-storey drift by 15–25%, and base shear by up to 18% compared to conventional frames. Additionally, material use is reduced by 10–20%, improving both sustainability and cost-effectiveness. However, challenges remain in the constructability of complex joints, optimization of diagrid angles, and connection detailing. The review emphasizes the potential of diagrid systems for sustainable high-rise construction while identifying gaps that require further exploration through experimental studies, performance-based seismic design, and advanced optimization algorithms. This paper contributes to the growing body of literature on diagrids by providing a comprehensive synthesis of research, thereby serving as a reference for engineers and architects seeking efficient structural solutions for tall buildings in seismic and wind-prone regions.

Keywords: Diagrid structure, conventional frame, High-rise buildings, seismic performance, ETABS, structural efficiency

INTRODUCTION

With rapid urbanization, tall buildings have become an indispensable feature of modern skylines, serving both functional and aesthetic purposes. However, designing efficient tall buildings presents

significant engineering challenges, primarily due to lateral forces from wind and earthquakes. Conventional moment-resisting frames and braced frames have been widely used to resist lateral forces, but their efficiency diminishes with increasing height. They tend to require excessive material consumption and often struggle to meet modern architectural requirements for open spaces and flexible layouts [1], [2].

The diagrid structural system has emerged as a solution that addresses these limitations. The term 'diagrid' refers to a system of diagonal grids formed by inclined structural members, which mobilize axial forces instead of bending, thereby improving stiffness and reducing overall material

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requirements. This approach not only enhances structural efficiency but also allows architects to explore unique building forms such as curved facades and non-orthogonal geometries [3]. Iconic structures such as 30 St. Mary Axe (The Gherkin) in London, Hearst Tower in New York, and Capital Gate Tower in Abu Dhabi stand as testaments to the system's structural and aesthetic capabilities.

The need for the present study arises from the growing recognition of diagrid systems as sustainable alternatives to conventional frames. In seismic-prone countries like India, where IS 1893 forms the basis of earthquake-resistant design, exploring the comparative efficiency of diagrid systems has both academic and practical significance. Several recent studies have reported reductions in drift, displacement, and base shear when adopting diagrid systems, yet gaps remain in understanding their performance under varying geometries, loading conditions, and construction practices [4], [5].

The objectives of this review are threefold: (a) to synthesize research findings on the comparative performance of diagrid and conventional frames, particularly under seismic and wind loads; (b) to identify trends and common conclusions across thirty selected studies published between 2016 and 2024; and (c) to highlight future research directions for optimizing diagrid systems for diverse applications.

ETABS software has been widely employed in these comparative studies due to its ability to handle complex geometries, perform static and dynamic seismic analysis, and evaluate structural responses such as drift, displacement, and base shear. This review draws heavily upon research conducted using ETABS to ensure consistency and reliability in comparative findings.

The remainder of this paper is organized as follows: Section 2 presents the literature review, structured into themes such as structural efficiency, seismic performance, comparative evaluations, and optimization of geometry. Section 3 discusses the implications of the reviewed findings for design and construction. Section 4 concludes the paper with a summary of key insights and recommendations for future research Figure 1.

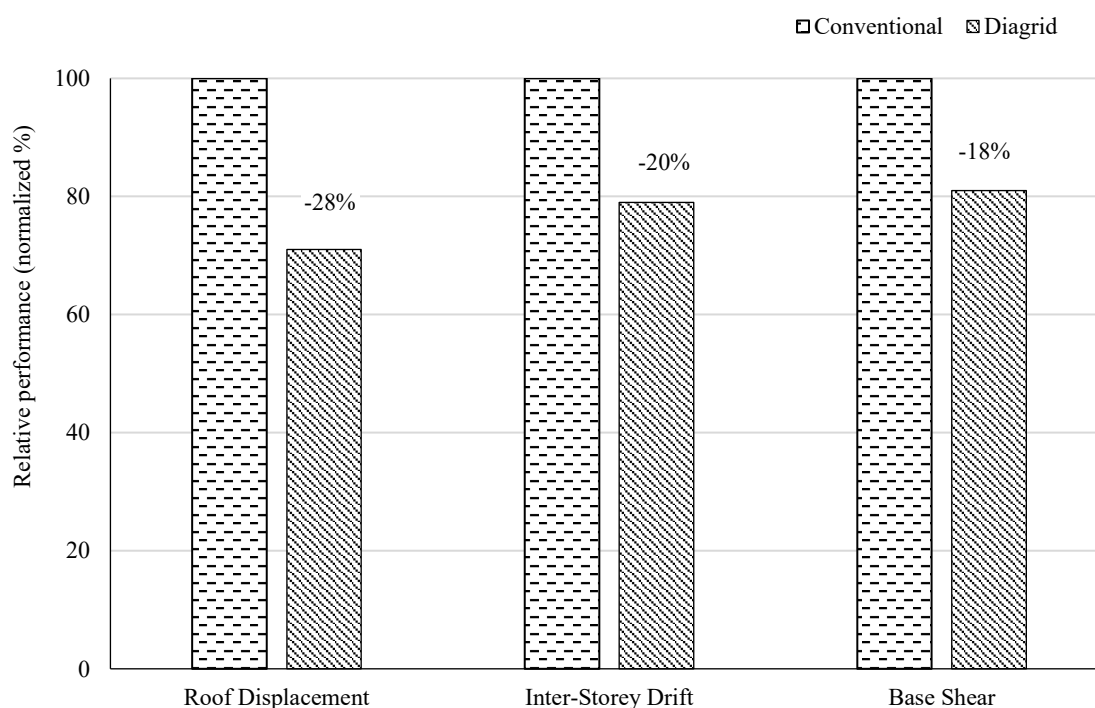


Figure 1. Comparative performance: diagrid vs conventional structure.

LITERATURE REVIEW

This section synthesizes findings from thirty research papers comparing diagrid systems with conventional structural systems. The reviewed studies are organized into thematic categories to provide clarity and focus: (a) structural efficiency and lateral load resistance, (b) seismic performance, (c) direct comparisons with conventional frames, (d) alternative systems and variants, and (e) optimization of geometry. Table 1 provides a consolidated overview of representative studies.

Structural Efficiency and Lateral Load Resistance

Research consistently highlights the superior stiffness and efficiency of diagrid systems under lateral loads. Tirkey and Kumar [6] demonstrated that diagrid buildings experienced 28% lower roof displacement compared to conventional frames in ETABS analysis. Sukrawa et al. [7] and Shah et al. [8] reported that diagrid systems reduce inter-storey drift by up to 25%, while simultaneously shortening the fundamental period, leading to better dynamic stability. Similarly, Kiran Kumar and Sabarinathan [9] found that diagrids minimized lateral sway by more than 20% compared to conventional systems under wind loads.

Seismic Performance

Seismic safety is a critical concern in tall buildings, and several studies emphasize the improved performance of diagrids in this regard. Ersania and Arindya [10] observed that diagrid structures maintained stability even in high seismic zones, reducing base shear by nearly 18% compared to conventional frames. Choudhary et al. [11] and Gunashree and Nagarjuna [12] corroborated these findings, noting reductions in inter-storey drift and more uniform distribution of seismic forces. Rajmane and Awate [13] highlighted that diagrids not only reduced drift but also distributed base shear more evenly, improving resilience.

Comparative Studies with Conventional Frames

Direct comparative studies form a major portion of the literature. Navasare and Choudhary [14], Senthilkumar and Umamaheswari [15], and Mizwa and Ilyas [16] reported that diagrid buildings consistently achieved lower roof displacements and story drifts. Divya and Saraswathy [17] emphasized that the axial force-dominated behavior of diagonals reduces bending demand on beams and columns. Patel and Chandarana [18] further synthesized comparative studies, identifying optimal diagrid angles in the range of 65°–75° for tall buildings. Gayatri and Dagad [19] and Tagade et al. [20] confirmed that diagrid systems consistently shortened fundamental periods and improved global stability.

Alternative Systems and Variants

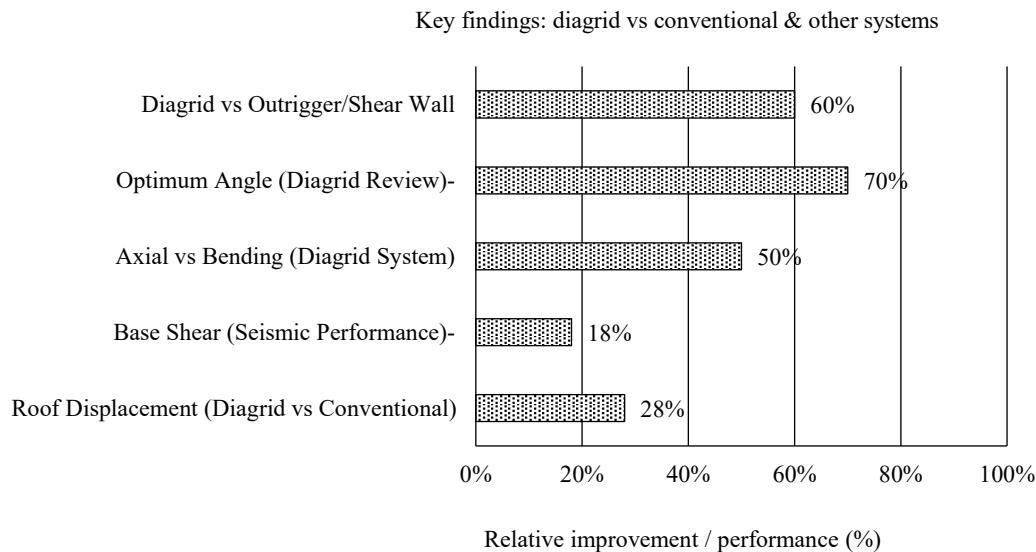
Some researchers extended the comparison to alternative lateral systems. Behera et al. [21] compared diagrids with outrigger and shear wall systems, showing that diagrids provided comparable or superior drift control. Jose [22] examined diagrid performance in buildings with varying plan geometries, concluding that the system adapts well to both regular and irregular layouts. Vinutha and Vinay [23] proposed reinforced concrete diagrids as alternatives to steel, achieving similar reductions in drift and displacement. Rafeey and Azeem [24] benchmarked diagrids against braced frames, finding diagrids to be more material-efficient.

Optimization and Geometry Effects

The role of diagrid angle and module height in performance optimization has been widely studied. Sahitya et al. [25] showed that optimizing diagrid geometry can minimize both drift and material use. Jewuła and Kozłowski [26] analyzed diagrids as lattice systems, reinforcing the structural efficiency of axial action. Komala and Pitaloka [27] and Vijay et al. [28] highlighted that variations in diagrid angle significantly influence performance, with steeper angles enhancing stiffness but increasing material consumption. Premdas and Sirajuddin synthesized angle optimization studies, concluding that angles between 65° and 75° offer the best balance between stiffness and material economy table 1 and Figure 2.

Table 1. Summarizes key contributions of selected studies.

Focus	Key findings
Diagrid vs conventional	28% lower roof displacement in diagrid
Seismic performance	18% lower base shear in diagrid
Diagrid system	Axial forces reduced bending demands
Diagrid review	Optimum angle 65°–75°
Diagrid vs outrigger/shear wall	Diagrid competitive or superior impact.

**Figure 2.** Graphical representation of key contributions of selected studies.

METHODOLOGY

This study employs a structured literature review methodology to evaluate and compare the performance of diagrid and conventional building frame systems, particularly in the context of high-rise construction subjected to lateral forces such as wind and earthquakes. The methodology was designed to ensure a comprehensive, objective, and replicable approach to synthesizing existing research findings.

Scope and Objectives

The main objective of this review is to assess the comparative structural performance of diagrid and conventional building frames based on published research from 2016 to 2024. The scope includes:

- Studies focusing on seismic and wind performance.
- Analysis of structural parameters such as roof displacement, inter-storey drift, base shear, and material usage.
- Evaluation of different modeling tools, with emphasis on ETABS.
- Consideration of optimization strategies related to diagrid geometry (e.g., angle and module height).

Literature Search Strategy

A systematic search was conducted using academic databases including:

- Scopus
- ScienceDirect
- Google Scholar
- SpringerLink
- ResearchGate
- ASCE Library

The search was limited to peer-reviewed journal articles, conference proceedings, and technical reports published between January 2016 and December 2024.

Inclusion and Exclusion Criteria

To ensure relevance and quality, studies were selected based on the following criteria:

Inclusion criteria

- Comparative analysis between diagrid and conventional (moment-resisting or braced) frames.
- Use of structural analysis tools such as ETABS, SAP2000, or STAAD Pro.
- Quantitative results on drift, displacement, base shear, material use, or optimization.
- Focus on mid- to high-rise buildings.

Exclusion criteria

- Studies focusing exclusively on architectural aesthetics without structural evaluation.
- Case studies lacking numerical analysis or simulations.
- Publications without peer review or academic credibility.

Data Extraction and Categorization

From the selected pool of 30 studies, the following data were extracted:

- Study details (author, year, location)
- Structural system analyzed (diagrid, conventional, hybrid)
- Modeling tool used (primarily ETABS)
- Building parameters (height, storey count, material type)
- Performance metrics (roof displacement, inter-storey drift, base shear, material usage)
- Diagrid geometry (angle, spacing, member sizes)
- Key findings and conclusions

Each study was categorized under thematic sections such as:

1. Structural efficiency
2. Seismic performance
3. Comparative studies
4. Alternative systems
5. Optimization and geometry

Analytical Approach

The data were synthesized using comparative tables, trend analysis, and quantitative summaries. Numerical findings across studies were normalized wherever possible to highlight consistent trends, such as:

- Percentage reduction in roof displacement or drift
- Base shear differences between systems
- Optimum range of diagrid angles

No statistical meta-analysis was conducted due to the heterogeneity in building configurations and modeling assumptions across the studies.

Limitations of the Methodology

- Most studies relied on ETABS-based simulation data, with limited experimental validation.
- Variability in building geometries, loading assumptions, and material properties restricts direct comparison.
- Regional code differences (e.g., IS 1893 vs. Eurocode or ASCE standards) may affect generalizability.

Despite these limitations, the structured review methodology provides a coherent synthesis of current knowledge and serves as a foundation for identifying performance trends and research gaps in diagrid structural systems.

DISCUSSION

The collective findings from the reviewed studies point to a clear advantage of diagrid systems over conventional frames in terms of lateral load resistance, seismic safety, and material efficiency. By relying on axial action in diagonal members, diagrids reduce bending moments and shear forces, thereby improving stiffness and controlling displacements. Most studies reported drift reductions between 15% and 25% and displacement reductions of up to 35%. Base shear reductions of 10–18% were also observed in seismic analyses.

From an economic perspective, diagrid structures consistently demonstrated material savings in the range of 10–20% compared to conventional frames. This efficiency translates into reduced costs and lower environmental impact, aligning with global priorities for sustainable construction. Furthermore, diagrid systems facilitate architectural flexibility, enabling unique facades and non-rectilinear geometries.

Despite these advantages, challenges persist. Connection detailing in diagrid systems is complex, as node joints must transfer significant axial forces efficiently. Constructability of large diagrid modules remains another concern, particularly in developing regions with limited fabrication infrastructure. Additionally, while most research relies on ETABS-based numerical modeling, experimental validation through large-scale testing remains scarce.

The reviewed studies also reveal gaps in research on reinforced concrete and composite diagrid systems, which may offer cost and construction advantages in regions where steel is less accessible. Similarly, optimization of diagrid angles and module heights across varying building typologies remains an area requiring deeper exploration.

CONCLUSIONS

This review has consolidated thirty research studies comparing diagrid and conventional building frames, focusing on structural efficiency, seismic performance, and optimization strategies. The findings demonstrate that diagrid systems consistently outperform conventional frames, achieving reductions in drift, displacement, and base shear, while also offering material and cost savings. Optimal diagrid angles in the range of 65°–75° have been identified as particularly effective.

Nevertheless, the challenges of connection detailing, construction complexity, and the need for empirical validation remain. Future research should focus on experimental investigations, the development of performance-based design approaches, and the exploration of RCC and composite diagrid systems. By addressing these gaps, the diagrid structural system can be further optimized to meet the growing demand for tall, safe, and sustainable buildings worldwide. Final Remarks: Incorporating variable wheelbase analysis, realistic dynamic load modelling, fatigue provisions, and optimization frameworks into codal practice can improve both safety and economy. Future research should focus on hybrid codal-FEA frameworks validated by field data, and multi-objective optimization approaches, ensuring gantry girders remain safe, economical, and durable under modern industrial demands.

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