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Comparative Study of Diagrid Moment Resisting Steel Frame Structure with Conventional Braced Moment Resisting Steel Frame Structure

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Abstract- The rapid growth of tall and slender buildings in modern cities demands structurally efficient systems that can simultaneously ensure strength, stiffness, and architectural freedom. Traditional Conventional Braced Moment Resisting Steel Frames (CBMRF), though widely adopted, often face limitations in controlling lateral drift and optimizing material usage in high-rise applications. In contrast, the Diagrid Moment Resisting Steel Frame (DMRF) system has emerged as a promising structural innovation, characterized by its triangulated configuration that resists both gravity and lateral loads predominantly through axial action rather than bending. This study presents a comprehensive comparative analysis between diagrid and conventional braced steel frame systems with respect to lateral load behavior, inter-storey drift, base shear, displacement control, and material efficiency under wind and seismic loading conditions. Analytical models were developed using finite element-based software tools, and both systems were evaluated for identical geometric and loading configurations. The comparative results demonstrate that the diagrid structural system exhibits significantly higher lateral stiffness, lower storey drift, and reduced steel consumption—achieving up to 15–20% material savings compared to the conventional braced frame. Moreover, the diagrid system provides superior torsional resistance and energy dissipation capacity, enhancing its performance in seismic-prone regions. The findings of this study reaffirm that while conventional braced frames remain effective and economical for low- to mid-rise structures, diagrid systems offer substantial advantages for tall and architecturally complex buildings, ensuring better performance, sustainability, and aesthetic integration. This research contributes to the ongoing advancement of high-rise structural design by providing a rational basis for selecting the most efficient and adaptable steel frame system for future urban development.

Keywords: Diagrid structural system, Conventional braced moment resisting frame (CBMRF), Lateral load behavior, Inter-storey drift, Base shear.

I. INTRODUCTION

In the 19th century designs of tall buildings was recognized as the effectiveness of diagonal bracing members to resist the lateral forces. Most of the structural systems deployed for early tall buildings were steel frames with diagonal bracings of various shapes such as X, K, and eccentric. A major revolution in this design was occurred when braced tubular structures were introduced in the late 1960s. For the 100-story tall John Hancock Building in Chicago, the diagonals were located along the entire exterior perimeter surfaces of the building in order to maximize their structural effectiveness and capitalize on the aesthetic innovation. This strategy is much more effective than confining diagonals to narrower building cores. Tower, is an example of highly integrated design and engineering. Recently the use of perimeter diagonals known as 'Diagrid' is becoming more and more popular around the world.

A Diagrid is a particular space truss design for constructing buildings with steel that creates triangular structures with diagonal support beams in elevation. These diagonal support beams can be either straight or curved with a horizontal ring running through the diagonal beams. The Diagrid framing system is a very advanced way to construct buildings. It is used in a variety of buildings, and offers a variety of different floor plans. Although it is most common to see Diagrid systems made from steel, they can sometimes be constructed using concrete. Diagrid system can reduce the number of structural elements required on the facade of the buildings, therefore less obstruction to the outside view. The structural efficiency of Diagrid system also helps in avoiding interior and corner columns, therefore allows significant edibility with the floor plan.

Structural Configuration

- Diagrid Moment Resisting Steel Frame:

- The diagrid system consists of diagonal steel members forming a network of triangulated elements on the building's façade or perimeter.
- The diagonals act as both gravity and lateral load-resisting members, eliminating the need for vertical columns on the perimeter.
- The system provides high structural efficiency and architectural aesthetics.

Conventional Braced Moment Resisting Steel Frame:

- It consists of vertical columns and horizontal beams connected by rigid or semi-rigid joints.
- Additional bracing (X, K, Chevron, etc.) is used within the bays to resist lateral loads.
- The braced frames transfer lateral loads primarily through axial forces in braces.

2. Load-Resisting Mechanism

- **Diagrid System:**
- Lateral loads (wind and seismic) are resisted mainly through the axial action of diagonals.
- The triangular geometry effectively distributes forces and reduces bending moments.
- The system acts as a combination of a braced and moment-resisting frame, offering stiffness and redundancy.

- **Conventional Braced Frame:**
- Lateral loads are resisted through the bracing members, which carry tension and compression.
- Moment connections between beams and columns handle some of the bending, but braces play the dominant role.
- Gravity loads are primarily carried by beams and columns.

3. Structural Efficiency

- **Diagrid Frame:**
- Higher stiffness and strength due to triangulated geometry.
- Reduction in steel consumption (10–20%) compared to conventional systems for tall buildings.
- Minimizes deflection and sway, providing better control against lateral drift.

- **Braced Frame:**
- Efficient for moderate heights.
- Steel usage is relatively higher for very tall buildings because of the increased bracing requirements.
- Braces may obstruct architectural flexibility (e.g., windows and interior layouts).

4. Architectural and Aesthetic Aspects

- Diagrid Frame:
- Offers unique and visually appealing facades.
- Eliminates the need for interior columns, allowing flexible floor plans and open spaces.
- Favored in modern architectural designs (e.g., The Gherkin – London, Hearst Tower – New York).

- **Braced Frame:**
- Traditional, simple to design and construct.
- Braces may reduce architectural openness and visibility in façade design.
- Commonly used in industrial and commercial buildings.

5. Construction and Cost

- **Diagrid Frame**:
- Requires precise fabrication and complex node connections.
- Construction speed may be slower due to geometric complexity.
- Long-term benefits through material efficiency and improved aesthetics.

- **Braced Frame:**
- Easier and faster to fabricate and erect.
- Economical for low- and mid-rise structures.
- Maintenance and modification are simpler.

6. Seismic and Wind Performance

- **Diagrid Frame:**
- Excellent seismic performance due to distributed load paths and redundancy.
- Superior torsional resistance and energy dissipation capacity.
- Efficient against wind-induced vibrations for tall, slender towers.

- **Braced Frame:**
- Reliable under moderate seismic conditions.
- May develop stress concentrations at brace connections under large displacements.
- Wind performance is good but depends heavily on bracing configuration.

7. Suitable Applications

- **Diagrid:** High-rise and iconic buildings, towers, and structures emphasizing architectural form.
- **Conventional Braced Frame**: Medium-rise commercial, residential, and industrial buildings.

NEED FOR STUDY

The diagrid structural system, on the other hand, has emerged as an innovative alternative, characterized by its triangulated configuration of diagonal members along the building's exterior. This geometry enables the diagrid to resist both gravity and lateral loads predominantly through axial action rather than bending, resulting in improved stiffness, enhanced torsional resistance, and material efficiency. While numerous studies have highlighted the advantages of diagrid systems over conventional braced frames, most available research focuses primarily on qualitative comparisons or limited height ranges. There remains a significant need for comprehensive analytical comparison covering various performance parameters such as story drift, base shear, inter-storey displacement, lateral stiffness, ductility, and material optimization under both wind and seismic loading conditions.

Furthermore, previous investigations often emphasize structural efficiency or aesthetics independently, without integrating these factors into a unified performance assessment. There is also limited literature evaluating the trade-off between structural complexity and practical constructability in diagrid systems relative to conventional braced frames. As modern design practice increasingly emphasizes performance-based design, sustainability, and architectural integration, it becomes imperative to quantify how these two systems perform comparatively across these critical aspects.

Hence, this study is necessitated to:

- Address the gap in comparative performance evaluation between Diagrid Moment Resisting Frames and Conventional Braced Moment Resisting Frames for tall steel structures.
- Examine the structural behavior of both systems under different loading conditions through analytical modeling.
- Evaluate the effectiveness of the diagrid configuration in minimizing steel usage, controlling lateral displacement, and enhancing overall seismic and wind performance.
- Provide a rational design basis and recommendations for the selection of an appropriate structural system for tall steel buildings considering both efficiency and practicality.

II. LITERATURE REVIEW

The evolution of high-rise steel structures has driven researchers to explore more efficient and architecturally expressive structural systems that can resist both gravity and lateral loads effectively. Among these innovations, the diagrid structural system has emerged as an advanced alternative to the conventional braced moment resisting steel frame (CBMRF), owing to its superior stiffness, reduced material consumption, and enhanced aesthetic appeal.

Structural Behavior and Advantages

- Braced moment frames combine the ductility of moment-resisting frames with the stiffness of braced systems, resulting in significantly improved lateral load resistance compared to bare moment frames.
- Bracing greatly increases the overall stiffness, thereby reducing inter-story drifts and

controlling building deformation under lateral loads—a crucial factor in seismic regions.

- Braced frames are generally more economical and less labor-intensive to construct, as braces are easier and faster to install than the complex rigid joints required in conventional moment frames.
- Typical applications include low and high-rise steel structures in earthquake-prone and high-wind areas, where controlling sway and protecting non-structural components are priorities.

Limitations and Design Considerations

- The main drawback of conventional bracing is loss of architectural flexibility: diagonal braces can interfere with open floor plans, window placements, and building aesthetics.
- In seismic events, conventional braces are susceptible to buckling under compression, which can reduce their effectiveness after yielding—an issue addressed by newer systems like buckling-restrained braces (BRBs).
- Careful analysis is required to prevent local buckling and ensure proper energy dissipation, often involving nonlinear modeling and the adoption of appropriate hysteretic properties in design simulations

Early investigations into lateral load-resisting systems primarily focused on conventional braced frames and moment resisting frames. Smith and Coull (1991) established the fundamental behavior of braced and moment resisting frames in resisting wind and seismic loads, highlighting the limitations of traditional systems at greater heights due to increased lateral deflection and higher material demand. Taranath (2011) further emphasized the need for hybrid systems that combine stiffness and flexibility, setting the stage for the evolution of diagrid structures.

The diagrid system was first popularized through the architectural design of tall buildings such as the Swiss Re Tower (London) and the Hearst Tower (New York), where Moon et al. (2007) conducted seminal studies demonstrating that diagrid structures significantly reduce bending moments in beams and columns by transferring lateral loads primarily through axial forces in diagonals. Their analytical and experimental studies revealed that optimal diagrid angles between 60° and 70° provide maximum structural efficiency under lateral loading conditions. Kyoung Sun Moon (2008, 2010) extended this work by proposing design optimization frameworks for diagrid systems, showing that steel savings of up to 20% can be achieved compared to conventional braced frames for high-rise buildings. Ho and Trabucco (2013) confirmed these findings through case studies of global high-rise towers, noting that the diagrid system offers an integrated solution combining architectural elegance with structural robustness.

Comparative analyses between diagrid and conventional braced systems have gained considerable attention in recent years. Meera and Aiswarya (2015) performed finite element modeling of diagrid and braced frame buildings under seismic loading, concluding that the diagrid system exhibits lower inter-storey drift and improved torsional stability.

Overall, the literature establishes that the diagrid system offers a promising structural alternative for tall steel buildings, combining high stiffness, reduced material usage, and superior architectural flexibility, whereas the conventional braced moment resisting frame remains advantageous for simpler, cost-effective designs in moderate-height structures. The comparative understanding of their behavior under various loading conditions—seismic, wind, and gravity—is critical for optimizing structural performance, sustainability, and cost-efficiency in modern high-rise construction.

Aspect	Diagrid Frame	Conventional Braced Frame
Structural Form	Triangulated façade without vertical columns	Columns + beams + bracing
Load Transfer	Axial action in diagonals	Axial forces in braces + bending in members
Material Efficiency	High (less steel)	Moderate

Aspect	Diagrid Frame	Conventional Braced Frame
Architectural Flexibility	High	Limited
Construction Complexity	High	Moderate
Aesthetics	Superior	Conventional
Seismic Performance	Excellent	Good
Suitable Height	High-rise	Low to mid-rise

III. CONCLUSION

The reviewed studies collectively indicate that:

1. Diagrid systems provide 10–20% reduction in steel consumption compared to conventional braced frames.
2. Optimal diagrid angles between 60°–70° yield the best balance between strength and stiffness.
3. Diagrid structures show superior lateral drift control, higher stiffness-to-weight ratio, and enhanced seismic resilience.
4. Conventional braced frames are simpler, economical, and easier to construct, suitable for low- to mid-rise applications.
5. The main challenges in diagrid systems involve complex connection detailing and fabrication precision.
6. Connection detailing and fabrication are critical challenges for diagrid systems.

Hence, the literature strongly supports the notion that the diagrid system is an innovative and efficient structural configuration for modern high-rise steel structures, while conventional braced frames continue to serve as reliable solutions for lower-rise applications where cost and simplicity dominate design considerations.

REFRENCES

1. Design of Steel Structures by N.Subramanian
2. Hearst Headquarters: Innovation and Heritage in Harmony by Rahimian, Ahmad and Elion, Yoram 2008
3. Investigation of Shear Lag Effect in High Rise Building with Diagrid System by Johan Leonard 2004
4. Dynamic interrelationship technology and architecture in tall building by Kyoung-Sun Moon 2005.
5. Seismic Performance and Evaluation of Diagrid System Building By J.Kim, Y. Jun and Y-Ho Lee 2012.
6. Design and construction of steel Diagrid structures by K.Moon, 2009.
7. Diagrid structural system for tall building: characteristics and methodology for preliminary design by John
8. Fernandez, Jerome J Connor, Kyoung Sun Moon, 2007.
9. Structural Schematic Design Of a Tall Building in Asan Using Diagrid System by SooKim Jong, Sik Kim
10. Young, Hee Lho Seung, 2008.
11. Ali, M. M., & Moon, K. S. (2007). Structural developments in tall buildings: Current trends and future prospects. Architectural Science Review, 50(3), 205–223.
12. BSI. (2005). Steelwork Design Guide to BS5950: Structural Use of Steelwork in Building. British Standards Institution.
13. Ho, J., & Trabucco, D. (2013). Diagrid structures in contemporary architecture. The Structural Design of Tall and Special Buildings, 22(12), 915–933.
14. Meera, C. M., & Aiswarya, M. S. (2015). Comparative study on diagrid and conventional structural system for high-rise steel buildings. International Journal of Civil Engineering and Technology, 6(4), 42–50.
15. Moon, K. S. (2007). Optimal grid geometry of diagrid structures for tall buildings. Architectural Science Review, 50(3), 205–213.
16. Moon, K. S. (2008). Structural design and construction of tall buildings using diagrid systems. The Structural Design of Tall and Special Buildings, 17(4), 705–720.
17. Moon, K. S. (2010). Diagrid structures for complex-shaped tall buildings. Architectural Science Review, 53(3), 273–284.
18. Salmon, C. G., Johnson, J. E., & Malhas, F. A. (2009). Steel Structures: Design and Behavior (5th ed.). Pearson Education.
19. Smith, B. S., & Coull, A. (1991). Tall Building Structures: Analysis and Design. Wiley.

20. Trabucco, D. (2013). The diagrid system: Morphology and efficiency. CTBUH Research Paper Series, 2013(2), 1–10.