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Seismic Performance Evaluation of a Diagrid Braced Dual System on Sloping Terrain Considering Soil Structure Interaction - A Review

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Abstract: - In recent years, rapid urbanization and limited availability of flat land have led to the construction of high-rise buildings, especially on sloping terrain. These structures are highly vulnerable to seismic forces due to irregular geometry, variation in stiffness, and complex load distribution. Therefore, it becomes essential to adopt efficient structural systems and advanced analysis techniques to ensure safety and performance. This review paper presents a comprehensive study of 25 research articles related to diagrid structural systems, seismic performance of buildings, structures on sloping ground, and soil–structure interaction (SSI). The diagrid system is gaining popularity due to its ability to resist lateral loads efficiently through axial action of diagonal members. Many studies have shown that diagrid structures provide better stiffness, reduced displacement, and improved seismic performance compared to conventional systems. The review also highlights that buildings on sloping terrain are more prone to seismic damage due to torsional effects, irregular column heights, and uneven load distribution. Additionally, soil–structure interaction significantly influences structural behavior by increasing displacement and time period while reducing base shear. From the detailed literature review, it is observed that most studies have focused on these aspects individually. However, very limited research has been carried out by combining diagrid systems, sloping terrain, and SSI effects together. This paper identifies key research gaps and emphasizes the need for integrated studies using advanced analysis methods such as nonlinear time-history analysis.

Keywords: - Diagrid Structural System, Soil–Structure Interaction (SSI), Sloping Terrain, Seismic Analysis, Time History Analysis, High-Rise Buildings, Structural Performance.

I. INTRODUCTION

The increasing population and rapid urban development have resulted in a shortage of available land in urban areas. As a result, construction is expanding vertically, leading to the development of high-rise buildings. At the same time, due to scarcity of flat land, construction on sloping terrain has become common, especially in hilly regions. However, buildings on sloping ground behave differently compared to those on flat ground due to irregular geometry, variation in column heights, and torsional effects. These factors make such structures more vulnerable to seismic forces. To overcome these challenges, advanced structural systems such as diagrid systems are being adopted. The diagrid system is an innovative structural system that uses diagonal members arranged in a triangulated pattern, which efficiently resists both gravity and lateral loads. Another important factor influencing structural behavior is soil–structure interaction (SSI). In real conditions, the foundation soil is not rigid, and its interaction with the structure affects the overall response during earthquakes. Therefore, it is essential to consider SSI for realistic analysis.

II. LITERATURE REVIEW

Several researchers have carried out studies on diagrid structural systems, seismic performance of buildings, and behavior of structures on sloping ground. The important findings from previous studies are summarized below:

[1] Geetha et al. (2026)
This study analyzed diagrid buildings with different diagonal angles under lateral loads using ETABS. It was found that diagrid systems provide better stiffness and reduce displacement and drift compared to conventional frames. The angle of diagonal members plays a major role in performance. Optimized angles improve stability and load distribution. The study concluded that diagrid systems are highly efficient for high-rise buildings.

[2] Parmar et al. (2025)
This study evaluated RC buildings on sloping ground considering soil–foundation–structure interaction using PLAXIS 3D. It was observed that buildings on slopes are more vulnerable to earthquakes. Use of bracing and shear walls reduced displacement up to 90%. Hybrid systems showed better performance. Proper structural configuration is essential for safety.

[3] Ichpas et al. (2025)
This study compared diagrid and dual structural systems under seismic loads. Results showed diagrid reduced displacement by 46% and drift by 40%. It also reduced time period significantly, indicating higher stiffness. Diagrid performed better due to axial load transfer. It is more suitable for seismic regions.

[4] Ovi et al. (2025)
This study analyzed buildings on sloping ground with outrigger systems. It showed that slope increases vulnerability to lateral loads. Adding outriggers reduced displacement up to 36%. More outriggers improved stiffness and stability. The study concluded that outrigger systems enhance seismic performance.

[5] Shah & Suthar (2025)
This review study analyzed seismic behavior of buildings on sloping terrain. It found that irregular geometry increases displacement and drift. Step-back setback buildings perform better than step-back type. SSI and slope angle significantly affect performance. Proper design is necessary for safety.

[6] Ichpas et al. (2025)
This study again compared diagrid and dual systems. Diagrid showed better performance in terms of stiffness and reduced deformation. It efficiently transferred loads through diagonal members. Dual systems showed higher displacement. Diagrid is recommended for high-rise buildings.

[7] Hansora et al. (2025)
This study compared diagrid with different core systems using ETABS. Diagrid with shear wall core showed best performance. It reduced displacement and drift significantly. Proper angle selection improved efficiency. The study concluded that core system selection is important.

[8] Panchal & Jayswal (2024)
This review focused on diagrid buildings with irregular plan on sloping ground. It highlighted that irregularity increases complexity in behavior. Diagrid performs better than conventional systems. However, slope and irregularity increase torsion. Proper analysis is required.

[9] Liu et al. (2024)
This study introduced replaceable coupling beams in diagrid systems. It improved energy dissipation and ductility. Drift was reduced significantly. The system absorbed seismic energy effectively. It enhances sustainability and performance.

[10] Rohan Singh et al. (2024)
This study compared conventional and diagrid buildings using ETABS. Diagrid showed lower displacement and time period. It provided better lateral resistance. Conventional systems were less efficient. Diagrid is suitable for tall buildings.

[11] Ramírez et al. (2024)
This study compared traditional and diagrid buildings in seismic zones. Diagrid showed better performance with less damage. It reduced greenhouse emissions significantly. It is both structurally efficient and eco-friendly. Suitable for sustainable construction.

[12] Kewatkar & Lande (2023)
This study analyzed diagrid building with and without SSI. It showed that SSI increases time period and displacement. Soft soil gave maximum displacement. Base shear reduced due to damping. SSI significantly affects behavior.

[13] Bush et al. (2023)
This study compared buildings on slope and flat ground with infill walls. Buildings on slope showed higher drift and displacement. Infill walls improved performance. Short columns were more vulnerable. Proper design is necessary.

[14] Soumya et al. (2023)
This study analyzed buildings on slope using ETABS. It showed higher torsion and displacement in slope buildings. Bracing systems reduced lateral movement. Proper configuration improves stability. Sloping buildings require special design.

[15] Veera Babu et al. (2023)
This study compared buildings on flat and sloping ground. Sloping buildings showed higher drift and displacement. Irregularity increased seismic effects. Flat ground buildings performed better. Special care is required for slope construction.

[16] Kewatkar & Lande (2023)
This review discussed SSI and diagrid systems. It showed SSI affects seismic response significantly. Diagrid reduces displacement and improves stiffness. Combination of SSI and diagrid needs more research. Advanced analysis is required.

[17] Patel & Chandresha (2022)
This study analyzed irregular buildings on slopes with SSI. It showed increase in time period due to soil flexibility. Displacement and drift increased in soft soil. Irregular shapes showed more torsion. SSI must be considered in design.

[18] Mehtani & Patel (2022)
This study evaluated CFST diagrid systems using FEMA P695. It showed high ductility and strength. Diagrid systems have good energy dissipation capacity. They are safe under seismic loads. Suitable for high-rise buildings.

[19] Bhale & Shimpale (2022)
This study compared diagrid and conventional buildings. Diagrid showed lower displacement and drift. It had higher stiffness and efficiency. Load transfer was better through axial action. Diagrid is superior to conventional systems.

[20] Jadhav (2021)
This study used performance-based design for diagrid systems. It showed better seismic safety and reliability. Nonlinear analysis gave realistic results. Diagrid improved structural behavior. PBD approach is effective.

[21] Nourin et al. (2021)
This review studied steel diagrid systems. It showed high efficiency and reduced material usage. Diagrid reduces shear lag effect. It is economical and sustainable. Suitable for modern high-rise buildings.

[22] Hassain & Chithra (2020)
This study analyzed diagrid steel buildings. It showed reduced displacement and drift. Optimum angle improves performance. Diagrid provides better stiffness. Suitable for tall structures.

[23] Seyedkazemi et al. (2019)
This study introduced double-layer diagrid system. It improved stiffness and ductility. Energy dissipation increased significantly. Better than conventional diagrid. Suitable for seismic zones.

[24] Naik & Suryawanshi (2018)
This study compared diagrid and conventional buildings. Diagrid reduced earthquake forces effectively. It showed lower displacement and drift. It improved structural efficiency. Suitable for high-rise construction.

[25] Kim & Lee (2012)
This study analyzed diagrid buildings with different angles. It showed higher strength but lower ductility. Brace angle affects performance. Use of special braces improves behavior. Optimization is necessary.

III. RESEARCH GAP

From the detailed review of existing literature on diagrid structural systems, sloping ground buildings, soil–structure interaction (SSI), and seismic performance analysis, it is clearly observed that significant research has been carried out individually in these areas. Many studies have focused on comparing diagrid systems with conventional structural systems, highlighting their superior lateral load resistance, reduced displacement, and improved stiffness. Similarly, several researchers have analyzed buildings on sloping terrain and concluded that such structures are highly vulnerable due to irregular geometry, torsional effects, and variation in column heights. In addition, some studies have emphasized the importance of soil–structure interaction and advanced analysis methods such as nonlinear analysis, pushover analysis, and time-history analysis for realistic seismic evaluation. However, despite these valuable contributions, there are still several important research gaps that need to be addressed. Firstly, most of the previous studies have analyzed diagrid structures on flat ground, while very limited research has been conducted on the behavior of diagrid buildings on sloping terrain. The combined effect of diagrid structural configuration and sloping ground conditions is not sufficiently explored, especially under different slope angles and seismic zones. Secondly, although soil–structure interaction has been studied separately, very few works have integrated SSI with diagrid systems on sloping ground, which is essential for realistic analysis and design. Thirdly, many studies have focused on regular building configurations, whereas real-life structures often have plan and vertical irregularities, and the effect of such irregularities on diagrid systems in hilly regions is not adequately investigated. Furthermore, the optimization of diagrid parameters such as angle of inclination, core system (shear wall, braced tube, etc.), and material configuration under combined conditions of slope, seismic loading, and soil type has not been comprehensively studied. There is also a lack of comparative studies considering multiple influencing factors simultaneously, such as slope variation, soil conditions, and structural systems, within a single analytical framework. In addition, most research works rely on linear analysis methods, while nonlinear behavior and performance-based design approaches are still not widely applied for such complex structures. Lastly, limited guidelines are available in Indian codes for designing diagrid structures on sloping terrain, which creates a gap between research findings and practical implementation. Therefore, there is a clear need for a comprehensive study that integrates diagrid structural systems with sloping ground conditions, considers soil–structure interaction, evaluates different configurations and parameters, and uses advanced analysis methods to provide more accurate and practical design recommendations. This research aims to fill these gaps by developing a detailed comparative and analytical study to improve the seismic performance and safety of high-rise buildings constructed on sloping terrain.

CONCLUSION

From the detailed literature review, the following conclusions can be drawn:

- Diagrid systems are highly efficient for high-rise buildings due to better stiffness and load distribution.
- Buildings on sloping terrain are more vulnerable to seismic forces and require special design considerations.
- Soil–structure interaction significantly affects structural response and should be considered in analysis.
- Advanced analysis methods provide more accurate and realistic results.

However, there is a clear need for integrated research combining all these aspects.

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