Review on Nonlinear Seismic Analysis of Normal Structure With Diagrid Structure Using Etabs

Mr. Anirudha Date[1], Dr. R A Dubal[2]
[1]Dept of Civil Engineering
[2]HOD, Dept of Civil Engineering
[1, 2] JSPM Rajarshi shahu college of engineering , Tathawade, Service Rd, Ashok Nagar,
Tathawade, Pimpri-Chinchwad, Maharashtra 411033

Abstract*- Buildings in high-seismic areas must be designed with particular attention to their lateral stability during extreme earthquakes. A modern concept of shifting the vertical column's orientation to a diagonal column aids in the transformation of all forces into axial forces. Diagrid (Diagonal Grid of Columns) is a brand new structural system designed to improve a building's lateral stability. The diagrid structural system's aesthetics and structural advantages have made it a popular option for many buildings around the world, including many prominent high-rise structures constructed in recent years. The nonlinear behavior and design of mid-to-high-rise steel diagrid structures are investigated in this paper. The results are compared to corresponding moment resisting frames and concentrically braced frames in terms of tale drift, time length, base share, and displacement in diagrids. Practical design guidelines are suggested using virtual work/energy diagrams and nonlinear seismic analysis using ETABs for G+7, G+11, and G+16 to improve nonlinear behavior and increase collapse load potential of diagrid structures in high seismic regions.*

Keywords- Diagrid building, Seismic, Response spectrum analysis.

I. INTRODUCTION

The word earthquake may be used to define any kind of seismic phenomenon that produces seismic waves, whether normal or caused by humans. Earthquakes are usually induced by seismic fault rupture, although they may also be sparked by volcanic activities, mine explosions, landslides, and nuclear testing. Many structures have primary construction systems that do not fulfill existing seismic standards and are severely damaged during an earthquake. India is divided into four zones based on seismic operations, according to the Seismic Zoning Map of IS: 1893-2002. Zones II, III, IV, and V are the four zones. Some companies construct full-scale models and do extensive research before mass-producing thousands of similar systems that have been studied and engineered with test outcomes in mind. Unfortunately, the construction industry may not have this choice, making large-scale creation unfeasible. Many current structures in India are built according to Indian standard code 456:2000, but in order to render buildings earthquake prone, IS 1893-2002 should be included.

In certain cases, the only loads acting on these systems are gravity loads, resulting in elastomeric structural behavior. However, in the case of a strong earthquake, a system can be exposed to forces that exceed its elastic limit. After the last earthquake in the last four decades, in which several concrete structures were severely weakened or destroyed, it has been essential to assess the seismic suitability of existing or planned structures. As a result, the structure's susceptibility to harm must be calculated. Simplified linear elastic approaches are not ideal for achieving or achieving this goal. As a result, structural engineers have devised a novel modeling approach and seismic protocol that incorporates performance-based structures and nonlinear techniques.

A. Diagrid Concept

The diagrid (a portmanteau of diagonal grid) is a structure for building and roof design that consists of diagonally intersecting metal, concrete, or wooden beams. In comparison to a traditional steel frame, it uses less structural steel. The diagrid structural system can be defined as a diagonal members formed as a framework made by the intersection of different materials like metals, concrete or wooden beams which is used in the construction of buildings and roofs. Diagrid structures of the steel members are efficient in providing solution both in term of strength and stiffness. But nowadays a widespread application of diagrid is used in the large span and high rise buildings, particularly when they are complex geometries and curved shapes.The diagonal member of the diagrid carries both shear and moment. So the optimal angle of placing of the diagonals is dependent of building height. The optimal angle of the columns for maximum bending rigidity in the normal building is 90 degree and for the diagonals for shear rigidity is 35 degree. It is assumed that the optimal angle of the diagrid falls in between the both. Usually adopted range is 60 -70 degree. As the height of the building increases the optimal angle also increases.

Fig 1 Diagrid Structure

II. STATE OF DEVELOPMENT

Giulia Milanaetal. (2015) The aim of this research is to evaluate the robustness of a tall diagrid structure. The aim is to determine whether gains in terms of sustainability have a detrimental effect on the structure's structural robustness. Different failure conditions are compared numerically and the results are presented. The diagrid (diagonal grid) structural structure is one of the most evocative designs for tall buildings. Because of its aesthetics and structural efficiency, diagrid (with perimeter structural configurations) has emerged as a new design trend for tall-shaped complex structures. It is a more sustainable structure since it uses less structural steel than a traditional steel frame.[7]

Seyed Saeid Tabaeeetal. (2015) The rising urban population and its demand on limited urban space has affected the construction of city dwellings, according to this paper. The high cost of property, as well as plans to discourage the construction of short buildings and modern architecture, has resulted in an increase in the number of tall buildings in urban areas. In comparison to the gravity load bearing mechanism, the resisting system against lateral forces becomes more critical as a structure rises. Moment frame, braced frame, dual frame, shear wall, outrigger system, and other lateral force resisting mechanisms are all commonly used. In recent years, designing engineers have embraced diagrid diagonal networks - as a structural framework for tall buildings, owing to the structural efficiency and aesthetic architectural potential provided by the geometric configuration of the components. The diagrid system is a type of space truss that is unique. This structural framework is made up of triangular space trusses that form peripheral networks.[6]

KiranKamath et al. (2016) The efficiency characteristics of diagrid structures were investigated using nonlinear static pushover analysis in this research. The models investigated are circular in plan, with an aspect ratio of H/B ranging from 2.67 to 4.26 (where H is the overall height and B is the structure's base width). 59°, 71°, and 78° are the three different angles of external brace regarded. The structure's height is varied in accordance with the width of the foundation, which is held unchanged at 12m. Plastic hinges based on the moment-curvature relationship as defined in FEMA 356 guidelines are used to model the elements' nonlinear behavior. Nonlinear static analysis was used to determine the seismic reaction of the system in terms of base shear and roof displacement corresponding to the output stage, and the findings were contrasted. All of the aspect ratios considered in the analysis indicate an improvement for the 71° brace angle model base shear at output. The brace angle and aspect ratio have an impact on the structure's efficiency.[14]

Deepak NathujiKakadeetal. (2017) This paper presents an analysis of a 32-story diagrid structural structure without a vertical column across the periphery building. Here is a comparison of the study results in terms of storey displacement and storey drifts for them. Tall buildings have traditionally served as industrial office buildings. Since then, other uses such as retail, mixed-use, and hotel tower projects have exploded. Economic considerations, aesthetics, infrastructure, urban legislation, and politics all play a role in tall building growth. The most important governing principle has been economics. The structural architecture of a very tall building is normally controlled by its lateral stiffness.[15]

Roham Afghani Khoraskani etal. (2018) The lower and upper floor plans' various geometries and dimensions, as well as the method of shape generation that determines the building's ascending development from base to top, resulted in 49 architectural schematic forms. The produced architectural forms are later mapped with diagrid members of identical steel tubular section as the framework of the tall buildings. The structure is then subjected to lateral loads that reflect analogous static behavior, and a static linear analysis is performed. Finally, the findings show that the structural behavior of initial models is largely determined by the base floor plan rather than other parameters, and that architectural models with a higher side count have a higher structural performance.[1]

U. A. Nawale et. al. (2018) In this article, Etabs and SAP software are used to compare storey drift and base shear of 32-story diagrid structural framework with or without vertical column around periphery building and simple frame building. Here is a comparison of the results of the study in terms of storey drift (as per IS 1893-2000) and base shear. The lateral loads caused by earthquakes and wind force have an effect on the design of high-rise buildings. Wall frame, shear wall, braced tube system, and outrigger system are examples of lateral load resistance systems. Because of its structural strength, the diagonal grid design is commonly used in steel buildings or tall buildings. It's a vertical bracing device with a triangulation configuration that transfers load. As far as the construction of a tall building is concerned, storey drift and displacement are the most significant factors. [2]

EsmaeelAsadiet. al. (2018) This paper presents a detailed 12 investigation of the performance of steel diagrid structures in order to assess their core seismic 13 performance factors. Nonlinear static, time-history dynamic, and gradual dynamic are three types of dynamic. In a high 15 seismic zone, 14 analyses are used to evaluate diagrid output and collapse mechanisms. Four different methodologies are used to quantify seismic output factors such as reaction adjustment factor, ductility factor, over strength factor, and deflection amplification factor. Four archetype classes of diagrid buildings with heights ranging from four to thirty floors have been studied. For steel diagrid frames with 8 to 30 stories, a R factor of 4 to 19 5 is recommended unless 20 supplementary analyses are performed to find the optimal diagonal angle. An R factor of 3.5 to 4 is recommended for low-rise 21 steel diagrids (under 8 stories). 22 Furthermore, a 2.5 and 2 over strength and ductility is recommended. The groundwork for using steel diagrids in design provisions is laid out in this document. [3]

Aida Mirniazmandanet. al. (2018) This is an academic paper. The diagrid structural system is currently very common among engineers and architects because of its structural efficiency and versatility in architectural planning. Since architects and engineers may use architectural and structural parameters to create more productive buildings, The aim of this study is to see how different geometric base and top plan configurations of tall buildings, as well as the angle of the diagrid framework, affect the total weight of structural elements per unit area and the horizontal displacement of the top floor in order to design efficient tall buildings (both minimized). To achieve this, the number of sides at the base and top plans are randomly increased, resulting in 64 parametric models with different cross-sectional shapes and a height of 180m. For varying angles of diagonal members, the created models are produced. Modeling is done with Rhino software and its plug-in Grasshopper, and structural analysis is done with Grasshopper's plug-in Karamba. Genetic algorithm-based optimization is used to find the best models. Finally, the optimum bound for diagrid angle is found to be between 53° and 70°, and the performance of buildings with diagrids that have the optimum diagonal angles increases as the number of polygonal cross-sections increases.[4]

Yue Liet. al. (2018) Using static, time-history reactive, and gradual dynamic studies, this paper provides a thorough inquiry into the nonlinear performance of steel diagrid frameworks. The ASCE/SEI 41-13 and FEMA P-58 performance-based assessment approaches are used to establish a system for seismic performance assessment and loss estimation of steel diagrid buildings. The seismic failure of archetype diagrid buildings is estimated using illustrative and quantitative criteria for diagrid frame efficiency and damage assessment. The diagrids are found to have a high degree of lateral stiffness and collapse capability. However, the non-structural loss caused by stiff diagrid frames' high maximum absolute floor acceleration can have an adverse effect on the estimated total loss. The corner diagonal members are the main elements in their action due to the shear lag effect. Building height, diagonal angle, and incomplete diagrid modules are also investigated for their impact on efficiency and loss.[8]

EsmaeelAsadi at el. (2018) The nonlinear behavior and architecture of mid-to-high-rise steel diagrid structures was investigated in this article. Steel diagrids are analyzed and compared to corresponding moment resisting frames and concentrically braced frames in terms of weight, storey drift, fundamental time, lateral stiffness, and sequence of plastic hinge forming. Practical architecture recommendations are suggested utilizing simulated work/energy diagrams and nonlinear static analysis to enhance the nonlinear behaviour and increase the failure load potential of diagrid structures in high seismic regions. The diagrid method has mostly been used in the construction of tall buildings with a height of 20 to 100 meters. The diagrid system may also be a powerful and cost-effective structural system for mid-rise buildings in the 8-15-story range, according to the findings of this study.[10]

VishalkumarBhaskarbhai Patel et al.(2019) The comparison of various forms of lateral load resisting systems is discussed in this article. The thesis is primarily concerned with evaluating the most efficient and cost-effective systems for resisting lateral loads such as wind and seismic loads. Conduct a comparative analysis of different lateral load resisting structures such as Shear wall, Belt Truss, Outrigger, Belt Truss + Outrigger, Diagrid, Staggered Truss, and Tube in Tube framework of a 10-story building with a plan size of 18m X 18m based on a literature examination. Static earthquake forces, dynamic earthquake forces (Response Spectrum analysis as per guidelines of IS: 1893-(Part 1) 2016), static wind forces as per IS: 875 (Part-3)-2015, and design based on IS: 800-2000 were all analyzed using ETABS-2017. It was discovered that storey displacements and storey drifts are less in diagrid systems in X direction.[9]

Vimlesh V. Agrawal at el.(2019) In this article, land scarcity stifled horizontal progress, leading to the evolution of the town's vertical growth, which culminated in the construction of tall buildings. Fazlur Khan pioneered the design of tall buildings in the early 1960s. Tall buildings were able to get off the ground thanks to various structural systems, although advancements in material and building technology hastened their progress. The major force that influences the construction of tall buildings is the lateral load caused by wind and earthquakes, which is primarily resisted by either an exterior or an internal structural framework.[11]

Alejandro Palacio Betancur et. al. (2020) The creation of various structural structures to ensure protection and serviceability against natural hazards has resulted from the study of high-rise buildings. Thanks to their high lateral stiffness and architectural potential, diagrid structures are a new trend in tubular high-rise buildings. Since the system's geometric flexibility allows for a wide range of element layouts that result in variations in the stiffness of each storey, determining an optimum configuration is critical for the design of these structures. Existing design codes and provisions do not provide precise guidance for diagrid structural structures, but there are many studies in the literature that use simplified calculation methods to provide design aids to engineers working with preliminary designs.[5]

VishalkumarBhaskarbhai Patel at el. (2020) The thesis is primarily concerned with evaluating the most efficient and cost-effective method for resisting lateral loads such as wind and seismic loads. Conduct a comparative analysis of different lateral load resisting structures such as Shear wall, Belt Truss, Outrigger, Belt Truss + Outrigger, Diagrid, Staggered Truss, and Tube in Tube framework of a 10-story building with a plan size of 18m X 18m based on a literature examination. Static earthquake forces, dynamic earthquake forces (Response Spectrum analysis as per IS: 1893-) and static wind forces as per a nd design based on IS: 800-2000 were all analysed using ETABS-2017. It was discovered that storey displacements and storey drifts are less in Diagrid systems in the X Direction as compared to other lateral directions.[12]

Snehal V. Mevada at el.(2020) The main topics covered in this paper are the design of Core and Outrigger structural systems using ETABS tools, link design between RCC core and steel framework, seismic analysis compared with standard moment resisting framed RCC building, and cost efficiency analysis comparison with framed RCC building. This structure is built in such a way that more forces are drawn to the building's central core and fewer forces are borne by the building's perimeter. This device was often used for a building of medium height, in addition to tall structures.[13]

III. CONCLUSION

This paper focuses only on the literature review of previously published studies. The gap findings of this study different geometric base and top plan configurations of tall buildings, as well as the angle of the diagrid framework, affect the total weight of structural elements per unit area and the horizontal displacement of the top floor in order to design efficient tall buildings.The optimum bound for diagrid angle is found to be between 53 and 70, and the performance of buildings with diagrids that have the optimum diagonal angles increases as the number of polygonal cross-sections increases.If the number of polygonal cross-sections goes up, the efficiency of the building with diagrid system increases.There are numerous possibilities for future work in this issue such as; the variation of steel sections can be studied. Concrete can be used for diagrid cross sections.

REFERENCES

[1] Rofooei, F. R., & Seyedkazemi, A. (2020). Evaluation of the seismic performance factors for steel diagrid structural systems using FEMA P-695 and ATC-19 procedures. In Bulletin of Earthquake Engineering (Vol. 18, Issue 10). Springer Netherlands. https://doi.org/10.1007/s10518-020-00876-2
[2] Counter, H., Neural, P., Model, D., Design, S., Of, O., & Structures, D. (2020). Hybrid Counter Propagation Neural Dynamic Model for. September, 1–12.
[3] Patel, K., Patel, P. V., & Mevada, S. (2020). Design and Analysis of Core and Outrigger Structural System. June, 3026–3033.
[4] Patel, V. B., & Mevada, S. V. (2019). Comparative Study of Diagrid Structure With Other Structural. June 2020. https://doi.org/10.5281/zenodo.2653613
[5] Asadi, E., Li, Y., & Heo, Y. (2018). Seismic Performance Assessment and Loss Estimation of Steel Diagrid Structures. Journal of Structural Engineering, 144(10), 04018179. https://doi.org/10.1061/(asce)st.1943-541x.0002164
[6] Asadi, E., & Adeli, H. (2018). Seismic performance factors for low- to mid-rise steel diagrid structural systems. Structural Design of Tall and Special Buildings, 27(15). https://doi.org/10.1002/tal.1505
[7] Mirniazmandan, S., Alaghmandan, M., Barazande, F., & Rahimianzarif, E. (2018). Mutual effect of geometric modifications and diagrid structure on structural optimization of tall buildings. Architectural Science Review, 61(6), 371–383. https://doi.org/10.1080/00038628.2018.1477043
[8] Patel, V. B., & Agrawal, V. V. (2018). Parametric Study of Diagrid Structures Subjected To Seismic Parametric

Study of Diagrid Structures Subjected To Seismic. July 2020.

[9] P. Kazemi, R. Afghani, M. T. (2017). Investigating the Effect of Architectural Form on the Structural Response of Lateral Loads on Diagrid Structures in Tall Buildings. The 5 Th International Conference on Architecture and Built Environment with AWARDs Book of Abstracts, June, 25.

[10] Nawale, U., Technology, D. K.-J. of S., & 2017, undefined. (2017). Comparative Analysis of Storey Drift and Base Shear Using E-TAB and SAP Software: Diagrid Structure. Matjournals.In, 2(3), 1–5. http://www.matjournals.in/index.php/JoST/article/view/2067

[11] U.A, N., & D.N, K. (2017). Analysis of Diagrid Structural System by E-Tab. Iarjset, 4(6), 193–196. https://doi.org/10.17148/iarjset.2017.4634

[12] Kamath, K., Hirannaiah, S., & Noronha, J. C. K. B. (2016). An analytical study on performance of a diagrid structure using nonlinear static pushover analysis. Perspectives in Science, 8, 90–92. https://doi.org/10.1016/j.pisc.2016.04.004

[13] Paper, C. (2015). Scenario Based Structural Robustness Assessment of. October 2016.

[14] Paper, C., Engin, E., Engin, E., & Engin, E. (2015). Evaluation of Hybrid Diagrid Structural System Behavior in Tall Buildings Evaluation of Hybrid Diagrid Structural System Behavior in. April 2016. https://doi.org/10.13140/RG.2.1.4785.3280