Progressive Collapse Analysis of RCC Diagrid Structure By Using Pushover Analysis

Amit Bhosale[1], Prof.Rahul S. Patil[2]
[1]Dept of Civil Engineering
[2]Assistant Professor, Dept of Civil Engineering
[1, 2] A Deogiri Institute of Engineering and Management Studies, Aurangabad, Maharashtra, India

Abstract- *The increasing frequency of seismic events in regions like India emphasizes the need to assess the seismic resilience of structures. This study focuses on the progressive collapse analysis of RCC (Reinforced Cement Concrete) diagrid structures, specifically using pushover analysis, a nonlinear static method to evaluate building performance under seismic loading. Pushover analysis accounts for material and geometric nonlinearities, offering a deeper understanding of structural behavior beyond the elastic limit, particularly when subjected to extreme seismic forces. The research compares RCC diagrid structures with conventional buildings (G+7, G+11, and G+16 configurations) to analyze their seismic performance. The findings highlight that diagrid structures exhibit improved lateral stability, reduced displacement, and better force distribution during seismic events. This study contributes to the development of more resilient and cost-effective earthquake-resistant designs, ultimately enhancing safety and sustainability in seismic-prone areas.*

Keywords- DiaGrid building, earthquake forces, time history analysis.

I. INTRODUCTION

The increasing frequency of seismic events underscores the importance of assessing the seismic resilience of structures, especially in earthquake-prone regions like India. Earthquakes, whether caused by natural faults, volcanic activities, or human-induced factors, can severely impact buildings not designed to withstand such forces. In India, buildings are constructed based on the standards set by IS 456:2000 and IS 1893-2002, with seismic zones ranging from II to V, indicating varying degrees of earthquake risk. However, many existing buildings do not meet the seismic standards outlined in IS 1893-2002, leaving them vulnerable to collapse during strong earthquakes.This research focuses on the progressive collapse analysis of RCC (Reinforced Cement Concrete) diagrid structures using pushover analysis. Pushover analysis is a nonlinear static procedure used to evaluate the performance of buildings under seismic loading, accounting for material and geometric nonlinearities. It enables engineers to understand the structural behavior beyond the elastic limit, particularly when forces exceed the yield stresses of materials. This study aims to explore the effectiveness of pushover analysis in predicting the behavior of diagrid structures during an earthquake, which is crucial for improving earthquake-resistant designs.

One such method is pushover analysis, a nonlinear static approach that evaluates a building's response under increasing lateral loads until it reaches a predefined failure state. This research focuses on the progressive collapse analysis of RCC diagrid structures using pushover analysis, a technique that can predict the behavior of structures beyond the elastic limit, especially when subjected to extreme seismic forces. Pushover analysis allows for the integration of material and geometric nonlinearities, providing a more realistic representation of a structure's performance during earthquakes. This method helps engineers determine the collapse mechanisms of buildings and identify vulnerable points that could compromise structural integrity.By using pushover analysis, this research aims to provide a deeper understanding of the behavior of diagrid structures during seismic events. The goal is to develop more effective strategies for designing earthquake-resistant buildings that ensure safety and sustainability in earthquake-prone areas. This study contributes to improving the performance-based seismic design protocols and provides valuable insights for future construction practices.

1.1 Diagrid Structure

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. Sir Norman Foster's proposal for the Hearst Tower in New York City uses 21% less steel than a conventional structure. The diagrid eliminates the need for columns and can be used to create massive roofs with no columns. 30 St Mary Axe, also known as "The Gherkin," is another legendary building built by Sir Norman Foster that employs the diagrid device.

Figure 1: Diagrid Structure

Vladimir Shukhov, the Russian genius, is without a doubt the inventor of 'diagonal' constructs. He developed modern scientific approaches in a variety of areas, and I've had the pleasure of visiting several of his completed ventures many times. Shukhov, as the leading engineer and mathematician during the late 19th and early 20th centuries, developed hyperboloid, thin shell, and tensile frameworks of exceptional refinement and beauty, left a lasting legacy to early Soviet Russia constructivism.

II. RELATED WORK

Sheikh et al. (2021) examined the progressive collapse response of low-rise RCC structures using both load-controlled and displacement-controlled methods. Their study of 2-storey and 3-storey frames located in high seismic zones found that the displacement-controlled method offers more reliable predictions of collapse behavior, accurately simulating hinge formations and joint movements. They emphasized the importance of adopting U.S. General Services Administration (GSA) guidelines for preventing progressive collapse and suggested the inclusion of target displacement predictions in future codes to improve structural resilience in earthquake-prone regions. **Panwar & Rai (2023)** conducted a comparative analysis of conventional RCC structures and diagrid systems in U-shaped building plans located in seismic zones II and III. Using ETABS, they analyzed G+3, G+11, and G+19 storey buildings under dynamic loads. Their findings showed that diagrid structures exhibit superior lateral load resistance, as the diagonal grid system redistributes forces through axial actions, reducing bending moments. Additionally, diagrids offer material optimization, with up to 20% less steel usage while maintaining stability. The study also noted the effectiveness of diagrids in mitigating torsion and stress concentrations during seismic events. **Date & Dubal (2021)** focused on the nonlinear seismic performance of RCC diagrid structures in high seismic zones. Their study on G+7, G+11, and G+16 storey diagrid buildings used pushover and time history analysis to evaluate seismic response. The results showed that diagrid structures significantly reduce story drift and displacement under high-frequency ground motion. The study highlighted the importance of the diagonal angle in diagrid systems, recommending an optimal range between 60° and 70° depending on building height. The findings emphasize diagrid structures' potential to improve seismic stability while offering aesthetic and functional benefits.

Vidhate& Sayyed (2021) explored the impact of incorporating soft stories at different levels in multi-storey buildings on seismic performance. Using ETABS for nonlinear static (pushover) analysis, they examined base shear, lateral displacement, and hinge formation in buildings with soft stories. The study found that soft stories make buildings more vulnerable to collapse during earthquakes due to abrupt stiffness changes. However, proper placement of soft stories can reduce seismic vulnerability by allowing controlled energy dissipation and deformation. The study recommended reinforcing critical areas with shear walls to enhance seismic stability and improve energy absorption. **Ramkumar et al. (2024)** evaluated the seismic performance of an RCC G+2 healthcare building using pushover analysis. The study aimed to determine the performance point, representing the maximum lateral displacement the building could sustain before collapse. The analysis incorporated incremental lateral loads and monitored hinge formation. The research emphasized the importance of time-history analysis in predicting seismic demands accurately for healthcare facilities located in seismic zone-3 regions. The findings suggested adopting performance-based design strategies to improve ductility and redundancy, ensuring better safety and serviceability of healthcare buildings during major earthquakes. **Javaid & Verma (2022)** studied how secondary buckling-restrained braces (BRBs) could enhance the seismic resistance of diagrid structures. Using dynamic analysis in ETABS, they modeled 50-storey diagrid buildings with regular and irregular geometries. The study found that X-arranged BRBs improve seismic performance by reducing the building's time period by 10%, story drift by 20%, and displacement by 25%. The research highlights that optimal bracing configurations significantly reduce seismic vulnerability and improve stability, making diagrid systems more resilient against strong ground motions.**Takle et al. (2021)** explored the seismic behavior of G+41 storey diagrid buildings under lateral loads using response spectrum analysis in ETABS. They found that diagrid systems, characterized by diagonal grids without vertical columns, perform better than conventional frames in seismic zones. The study showed that diagrids' efficient axial load transfer reduces storey displacement, and their architectural flexibility enhances stiffness. The research suggests that the optimal angle of the diagonal members is crucial to improving stiffness and reducing displacement, making diagrids a robust solution for high-rise buildings in seismic regions.

Haq & Agarwal (2019) analyzed the progressive collapse potential of regular and irregular 20-storey RC frame buildings using SAP2000. Irregularities were introduced through stepped geometry, and the study assessed vulnerability using Demand Capacity Ratio (DCR) and plastic hinge formation. The research showed that irregular buildings with stepped geometries are more susceptible to collapse due to load redistribution. It emphasized the importance of improving redundancy and providing alternative load paths to prevent progressive collapse. The study also recommended enhancing the design of irregular buildings to ensure structural stability during critical load redistribution. **Patel & Pasha (2023)** investigated the seismic performance of a G+15 RCC building with a diagrid system under lateral loading in seismic zones IV and V. The study found that the diagrid system, which uses axial action to manage both gravity and lateral forces, significantly reduces base shear, story drift, and displacement. The research showed that optimal diagonal angles in the diagrid structure provide superior structural stability, with reduced material use. The study highlighted that diagrids offer an efficient solution for modern high-rise buildings, combining structural stability with aesthetic flexibility. **Jeyanthi & Mohan Kumar (2016)** evaluated the progressive collapse behavior of a G+8 RCC educational building by simulating column failure using pushover analysis. The study followed the General Services Administration (GSA) guidelines and analyzed the formation of plastic hinges and the Demand Capacity Ratio (DCR). The findings showed that critical columns play a significant role in maintaining structural stability, and their failure leads to disproportionate collapse. The study recommended designing buildings with alternate load paths and increased redundancy to prevent progressive collapse under seismic conditions.

Yadav & Malviya (2019) reviewed the effects of diagrid and hybrid diagrid systems on tall structures. The study found that diagrids, characterized by diagonal members, enhance seismic performance by transferring loads through axial forces rather than bending moments. The review covered multiple case studies, illustrating how diagrid configurations optimize material usage, reduce obstructions in the building façade, and improve structural performance. The study highlighted the advantages of diagrids in terms of stability and energy dissipation, especially during seismic events. **Nikham& Dubal (2021)** evaluated the progressive collapse behavior of a G+5 RCC framed building subjected to critical column removal scenarios. Using pushover analysis in ETABS, the study analyzed the effects on base shear, lateral displacement, and hinge formation. The results emphasized that critical column failure leads to collapse unless sufficient alternative load paths are provided. The study recommended design strategies to ensure uniform stiffness across stories and to enhance load distribution, which would prevent disproportionate collapse under seismic loads. **Brunesi et al. (2015)** conducted a fragility-based risk assessment of low-rise reinforced concrete structures under progressive collapse scenarios using incremental dynamic analysis. The study used fiber-based finite element models and Monte Carlo simulations to account for uncertainties in structural capacity and load intensity. The results showed that seismic detailing significantly enhances structural robustness, reducing the risk of collapse during column removal. The study emphasized the importance of probabilistic modeling for assessing vulnerability and improving the resilience of structures against progressive collapse.

III. METHODOLOGY

The methodology for this study involves analyzing the seismic response of RCC buildings with square diagrid structures using a systematic approach. The project begins with defining the problem and designing models for G+7, G+11, and G+16 storey buildings, considering factors such as seismic zone (III), floor height (3.6 m), and diagrid angle (67.4°). A literature review is conducted to gather primary data, followed by the establishment of the issue statement. ETABS software is chosen for structural analysis, providing an interactive platform to input material properties, loads, and structural elements. The analysis steps include defining plan grids, assigning materials, loads, and restraints, and running simulations to obtain dynamic responses like storey shear, drift, and displacement. The results are evaluated to assess the efficiency of diagrid structures, with a focus on improving stability and seismic resistance, ultimately offering valuable insights for optimizing modern building designs in seismic regions.

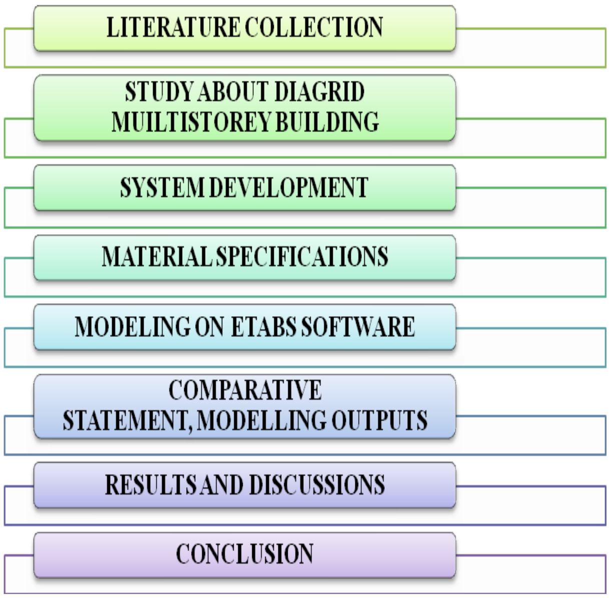


Figure2: Methodology

3.1 Software Analysis and Design Procedure

The software analysis and design procedure begins by defining the plan grids and story data, which sets the foundation for the structural layout. Material properties are then defined, specifying the characteristics of the construction materials used. Frame sections and slab sections are established to model the structural components. Load cases are defined to simulate various load scenarios. Next, beam and column objects are drawn to represent the frame members, followed by assigning slab sections and restraints to ensure structural integrity. Slab loads are assigned, and the input data is reviewed in tabular form. The analysis is then run, and the results are viewed graphically. Finally, the concrete frame elements are designed based on the analysis results. This process ensures accurate modeling, efficient analysis, and optimal design for structural stability.

The following flow chart shows the steps involved in the analysis by Software:

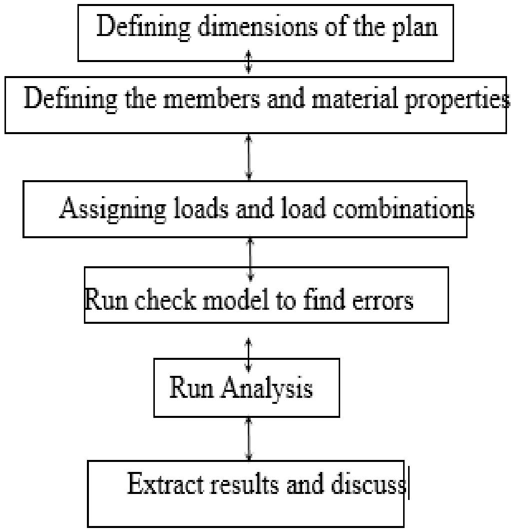


Figure 3: Steps in Analysis of Structure

3.2Experiential Output from Etabs

Storey shear, storey drift, storey displacement, time frame, Base shear, Base moments, storey displacement, and other dynamic responses of these buildings

1. Shears from Storey

Storey shear is the seismic energy that must be exerted at each floor level. At - floor stage, it is a fraction of the overall dead load and a portion of the live load.

2. Storey sway

The disparity in displacements for two successive stories separated by the height of that tale is known as storey drift.

3.The Basic Natural Building Period

Any structure has a set of natural frequencies at which it provides the least amount of resistance to shaking caused by external forces (such as earthquakes and wind) as well as internal forces (like motors fixed on it). A Natural Mode of Oscillation is made up of these natural frequencies and the resulting deformation shape of a house.

4.Shear at the base

Base shear is a calculation of the overall expected lateral force at the base of a system owing to seismic ground motion.

5.Moments of foundation

The base moment is the moment formed at the structure's base as a result of various loading conditions.

6.Displacement of Storey

"This is the displacement of a storey with respect to the base of a building," says the definition.

3.3 Problem Statement

The planned work's plan area is 18 x 18 m, with panels measuring 3x3 m for traditional with square diagrid buildings, and related areas considered for various levels. G+7, G+11, and G+16.

Design parameters used for Study-

- Seismic Zones: III • Models: G+7, G+11, G+16
- 3.6 m floor height
- Both configurations have the same grid configuration: a square 3 x 3 grid.
- Diagrid angle: 67.4°
- The plan is 18X18 inches in dimension.
- Column dimensions: 500mm x 500mm
- Beam dimensions: 300mm x 500mm
- Slab thickness: 125 mm
- Diagonals Dimensions: 300X500 mm
- M30 is the concrete grade.
- Steel grade: Fe 500

IV. MODELLING

This section presents the modeling of three building configurations (G+7, G+11, and G+16) using ETABS software. Two types of structural designs are analyzed for each configuration: the conventional normal building and the innovative diagrid building. The diagrid system, characterized by its diagonal grid pattern, is designed to provide enhanced lateral stability compared to the traditional frame structure.

4.1 Modeling in Etabs

Model 1 – G+7	Normal Building
	Diagrid Building
Model 2 – G+11	Normal Building
	Diagrid Building
Model 3 – G+16	Normal Building
	Diagrid Building

Modeling G+7

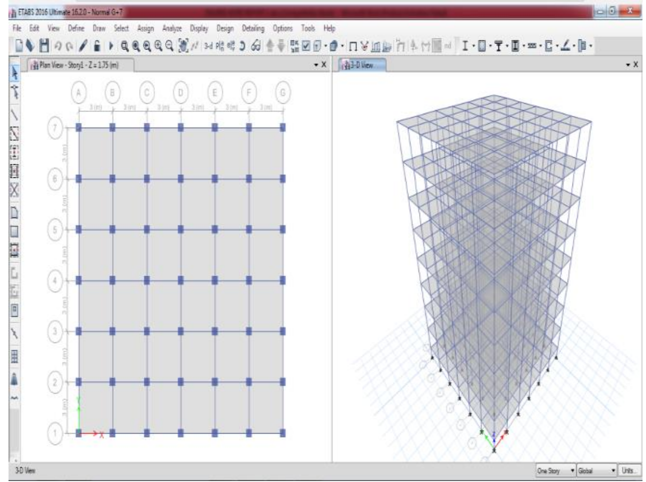


Figure 4: Normal Building G+7

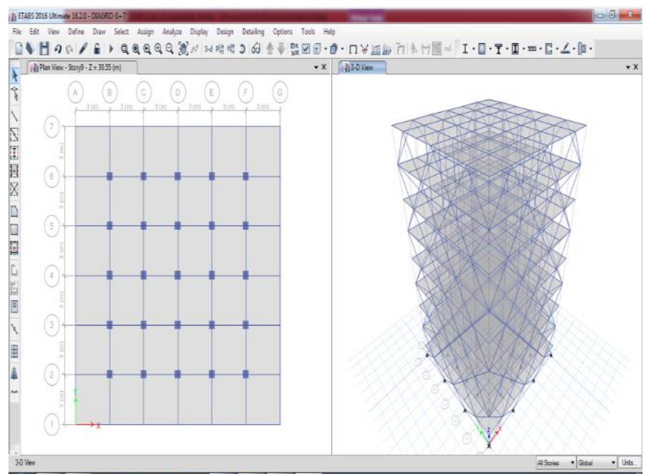


Figure 5: Diagrid Building G+7

Modeling G+11

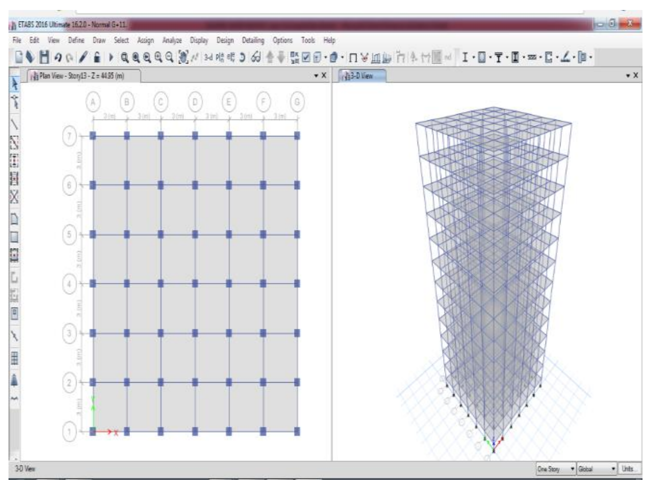


Figure 6: Normal Building G+11

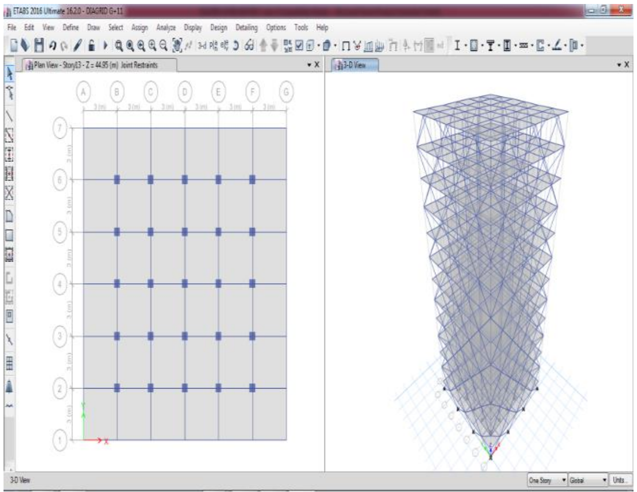


Figure 7: Diagrid Building G+11

Modeling G+16

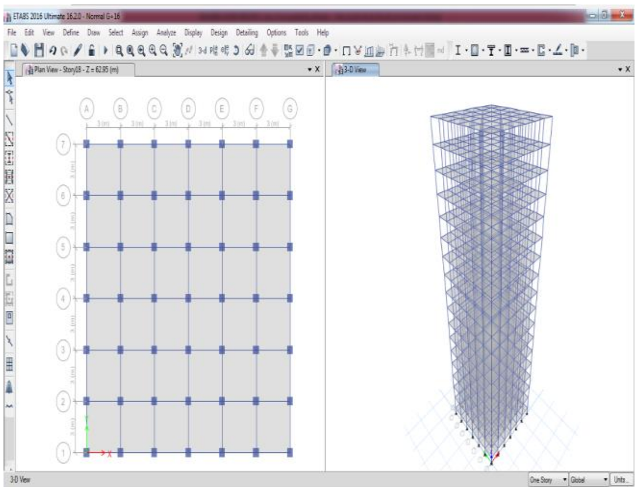


Figure 8: Normal Building G+16

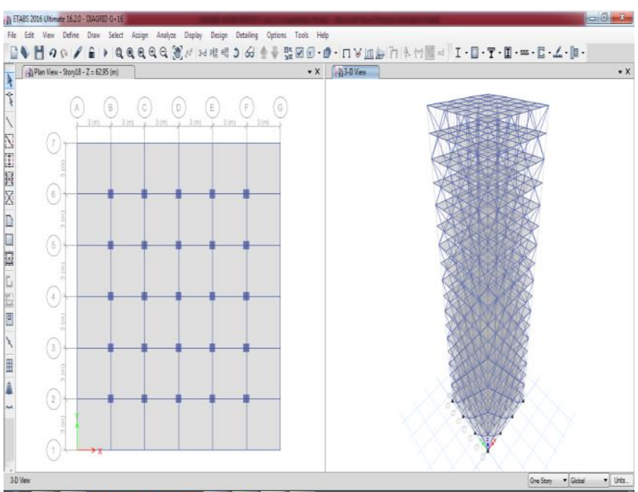


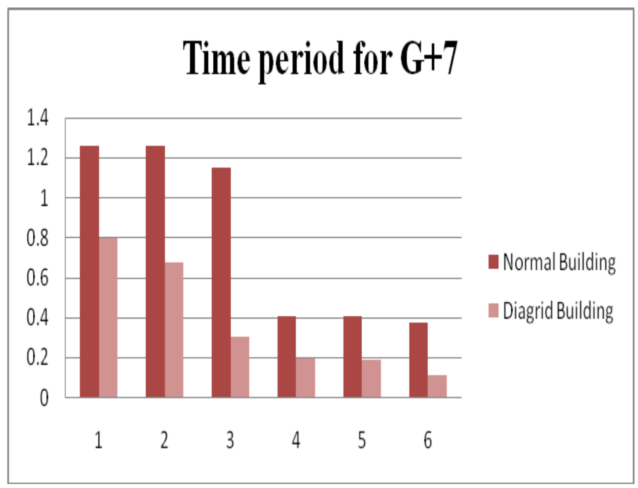
Figure 9: Diagrid Building G+16

V. RESULTS AND DISCUSSION

This section presents and discusses the analysis results for G+7, G+11, and G+16 building models, comparing normal and diagrid structures under seismic loads. Key parameters like time period, displacement, storey drift, and base shear are evaluated to assess the dynamic behavior and structural performance of both systems. The results highlight the advantages of the diagrid system, including enhanced seismic resistance, reduced displacement, and better force distribution. This comparative analysis demonstrates the superior performance of diagrid structures, particularly in high-rise buildings.

Time Period for G+7

For the G+7 building, the time period for the diagrid structure is significantly reduced (by 30-40%) compared to the normal building. This indicates that the diagrid structure is more flexible, which allows it to absorb seismic forces more effectively, reducing its response time and improving its earthquake resilience.

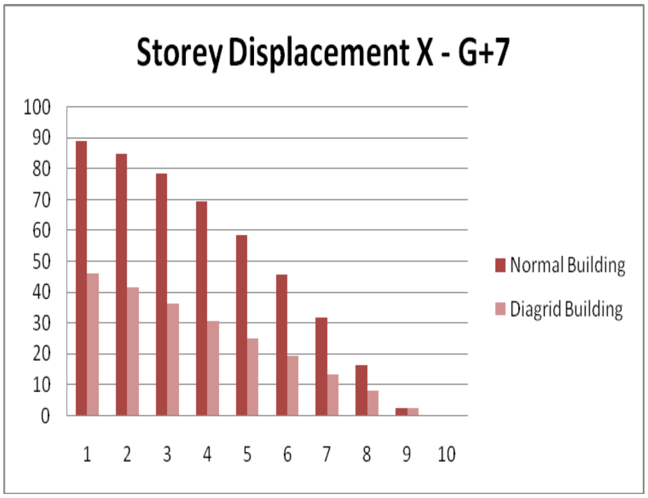


Graph 1: Time period for G + 7

The Above graph shows results for Time Period for G+7 for normal and diagrid structure for the responcs spectrum analysis , the time period reduces of diagrid structure than normal structure by 30-40% .

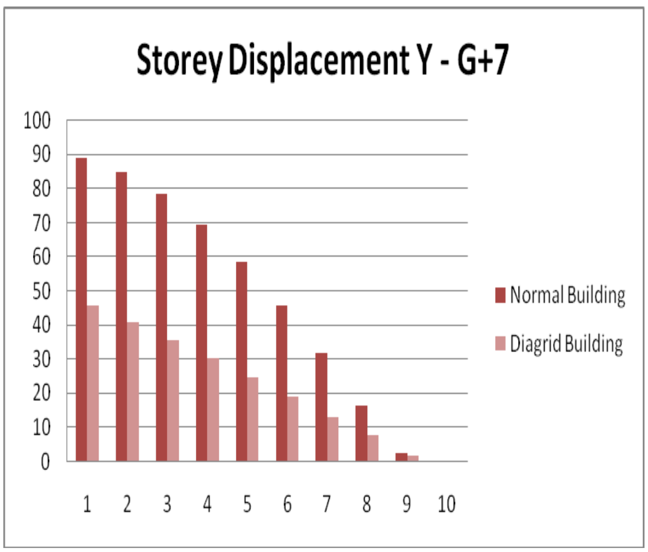
Displacement for G+7

For the G+7 structure, the storey displacement for the diagrid building is notably lower by 40-50% compared to the normal building. This reduction indicates better energy dissipation in the diagrid structure, ensuring lesser movement at higher storeys during seismic events, which contributes to overall stability.



Graph 2: Time period for G + 7

The Above graph shows results for storey displacement for G+7 for normal and diagrid structure for the responcs spectrum analysis , the time period reduces of diagrid structure than normal structure by 40-50%

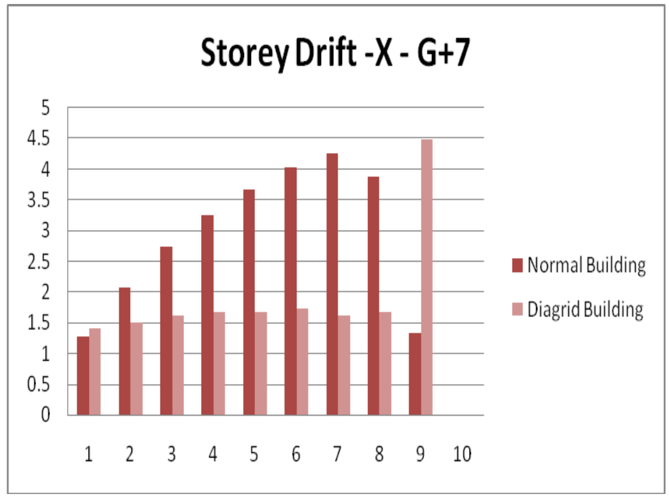


Graph 3: Time period for G + 7

The Above graph shows results for storey displacement for G+7 for normal and diagrid structure for the responcs spectrum analysis , the time period reduces of diagrid structure than normal structure by 20-30%

Storey Drift for G+7

The storey drift for G+7 shows that the diagrid structure experiences a reduction in drift by 30-40% compared to the normal structure. This means the diagrid system provides better lateral stability, minimizing excessive horizontal displacement between floors during an earthquake.

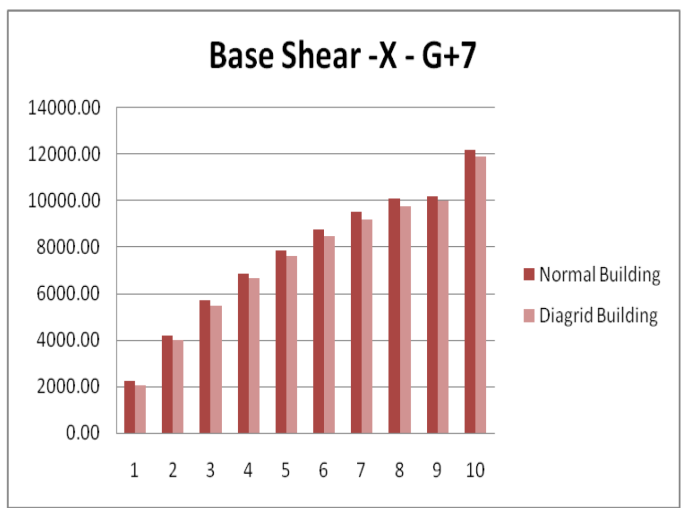


Graph 4: time period for G + 7

The Above graph shows results for storey drift for G+7 for normal and diagrid structure for the responcs spectrum analysis , the time period reduces of diagrid structure than normal structure by 30-40%

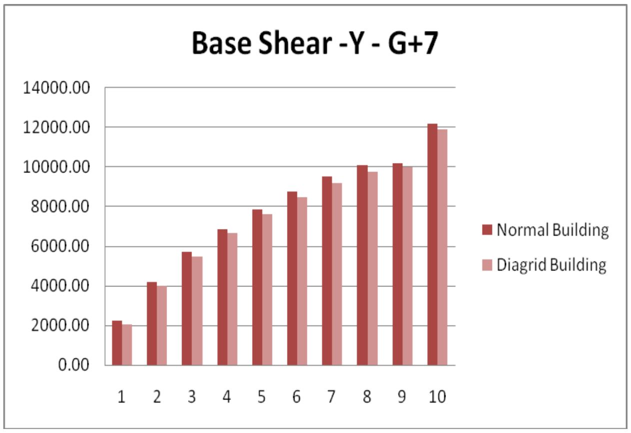
Base Shear for G+7

For the base shear, the diagrid structure reduces the shear by 30-40% compared to the normal building, indicating that the forces transferred to the foundation are better distributed, minimizing the risk of foundation failure or damage during seismic loading.



Graph 5 : Base Shear for G + 7

The Above graph shows results for Base Shear for G+7 for normal and diagrid structure for the responcs spectrum analysis , the time period reduces of diagrid structure than normal structure by 30-40%

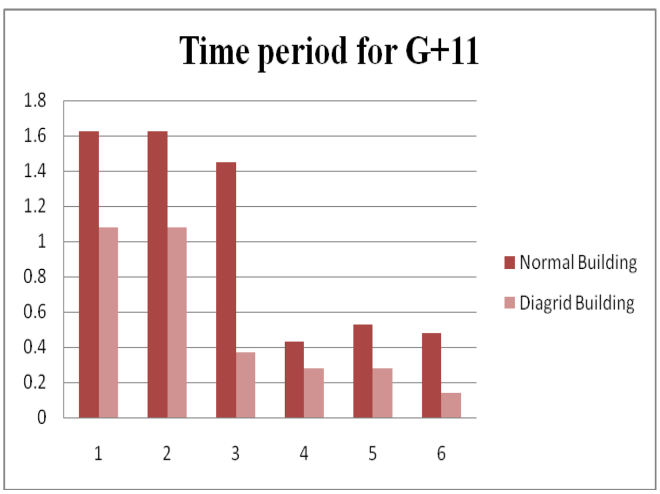


Graph 6 : Base Shear for G + 7

The Above graph shows results for Base Shear for G+7 for normal and diagrid structure for the responcs spectrum analysis , the time period reduces of diagrid structure than normal structure by 20-40%.

Time Period for G+11

The time period for the G+11 diagrid structure is reduced by 30-40% compared to the normal building. This reduction highlights the diagrid structure's increased flexibility, which helps it handle seismic forces more effectively, particularly under higher loading conditions.

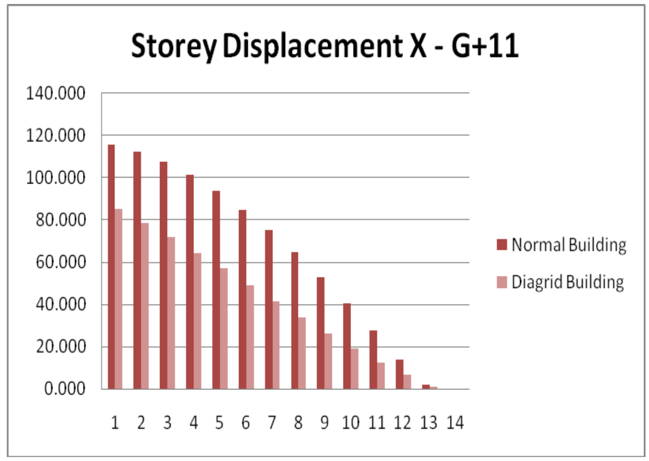


Graph 7: Time period for G + 11

The Above graph shows results for Time Period for G+11 for normal and diagrid structure for the responcs spectrum analysis , the time period reduces of diagrid structure than normal structure by 30-40%.

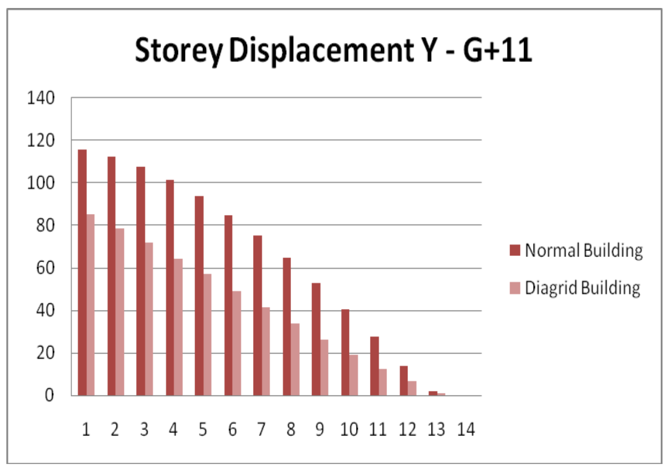
Displacement for G+11

For G+11, the displacement for the diagrid structure is reduced by 20-30% compared to the normal building. The reduction shows that the diagrid structure is more efficient in controlling movements, ensuring that higher storeys experience less displacement during seismic activity.



Graph 8: Time period for G + 11

The Above graph shows results for Storey Displacement for G+11 for normal and diagrid structure for the responcs spectrum analysis , the time period reduces of diagrid structure than normal structure by 20-30%

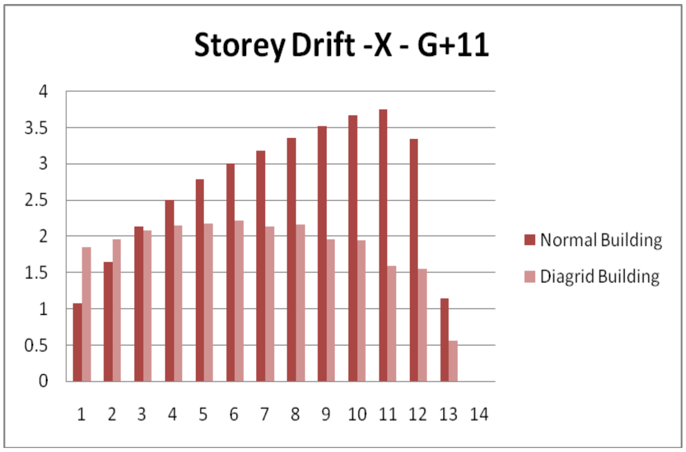


Graph 9: Time period for G + 11

The Above graph shows results for Storey Displacement for G+11 for normal and diagrid structure for the responcs spectrum analysis , the time period reduces of diagrid structure than normal structure by 10-30% .

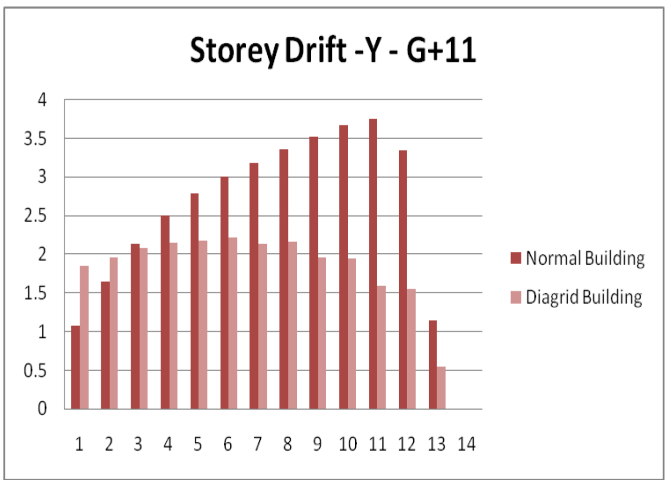
Storey Drift for G+11

The storey drift for G+11 indicates that the diagrid system reduces drift by 20-30%, providing better stability under lateral forces. This enhancement prevents excessive deformation between floors, thereby increasing the overall structural integrity during earthquakes.



Graph 10: Time period for G + 11

The Above graph shows results for Storey Drift for G+11 for normal and diagrid structure for the responcs spectrum analysis , the time period reduces of diagrid structure than normal structure by 20-30%

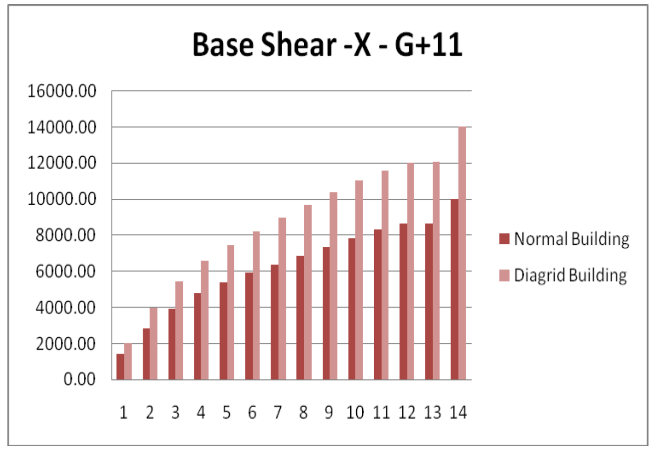


Graph 11: Time period for G + 11

The Above graph shows results for Storey Drift for G+11 for normal and diagrid structure for the responcs spectrum analysis , the time period reduces of diagrid structure than normal structure by 30-40%.

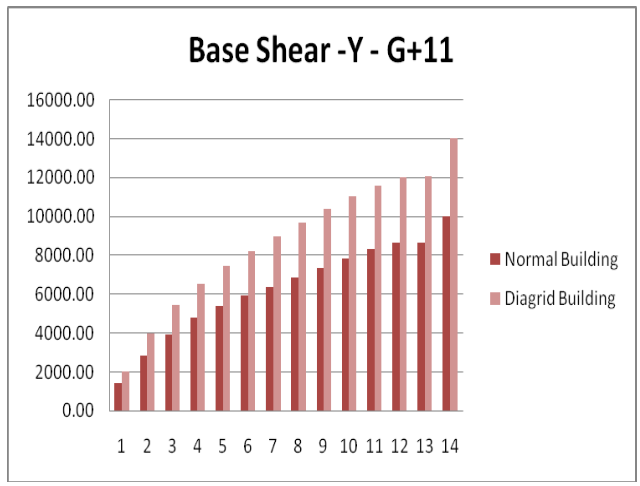
Base Shear for G+11

The base shear for the G+11 diagrid structure is reduced by 30-40% compared to the normal building. This demonstrates the diagrid structure’s superior lateral load distribution, reducing the seismic forces transferred to the base and improving the building’s earthquake resistance.



Graph 12: Time period for G +11

The Above graph shows results for Base Shear for G+11 for normal and diagrid structure for the responcs spectrum analysis , the time period reduces of diagrid structure than normal structure by 30-40%

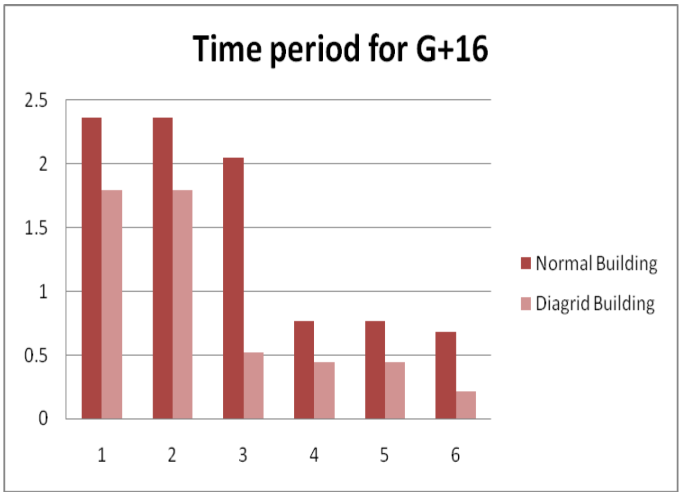


Graph 13 : Time period for G + 11

The Above graph shows results for Base Shear for G+11 for normal and diagrid structure for the responcs spectrum analysis , the time period reduces of diagrid structure than normal structure by 20-30%.

Time Period for G+16

For the G+16 building, the time period is reduced by 30-40% for the diagrid structure, reflecting its enhanced flexibility and ability to dissipate seismic energy more efficiently than the normal building.

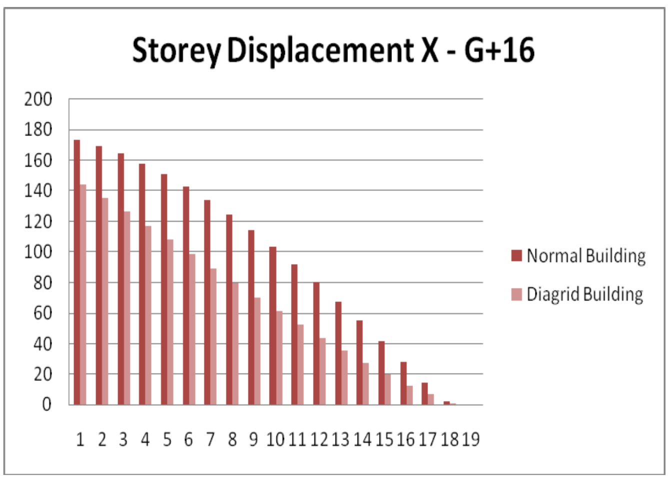


Graph 14: time period for G + 11

The Above graph shows results for Time Period for G+16 for normal and diagrid structure for the responcs spectrum analysis , the time period reduces of diagrid structure than normal structure by 30-40%.

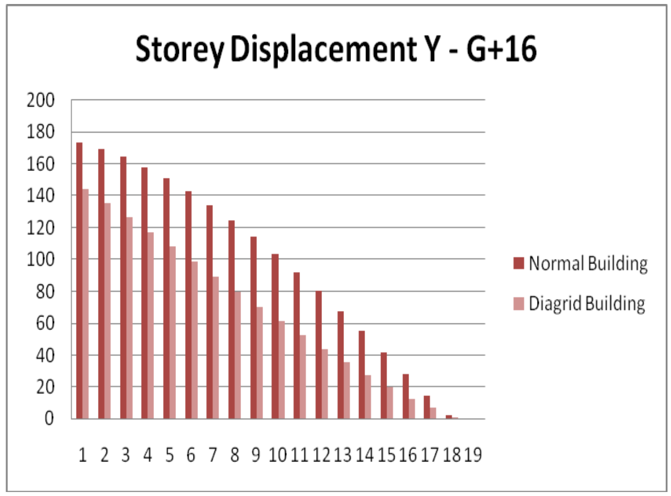
Displacement for G+16

The displacement for the diagrid structure in G+16 is reduced by 20-30%, showing better control over movement at higher storeys, which contributes to a more stable structure under seismic forces.



Graph 15 : Time period for G +16

The Above graph shows results for Storey Displacement for G+16 for normal and diagrid structure for the responcs spectrum analysis , the time period reduces of diagrid structure than normal structure by 20-30%.

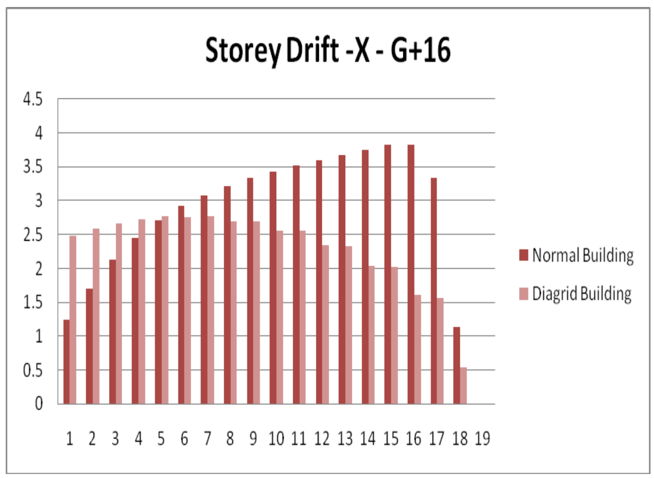


Graph 16: time period for G + 16

The Above graph shows results for Storey Displacement for G+16 for normal and diagrid structure for the responcs spectrum analysis , the time period reduces of diagrid structure than normal structure by 20-30%

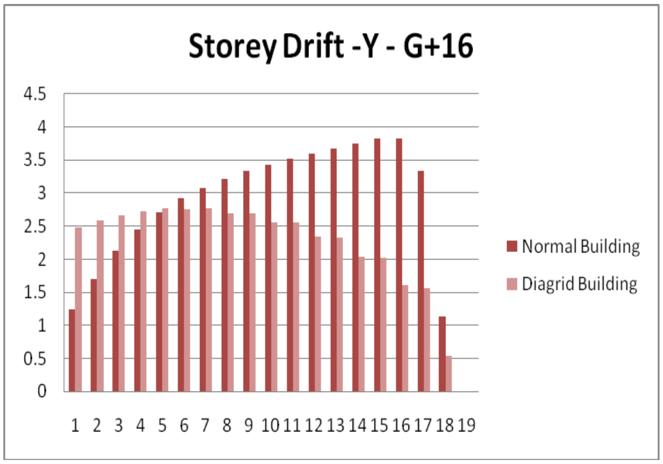
Storey Drift for G+16

The storey drift for G+16 shows a reduction of 20-30% for the diagrid structure. This indicates that the diagrid system performs better in preventing excessive horizontal displacement between storeys, ensuring structural stability during earthquakes.



Graph 17: time period for G + 16

The Above graph shows results for Storey Drift for G+16 for normal and diagrid structure for the responcs spectrum analysis , the time period reduces of diagrid structure than normal structure by 20-30%

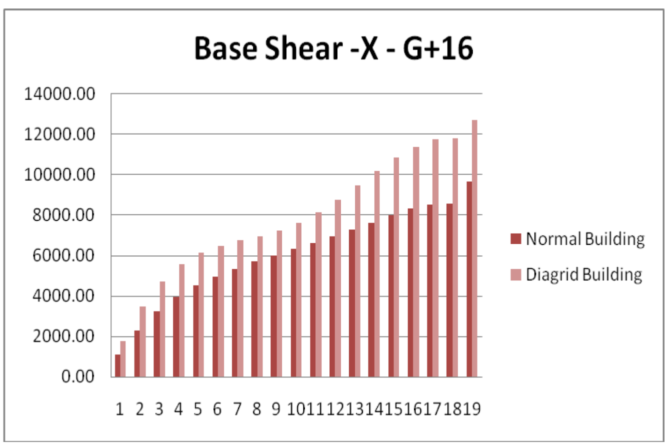


Graph 18 : Time period for G + 16

The Above graph shows results for Storey Displacement for G+16 for normal and diagrid structure for the responcs spectrum analysis , the time period reduces of diagrid structure than normal structure by 30-40%

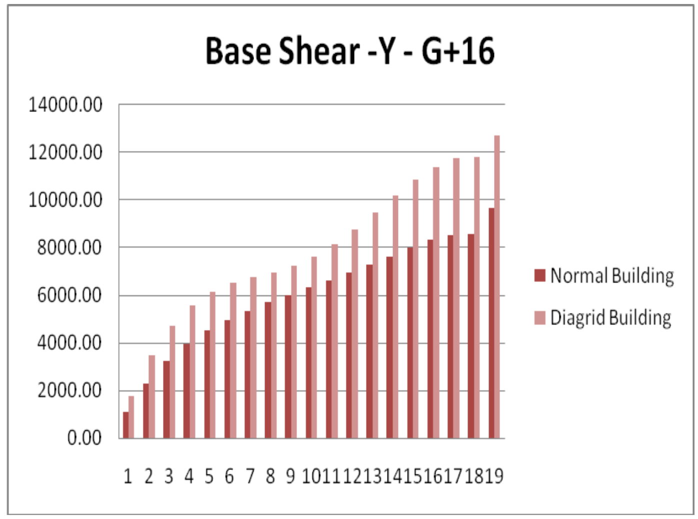
Base Shear for G+16

For G+16, the base shear for the diagrid structure is reduced by 20-30%, demonstrating that the diagrid design helps in better distributing seismic forces throughout the structure, reducing the stress on the foundation.



Graph 19: Time period for G + 16

The Above graph shows results for Base Shear for G+16 for normal and diagrid structure for the responcs spectrum analysis , the time period reduces of diagrid structure than normal structure by 20-30%



Graph 20: Time period for G + 16

The Above graph shows results for Storey Displacement for G+16 for normal and diagrid structure for the responcs spectrum analysis , the time period reduces of diagrid structure than normal structure by 30-40%

5.1 PUSHOVER ANALYSIS PERFORM ON G+16

This section presents the pushover analysis conducted on the G+16 building models, comparing the normal and diagrid structures. Pushover analysis helps in understanding the nonlinear behavior of buildings under increasing seismic loads, providing insights into their deformation and failure mechanisms. The results from this analysis will highlight the differences in performance between the normal and diagrid structures, particularly under extreme loading conditions.

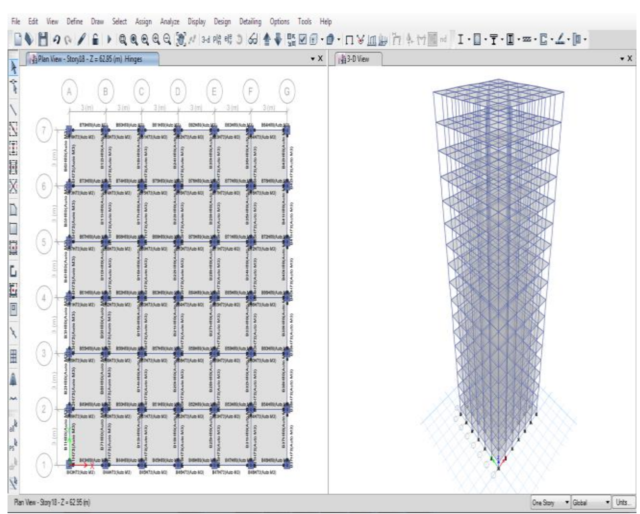


Figure 10: Pushover analysis on normal building

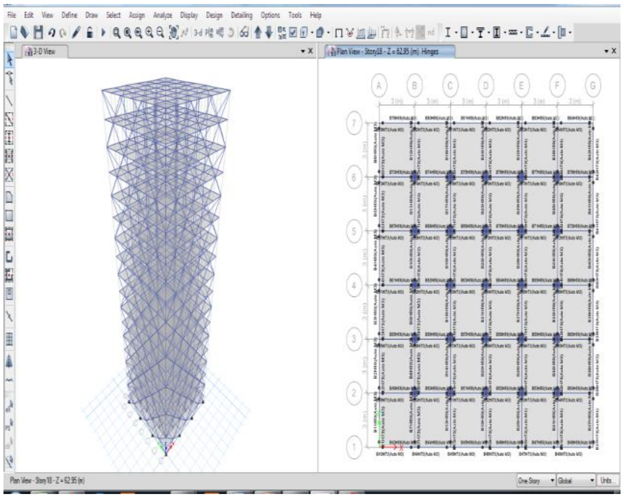


Figure 11: Pushover analysis on normal building

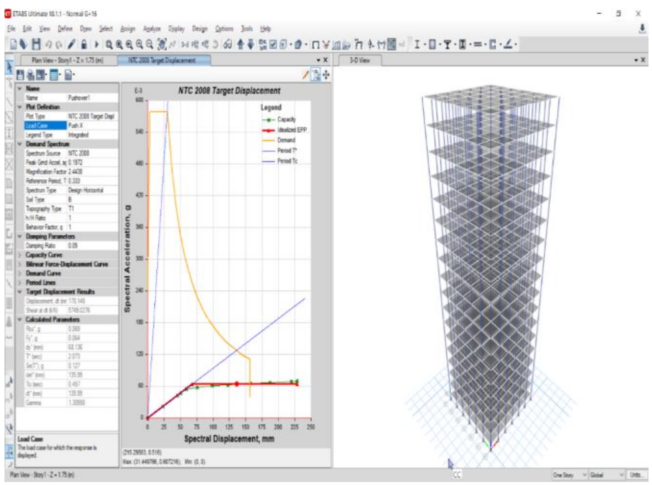


Figure 12: Pushover Analysis on Normal Building (G+7)

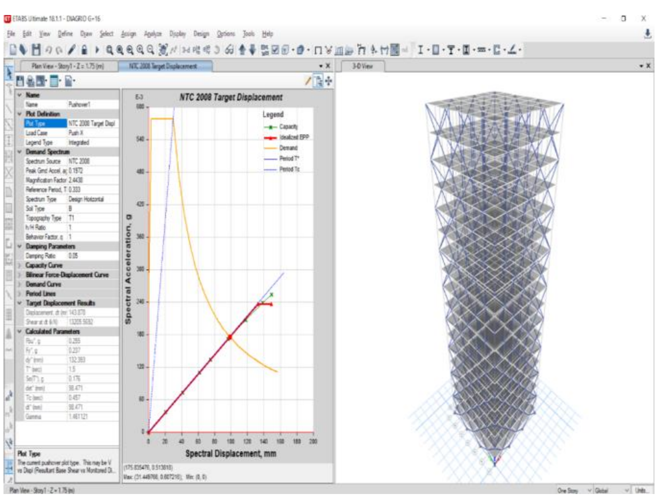
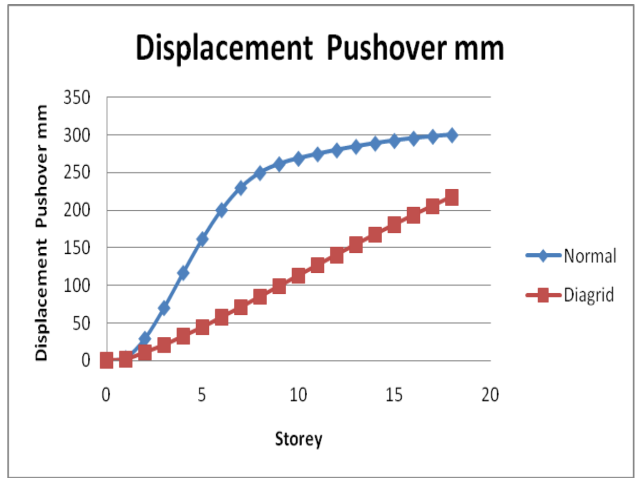


Figure 13: Pushover Analysis on Diagrid Building (G+7)

5.2 Displacment After pushover analysis



Graph 21:Displacement Pushover

The pushover analysis results show a clear difference in displacement between the normal and diagrid buildings. The normal building experiences significant displacement at the top storeys, with a maximum displacement of 300mm at the 18th floor. As we move down, the displacement gradually decreases. In contrast, the diagrid building exhibits much lower displacements, with a maximum displacement of 217.655mm at the 18th floor, reflecting its superior seismic resistance. The diagrid system's diagonal grid structure helps distribute lateral forces more effectively, minimizing displacement and enhancing stability, making it more resilient under seismic loads compared to the normal structure.

VI. CONCLUSION

This study presents a detailed analysis of RCC diagrid structures subjected to seismic forces using pushover analysis. The results clearly demonstrate that diagrid structures outperform conventional buildings in terms of seismic resistance. The diagrid system, characterized by its diagonal grid pattern, significantly reduces displacement and storey drift by 20-50%, depending on the building configuration. The analysis also reveals a considerable reduction in base shear, highlighting the efficiency of the diagrid system in distributing seismic forces more effectively. These improvements are most notable in higher buildings, such as the G+16 model, where diagrid structures show a 20-30% reduction in base shear compared to traditional designs. Furthermore, the diagrid system enhances flexibility and stability, allowing for better energy dissipation during seismic events, which minimizes the risk of progressive collapse. Overall, the study advocates for the adoption of diagrid structures in seismic regions, contributing to safer, more resilient building designs that can withstand extreme seismic forces with reduced material use and improved performance.

REFRENCES

[1] Al-bared, M. A. M., & Marto, A. (2019). Evaluating the compaction behaviour of soft marine clay stabilized with two sizes of recycled crushed tiles, In: Pradhan B. (eds) GCEC 2017. GCEC 2017. Lecture Notes in Civil Engineering, vol 9. Springer, Singapore. *GCEC 2017 Conference Paper*, 1273–1284. https://doi.org/10.1007/978-981-10-8016-6

[2] Amrapali Kasabe, & Vaibhav Shelar. (2023). Pushover analysis of building using soft story at different levels. *World Journal of Advanced Engineering Technology and Sciences*, *9*(1), 203–210. https://doi.org/10.30574/wjaets.2023.9.1.0160

[3] Brunesi, E., & Parisi, F. (2017). Progressive collapse fragility models of European reinforced concrete framed buildings based on pushdown analysis. *Engineering Structures*, *152*, 579–596. https://doi.org/10.1016/j.engstruct.2017.09.043

[4] Brunesi, E., Nascimbene, R., Parisi, F., &Augenti, N. (2015). Progressive collapse fragility of reinforced concrete framed structures through incremental dynamic analysis. *Engineering Structures*, *104*, 65–79. https://doi.org/10.1016/j.engstruct.2015.09.024

[5] Darak*, S., & Patil, D. H. R. M. (2020). Non-linear Static Progressive Collapse Analysis of Asymmetric High Rise R.C.C. Structure. *International Journal of Innovative Technology and Exploring Engineering*, *9*(9), 586–592. https://doi.org/10.35940/ijitee.i7226.079920

[6] Date, A., & Dubal, R. A. (2021). Nonlinear Seismic Analysis of Normal Structure With Diagrid Structure Using Etabs. *International Journal of Science and Engineering*, *6*(7), 22–28. https://doi.org/10.51397/OAIJSE07.2021.0004

[7] Dhole, A. G., Tupe, D. H., &Gandhe, G. R. (2020). Progressive Collapse Analysis of R.C.C. Framed Structure using Etab's. *International Research Journal of Engineering and Technology*. www.irjet.net

[8] He, X. H. C., Yi, W. J., & Yuan, X. X. (2019). A non-iterative progressive collapse design method for RC structures based on virtual thermal pushdown analysis. *Engineering Structures*, *189*(March), 484–496. https://doi.org/10.1016/j.engstruct.2019.03.102

[9] Javaid, K., & Verma, N. (2022). Increasing the seismic resistance of diagrid structures using buckling restrained braces as secondary bracings in different arrangements as per IS 1893:2016. *International Journal of Mechanical Engineering*, *4*(4). https://kalaharijournals.com/resources/APRIL_125.pdf

[10] Kiran, S. (2022). Comparative Analysis of Conventional Structure and Diagrid Structure. *Research in Engineering and Science (IJRES)*, *10*(1), 46–53.

[11] Mohammed Shoaib, & Dr. A Swetha. (2023). Non-Linear Pushover Analysis Of RCC Framed Structure By Providing Fluid Viscous Dampers At Different Locations. *Journal of Scientific Research and Technology*, 21–47. https://doi.org/10.61808/jsrt76

[12] Patel, P., & Pasha, P. N. (2024). Analysis of High-Rise Building With Diagrid Structure Subjected To Lateral Loading. *Futuristic Trends in Construction Materials & Civil Engineering Volume 3 Book 5*, 185–208. https://doi.org/10.58532/v3bjce5p3ch2

[13] R. Jeyanthi, & S. Mohan Kumar. (2016). Progressive Collapse Analysis of a Multistorey RCC building using Pushover Analysis. *International Journal of Engineering Research And*, *V5*(03), 747–750. https://doi.org/10.17577/ijertv5is031275

[14] Ramkumar, A., Jegadeeswaran, C., Keerthana, R., Gayathri, S., &Venkateshan, A. (2024). An existing RCC G + 2 healthcare building ' s performance point in ETAB was determined by a non-linear static pushover analysis. *International Journal of Engineering Research and Science & Technology*.

[15] Salah, E., & Din, U. (2020). International Journal of Advance Engineering and Research. *International Journal of Advance Engineering and Research Development*, *6*(December 2019), 270–276.

[16] Shah, J. S., Karthikeyan, K., & Shah, B. R. (2017). Study of progressive collapse analysis of transfer girder system RCC building. *International Journal of Civil Engineering and Technology*, *8*(3), 324–336.

[17] Sheikh, T. A., Banday, J. M., & Hussain, M. A. (2021). Study on non-linear static behavior of 2d low-rise rcc framed structure subjected to progressive collapse. *Advances in Computational Design*, *6*(4), 257–278. https://doi.org/10.12989/acd.2021.6.4.257

[18] Takle, S. R., Patil, A. S., & Mahajan, B. V. (2020). Dynamic Analysis of Diagrid Structural System in High Rise RCC Buildings with Varying Geometry. *International Journal of Engineering Research & Technology*, *9*(12), 336–342.

[19] Tripathi, S., & Jain, A. K. (2019). Progressive Collapse Assessment of RCC Structure under Instantaneous Removal of Columns and its Modeling Using Etabs Software. *IOSR Journal of Engineering (IOSRJEN)*, *09*(October 2019), 2278–8719. www.iosrjen.org

[20] Yadav, P., & Malviya, P. (2019). Analysis of Tall Structure Project Considering Effect of Diagrid and Hybrid Diagrid Members: A Review. *International Journal of Scientific Research in Civil Engineering © 2019 IJSRCE* |, *3*(10), 2456–6667. https://ijsrce.com/paper/IJSRCE193213.pdf