



# Analysis Of High Rise Building With Steel Staggered Truss & Diagrid System

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**Abstract:** The study examines three different structural systems for tall buildings—the Diagrid system, the Steel staggered system, and the Conventional RCC system—are compared in this study. The study examines the seismic performance and lateral load resisting capabilities of a G+16 structure Height 55 m. Given how tall building construction is changing and how much attention is being placed on earthquake-resistant design, the analysis is very significant. In compliance with Indian Standards, the Response Spectrum Method was used for dynamic analysis when modeling and analyzing the structures using ETABS software. Critical factors such base shear, storey displacement, and story shear, storey stiffness are examined in the comparison evaluation. With a focus on seismic response characteristics, the study assesses how well these systems operate under lateral loading situations. The purpose of this study is to advance knowledge of how contemporary structural systems behave in seismic conditions and offer insightful information for choosing the best structural systems for tall building design. The results of this investigation will help structural engineers and designers choose the best lateral load resisting solutions for tall buildings

**Index Terms** - Steel Staggered system, Diagrid system, Conventional Rcc System, Seismic analysis, Etabs, Comparative Study

## 1. INTRODUCTION

**Jinkoo Kim et.al (2017):** This work created a performance-based seismic design technique and assessed the seismic performance of staggered truss frames with friction dampers in the Vierendeel panels. The capacity design process was used to create 6- and 12-story analysis model structures with friction dampers. The strength-based approach was used to design the identical structures without dampers for comparison. The seismic performances of all the model structures were then evaluated. To verify the response modification factor utilized for seismic design and assess the seismic safety of the model structures, fragility assessments were performed. The analysis's findings demonstrated that the capacity design technique caused a concentration of plastic hinges at the vierendeel panels.

**Neha Tirkey et.al (2020):** This article describes the ETABS (Extended Three Dimensional Analysis of Building System) software case study on diagonal perimeter, also referred to as the diagrid construction. In contemporary construction, the diagrid structure has become a cutting-edge technique that has advanced the development of tall buildings and high-rise structures in both the architectural and engineering domains. In addition, the construction is now lighter and more rigid than typical conventional buildings. ETABS software is used to design, evaluate, and compare the diagrid structure with the conventional building, with a primary focus on seismic and wind analysis parameters. All of the structural components of the diagrid model are constructed in accordance with Indian codes and the Linear Static Method

**Harshvardhan Rangari et.al (2020)** : The objective of this project is to use the ETABS software set up to conduct an analytical examination into the behavior of an eight-story steel staggered truss system. The effects of several characteristics, including the type of structural truss and the placement of the trusses, on the system's seismic behaviors are investigated. Additionally, various indicators of the system's seismic behaviors, including yield load, deformation, and strength, are examined in light of the test results. Finally concluded the structure with hybrid truss have maximum strength & with min values of lateral displacement the maximum value of lateral displacement & storey shear is observed in normal frame.

**Dharmin B Mistry et.al (2021)**: The objective of this study is to use the ETABS software to compare staggered truss designs for 8, 9, and 10-story structures with and without a shear wall. Time histories are used in this analysis to utilize. These structures are modeled in the ETABS software for the analysis, and distinct displacement data are obtained for the various kinds of structures. Following the models' analysis, some results were noted, leading to the conclusion that, in the x and y directions, the staggered truss system with the shear wall has lower displacement values than the other. Compared to the traditional staggered truss system, the displacement was 3% to 62% less in the x direction and 64% to 85% less in the y direction.

**Manthan I. Shah et.al (2016)**: Seven steel buildings with the same base area and loadings but varying heights are studied in this work to determine the best sections for both the diagrid and conventional frame structural systems in ETABS. Numerous factors, such as this study takes into account the basic time period, maximum lateral displacement of the top story, maximum base shear, steel weight, percentage differences in the change of steel weight, maximum storey displacement, and maximum storey drift. A diagrid construction works better than a traditional frame structure, and its steel weight increases with building height much less dramatically.

## 1.1 RCC Structure

In modern construction engineering, Reinforced Cement Concrete (RCC) represents a fundamental composite material that has revolutionized the building industry. It consists of a strategic combination of concrete, renowned for its superior compressive strength characteristics, and high-tensile steel reinforcement positioned at calculated locations. The concrete matrix, comprising Portland cement, coarse and fine aggregates, and water at specific ratios, encapsulates carefully designed reinforcement configurations. This structural synergy enables RCC members to effectively resist multidirectional forces, including axial loads, bending moments, and shear stresses. The exceptional durability, fire resistance, and cost-effectiveness of RCC structures, coupled with their ability to be cast into diverse architectural forms, have established them as the predominant choice in contemporary construction methodology. The material's inherent properties allow engineers to design safe, serviceable structures that comply with building codes while meeting the demanding requirements of modern infrastructure development.

## 1.2 Staggered Truss System:

The staggered truss structural system is made up of story-high steel trusses placed on alternating column lines on each floor, ensuring that the long axis of one truss is always between the trusses on the floor below. The interaction of the floors, trusses, and columns allows the structure to perform as a single unit, maximizing the strength and rigidity of all components at the same time. Each component serves a specific purpose and is completely dependent on the others to function. When lateral loads are applied to the total frame, it behaves like a cantilever beam. All columns are placed on the exterior wall of the building and serve as the flanges of the beam, while the trusses that span the total transverse width between columns function as the web of cantilever beam.

## 1.3 The Diagrid Structural System:

The diagrid structural system is defined as diagonal members formed as a framework by the intersection of different materials such as metals, concrete, or wooden beams used in the construction of structures and roofs. Diagrid structures of steel members are effective at providing solutions in terms of strength and stiffness. However, diagrid is now widely used in large span and high-rise buildings, particularly those with complex geometries and curved shapes. The diagonal member of the diagrid transmits both shear and moment. As a -

result, the optimal angle for placing the diagonals varies with building height. The optimal angle of the columns for maximum bending rigidity in a normal building is 90 degrees & for shear rigidity in diagonals is 35 degree. The advantages of using diagrids in structure construction significantly improve the building's aesthetic appearance. The use of diagrid saves up to 20% on steel when compared to a brace frame structure. It does not require technical labor because the construction technology is simple. If the structural material is used, the diagrid makes the most of its potential. When glass is used with the diagrid, it allows a lot of light into the structure. These structures have mostly column-free exteriors and interiors, as well as open and clear floor plans that can be implemented.

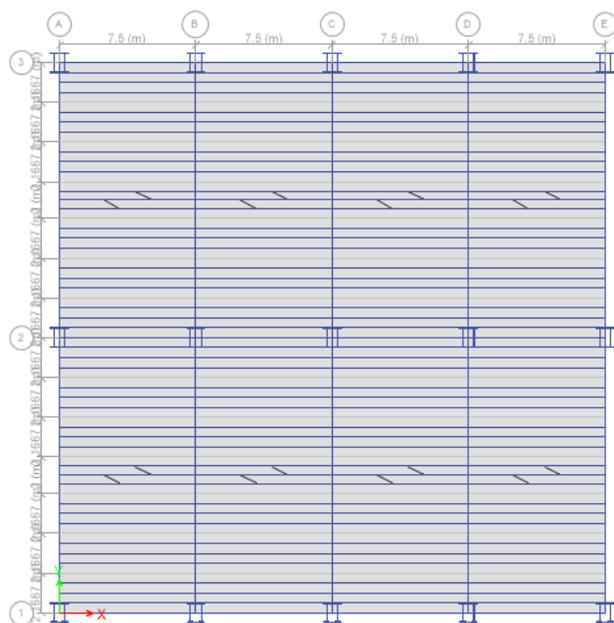
## 2. METHODOLOGY:

1. Selection of three distinct structural systems for comprehensive analysis comprising conventional RCC frame structure, steel staggered truss system, and diagrid structural system to evaluate their seismic response characteristics.
2. Implementation of ETABS structural analysis software for detailed modeling of the selected structural systems, maintaining consistent plan dimensions across all three systems for a G+16 storey configuration to ensure comparable results.
3. Systematic development of structural models through precise application of material specifications, load calculations, and appropriate boundary conditions following current Indian standard code provisions.
4. Detailed configuration of seismic analysis parameters specifically for Zone-II, incorporating all relevant specifications and requirements as mandated by Indian seismic code provisions for structural design.
5. Comprehensive analysis of structural response mechanisms through detailed measurement and evaluation of critical parameters including storey drift, storey displacement, and base shear forces generated under seismic conditions.
6. Execution of thorough performance comparison studies across all three structural systems under identical seismic conditions to determine their relative effectiveness and behavior patterns.
7. Systematic evaluation and detailed documentation of structural behavior patterns and seismic performance characteristics for each system to establish comparative efficiency and response mechanisms.
8. This methodological approach enables a detailed and systematic investigation of the seismic response behavior of different structural systems under Zone-II conditions, facilitating a comprehensive understanding of their performance characteristics and relative advantages.

## 3. MODELLING:

1. The modeling process begins with creating a new model in ETABS, setting the unit system as kN and m to ensure consistent analysis throughout the process.
2. The structural grid system is developed according to the architectural plans, followed by inputting the story heights for the G+16 building configuration to establish the basic framework.
3. Material properties are defined through specification of concrete and steel grades that are appropriate for high-rise construction and comply with code requirements.
4. Structural element sections are created including columns with varying sizes for different heights, beams, and slab sections to ensure proper load distribution and structural integrity.
5. Various load patterns are defined including dead load, live load, super dead load, and seismic loads in both X and Y directions for comprehensive analysis.
6. Response Spectrum parameters are configured by defining the zone factor, importance factor, response reduction factor, soil type, damping ratio of 5%, and spectrum curve according to code specifications.

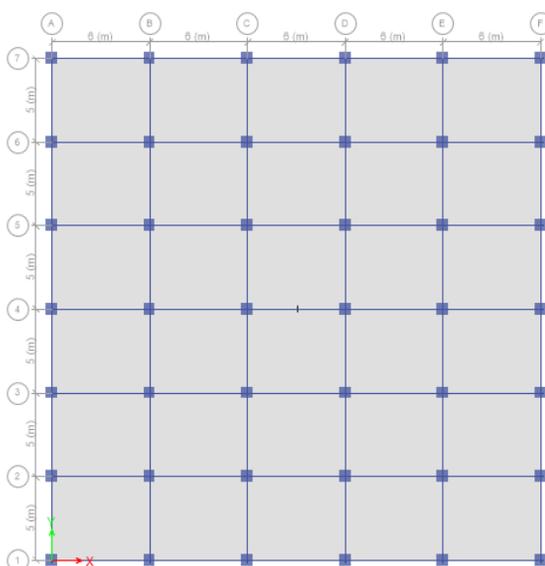
- 7. The structural model is developed by drawing columns at grid intersections, creating beams between columns, assigning slab sections, defining floor diaphragms, and setting appropriate support conditions.
- 8. Loads are implemented by assigning floor loads on slabs, applying wall loads on beams, defining necessary load combinations, and setting mass source parameters for seismic analysis.
- 9. Analysis is executed through systematic model checking, followed by running the analysis, verifying for errors, and validating the results for accuracy.
- 10. Structural parameters are evaluated through assessment of storey drifts, base shear, storey displacements, and storey drift ratio to verify structural performance.
- 11. The process concludes with generating a comprehensive analysis report and creating proper model backups for documentation and future reference.



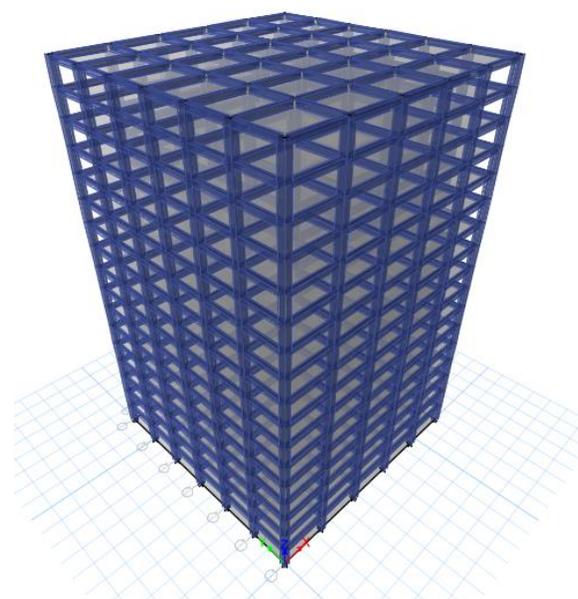
**Fig.-1:** Plan view of Conventional RCC structure



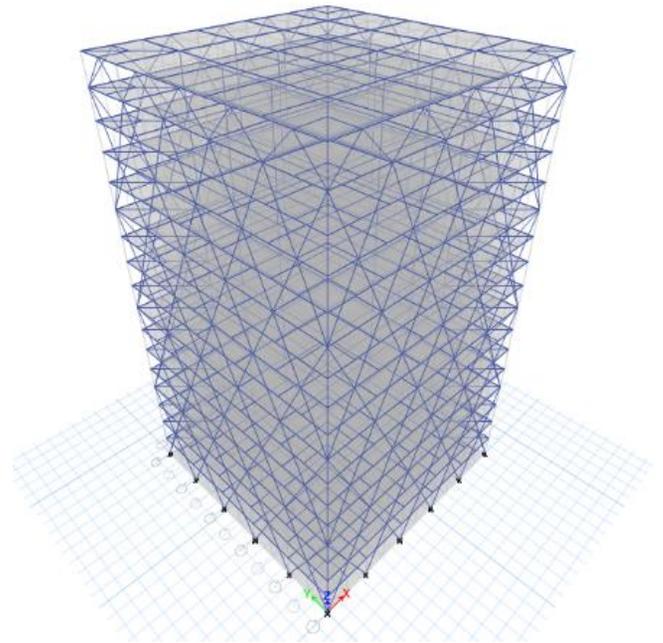
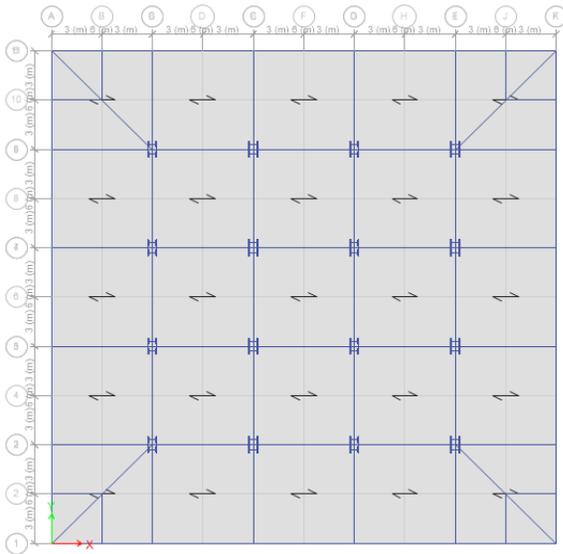
**Fig 2:** 3D View of RCC Conventional Building



**Fig.3:** Plan View of Steel staggered system



**Fig 4:** 3D View of Steel Staggered System



**Fig.5:** Plan View of Diagrid system

**Fig 6:** 3D View of Diagrid Structural System

**Fig.1, 2, 3, 4, 5, 6** represents the models which are considered for the analysis and the results of the following models is shown below.

**Table 1:** Specifications of the conventional RCC structure

SL.NO	ITEM	DESCRIPTION
1	Plan area	900 m <sup>2</sup>
2	Storey height	3m
3	No of stories	G+16
4	Total height of building	51 m
5	Size of column	0.7m x 0.7m
6	Size of beam	0.6m x 0.45m
7	Plate thickness	0.125m
8	Seismic zone	Zone II
9	Foundation depth	4m

**Table 2:** Specifications of the steel staggered structure

SLNO	ITEM	DESCRIPTION
1	Plan area	900m <sup>2</sup>
2	Storey height	3m
3	No of stories	G+16
4	Total height	51 m
5	Size of the column	Built up section
6	Size of the beam	ISMB 600
7	Plate thickness	275mm
8	Seismic zone	Zone II

**Table 3:** Properties of Built-up column

<b>Height (mm)</b>	800
<b>Top width (mm)</b>	400
<b>Top thickens(mm)</b>	23.6
<b>Web thickness ( mm)</b>	11.8
<b>Bottom width (mm)</b>	400
<b>Bottom thickness (mm)</b>	23.6

**Table 4:** Properties of Plate Section

<b>Width(mm)</b>	1000
<b>Thickness (mm)</b>	40

**Table 5:** Specifications of the diagrid structure

SLNO	ITEM	DESCRIPTION
1	Plan area	900m <sup>2</sup>
2	Storey height	3m
3	No of stories	G+16
4	Total height	51 m
5	Size of the column	Built up section
6	Size of the beam	ISMB 600
7	Plate thickness	275mm
8	Seismic zone	Zone II

**Table -6:** Specifications provided for Built-up column for Diagrid structure.

<b>Height (mm)</b>	800
<b>Top width (mm)</b>	400
<b>Top thickness(mm)</b>	23.6
<b>Web thickness ( mm)</b>	11.8
<b>Bottom width (mm)</b>	400
<b>Bottom thickness (mm)</b>	23.6

**Table -7:** Properties of Plate Section diagrid Structure.

<b>Width(mm)</b>	1000
<b>Thickness (mm)</b>	40

### 3. RESULTS AND DISCUSSIONS

The study of results has been described below of the above specified specifications of the structure

#### A. RCC CONVENTIONAL STRUCTURE

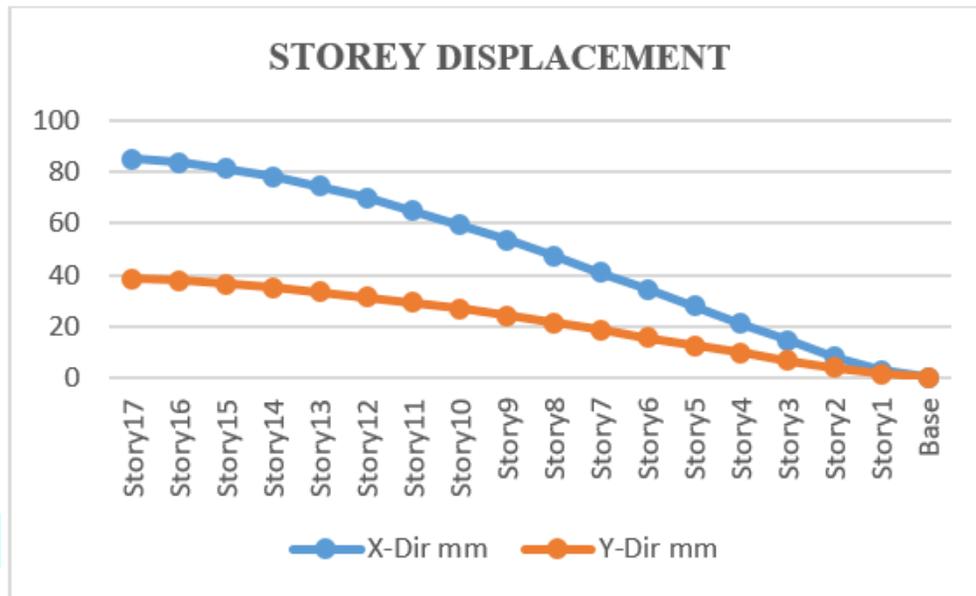


Fig 7: Storey displacement Rcc conventional structure.

#### B. STAGGERED SYSTEM

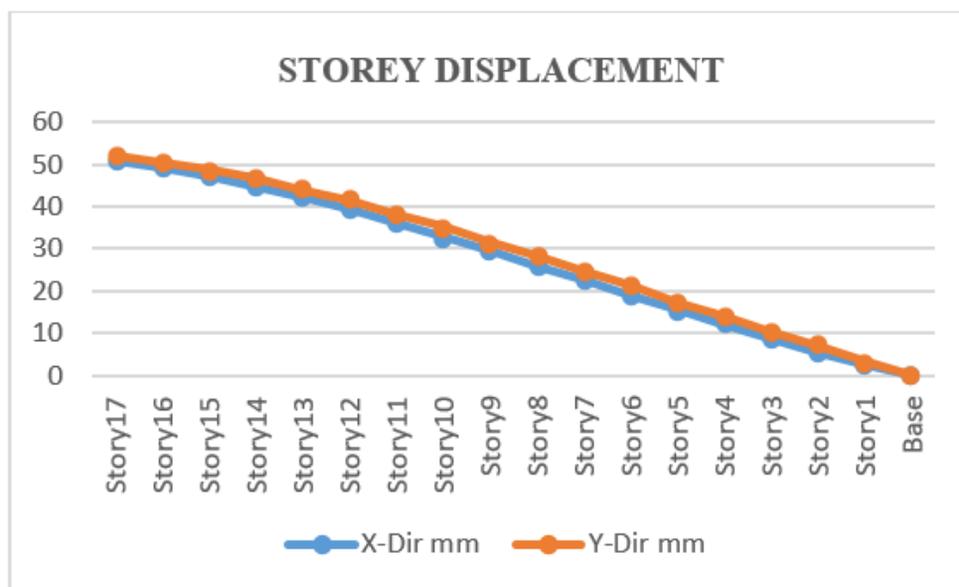
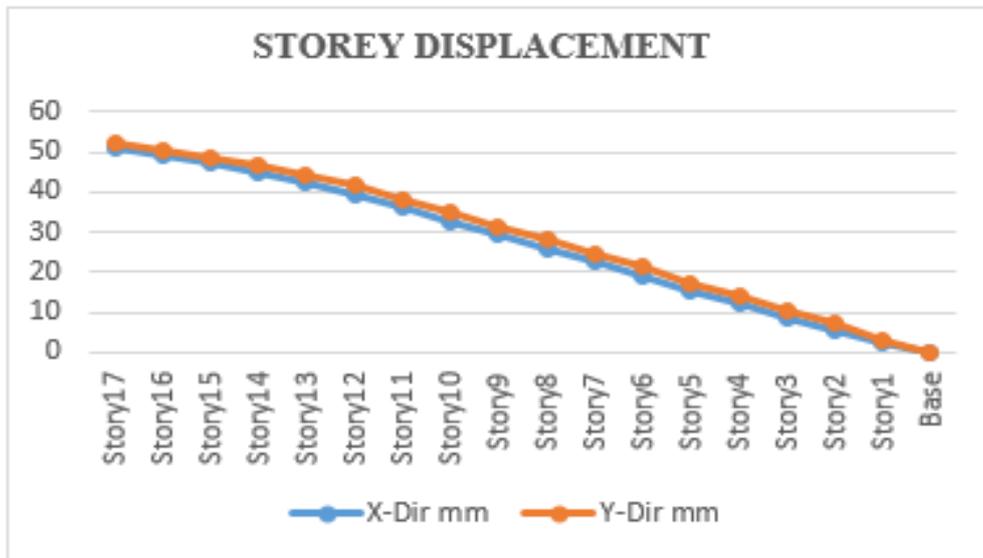


Fig 8: Storey displacement staggered system

### C.DIAGRID SYSTEM

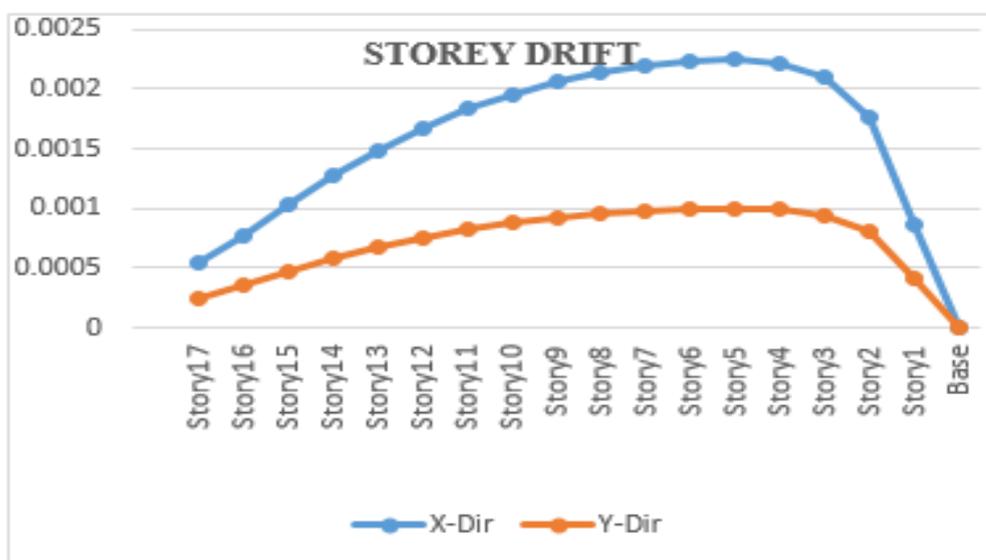


**Fig 9:** Storey displacement diagrid system

The analysis of storey displacement patterns across three structural systems reveals distinct behavioral characteristics in high-rise construction. The conventional RCC structure exhibits maximum displacement values of 80-90 mm, indicating significant lateral movement at upper levels. In contrast, the staggered system demonstrates enhanced stability with peak displacements of approximately 50 mm and more uniform deformation patterns. Notably, the diagrid system emerges as the most efficient, displaying minimal displacement values of 16 mm maximum, thus establishing its superior performance in lateral load resistance. This comparative analysis underscores the diagrid system's effectiveness in controlling building sway and optimizing structural response to lateral forces, making it a preferred choice for high-rise construction where displacement control is crucial.

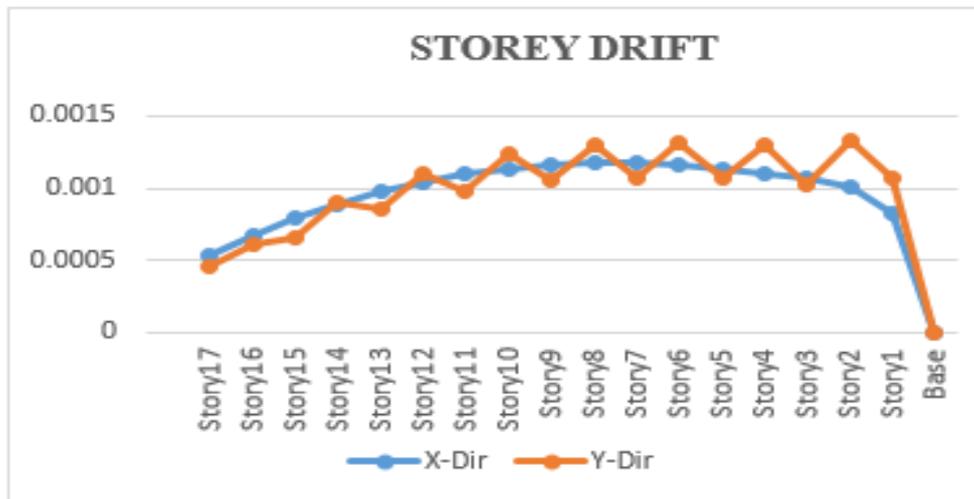
### STOREY DRIFT

#### A. RCC CONVENTIONAL STRUCTURE:



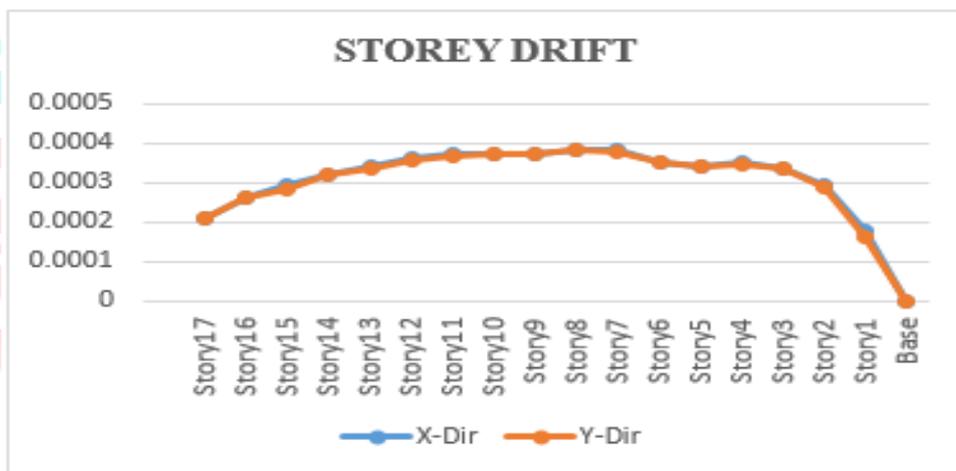
**Fig 10:** Storey Drift Conventional Rcc Structure

**B. STAGGERED SYSTEM**



**Fig 11:** Storey Drift Staggered Truss Building

**C. DIAGRID SYSTEM**



**Fig 12:** Storey Drift Diagrid Truss Building

The storey drift analysis across the three structural systems reveals significant variations in their seismic performance characteristics. The conventional RCC structure demonstrates the highest drift values, reaching approximately 0.0022, suggesting greater susceptibility to lateral deformation. The staggered system exhibits moderate drift values with more uniform distribution across storeys, indicating improved lateral stability. Most notably, the diagrid system showcases superior drift control with maximum values of about 0.00038, representing an 82% reduction compared to the conventional system. This marked improvement in drift control of the diagrid system validates its enhanced structural efficiency and lateral force resistance capability, making it particularly suitable for high-rise applications where drift control is a critical design parameter.

### STOREY SHEAR & STOREY STIFFNESS

#### A. RCC CONVENTIONAL STRUCTURE:

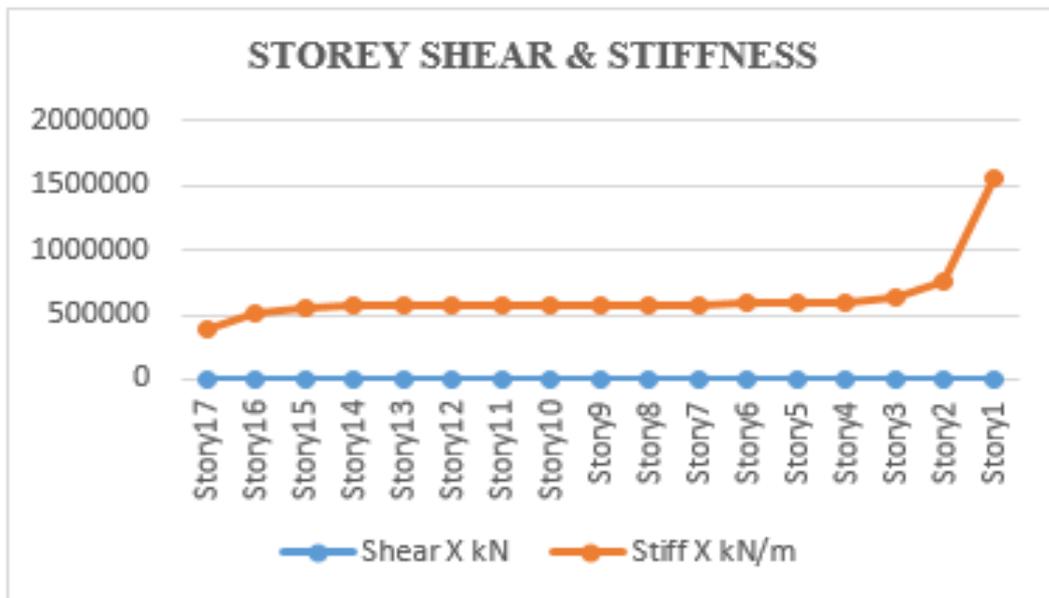


Fig 13: Storey Shear& Stiffness Rcc Conventional Structure.

#### B. STAGGERED SYSTEM:

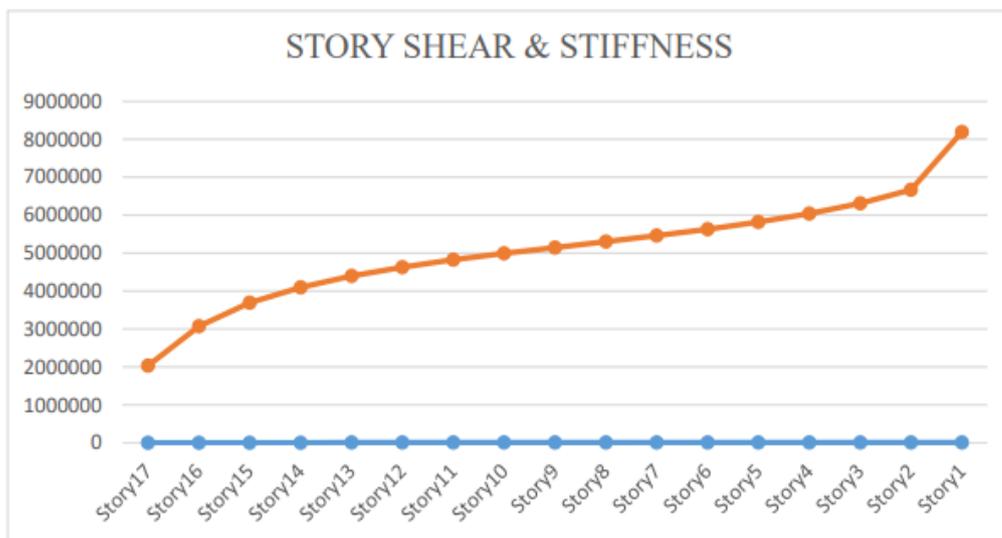
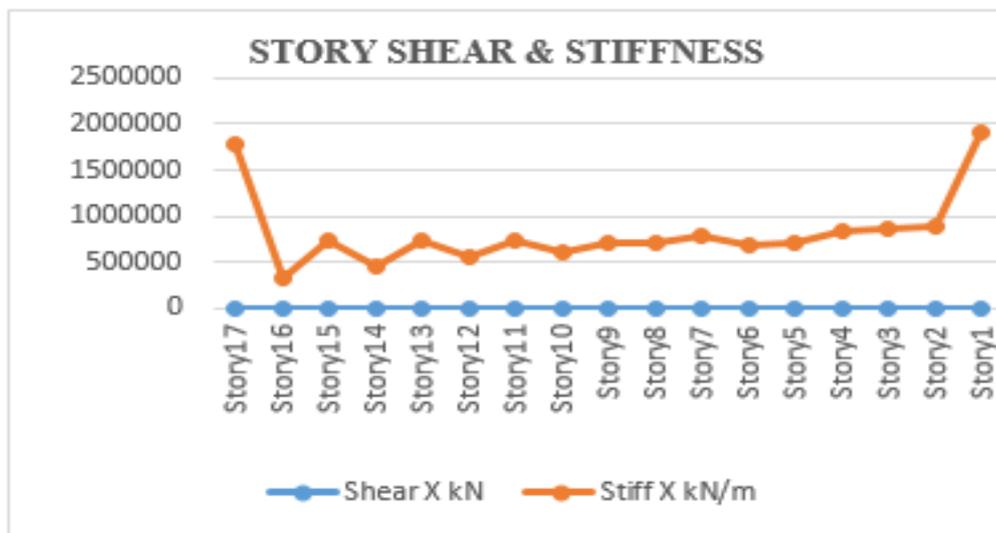


Fig 14: Storey Shear& Stiffness Staggered Truss System.

### C. DIAGRID SYSTEM:



**Fig 15:** Storey Shear & Stiffness Diagrid System.

A comparative analysis of storey shear and stiffness characteristics across the three structural systems reveals distinctive patterns in their load-resisting behavior. The conventional RCC structure and steel staggered structure exhibit similar stiffness trends, with values ranging from approximately 2,000,000 to 8,000,000 kN/m, increasing progressively towards the base. However, the diagrid system demonstrates a notably different pattern with lower stiffness values ranging from 500,000 to 2,000,000 kN/m, yet maintains more uniform distribution throughout the height. The shear forces, represented by the blue lines, remain relatively constant across all three systems, though the diagrid system shows marginally lower values. This analysis indicates that while the conventional and staggered systems offer higher absolute stiffness values, the diagrid system achieves efficient load distribution with lower material requirements, suggesting its potential for optimal structural efficiency in high-rise construction.

### 4. CONCLUSIONS

1. The diagrid structural system demonstrates exceptional performance metrics in comparison to conventional RCC structures. With a notably low uniform drift value of 0.00037 and top displacement of 16mm, the system achieves remarkable structural efficiency, manifesting in drift reductions of 485.6% and displacement reductions of 426% along the X-direction.
2. Analysis of the staggered system reveals moderate structural improvements over conventional RCC frameworks. The system exhibits a top displacement of 50mm and drift value of 0.0012, translating to displacement reductions of 67-74% and drift reductions of 25-43%. However, these performance metrics remain substantially inferior to those achieved by the diagrid system.
3. Under serviceability load combination i.e 1DL+1EQ, the structural systems exhibited peak responses across all critical parameters, including maximum values for drift, displacement, base shear, storey shear, and stiffness characteristics.
4. Comprehensive evaluation of structural parameters indicates the superior performance of the diagrid system across multiple metrics. The system demonstrates optimal behavior in critical aspects such as storey shear and storey displacement, significantly outperforming both staggered and conventional RCC structural configurations.

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