“Comparison Study of Shear Wall and Outrigger System for Lateral Load Resisting In High Rise Building”

Harsha valand[1], **Prof. Vishudha Dattani**[2] **,Dr.Nanak Pamnani**[3]

[1]*M.Tech Student, Department of civil engineering , S.P.C.E.T Anand, Gujarat, India.*
[2]*Professor,Department of civil engineering , S.P.C.E.T Anand , Gujarat, India.*
[3]*Principal, Sardar Patel College of engineering and Technology, Anand , Gujarat, India.*

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Abstract - *The performance of tall buildings is greatly influenced by their ability to resist lateral loads such as wind and seismic forces. As building heights increase, controlling drift, acceleration, and overall stability becomes a critical aspect of structural design. Various lateral load–resisting systems have been developed to address these challenges, including rigid frames, shear walls, braced frames, tube systems, and outrigger belt truss systems. Rigid frames provide flexibility but are less efficient for very tall structures, whereas shear walls offer high stiffness and are effective in resisting lateral forces, especially in seismic zones. Braced frames enhance structural strength with minimal material usage, making them economical for mid- to high-rise structures. Tube systems, including framed tube, tube-in-tube, and bundled tube configurations, significantly improve stiffness and are widely adopted in super-tall buildings. Outrigger and belt truss systems effectively reduce lateral drift by linking the core to perimeter columns, optimizing both stiffness and strength. Comparative studies show that the choice of system depends on building height, functional requirements, architectural constraints, and environmental conditions. The efficient integration of these systems ensures serviceability, cost-effectiveness, and safety of tall buildings under diverse lateral loading conditions.*

Keywords*:* Outrigger system, Shear wall, Tall building, Storey drift, Displacement, Base shear, ETABS.

1. INTRODUCTION

To overcome these limitations, advanced structural systems such as outrigger systems have been developed. An outrigger system consists of horizontal structural elements (trusses or walls) that connect the central core to the exterior columns. This connection enables the exterior columns to participate in resisting lateral loads by developing axial tension and compression forces. As a result, the overall stiffness of the structure increases, and the lateral displacement is significantly reduced.

The working mechanism of an outrigger system can be understood as a lever arm action, where the central core acts as a cantilever, and the outriggers engage the perimeter columns to resist overturning moments. This system effectively reduces core rotation, enhances structural efficiency, and allows for a reduction in core size compared to conventional shear wall systems.

In recent years, the combination of shear wall and outrigger systems has gained popularity in high-rise construction. This hybrid system utilizes the advantages of both systems — shear walls provide primary stiffness, while outriggers improve load distribution and reduce lateral deflections. The placement and number of outriggers play a crucial role in determining the overall performance of the structure, with mid-height locations often proving to be the most effective.

Therefore, this study aims to perform a comparative analysis of tall reinforced concrete buildings using shear wall and outrigger systems. The behavior of these systems is evaluated in terms of storey displacement, storey drift, and base shear under seismic loading conditions. The objective is to identify the most efficient structural configuration for high-rise buildings, particularly in different seismic zones.

2. Literature Review

Recent advancements in high-rise structural systems have focused on improving lateral load resistance, optimizing material usage, and enhancing overall structural efficiency under wind and seismic forces.

James Helal et al. (2024) emphasized the importance of reducing embodied carbon in tall buildings. Their study highlighted that non-functional architectural elements such as spires increase structural loads and indirectly lead to higher material consumption in columns, cores, and foundations. The research concluded that minimizing unnecessary structural height can significantly improve sustainability without compromising structural performance.

Maria Grazia Mallardi et al. (2025) investigated the behavior of shear walls combined with perpendicular walls in multi-storey buildings. Their results demonstrated that perpendicular walls can increase lateral stiffness by nearly **20% to 36%** and reduce displacement by approximately **20%.** The study also emphasized the importance of connection stiffness and proper wall placement for efficient load transfer.

Giulia Angelucci et al. (2020) explored the use of topology optimization for designing lateral load-resisting systems in tall buildings. The study revealed that simplified wind load models can be effectively used in early-stage design, while accurate seismic modeling is essential in high seismic regions. Their research provided a framework for optimizing structural systems considering both wind and earthquake effects.

Zixiao Wang et al. (2023) studied modular tall buildings and demonstrated that optimized structural design can reduce material usage by **10–20%** while maintaining adequate resistance to wind loads. Their approach also improved construction efficiency by enabling prefabrication, making high-rise construction more economical and sustainable.

Yogesh R. Carpenter et al. (2023) analyzed bundled tall buildings with various outrigger systems. Their findings indicated that the optimum location of outriggers depends on building height, with **2H/3 and H/3 positions** being most effective for reducing displacement. The study also concluded that conventional outrigger systems perform better than virtual outriggers in minimizing lateral deflection.

Hussin Ahmad Hasrat et al. (2024) conducted a comparative study of different lateral load-resisting systems under seismic conditions. The results showed that the outrigger system provided the best performance, reducing lateral displacement by **64%** and storey drift by **60%** compared to shear wall systems. The study also observed that outrigger systems exhibit higher base shear due to increased stiffness, which enhances structural stability.

Suraj Sangtiani et al. (2017) compared various structural systems under wind and earthquake loads. Their research indicated that outrigger systems offer superior performance for tall buildings, although they require advanced design considerations. Shear wall systems were found to be less economical for very tall structures due to increased material requirements.

Vishvesh Jayswal et al. (2024) studied the influence of dynamic loading and damping systems on high-rise buildings. The results showed that shear wall systems with dampers significantly reduce acceleration and drift. However, braced systems and hybrid systems demonstrated better control over storey shear and lateral displacement, particularly in irregular structures

2. Methodology

The present study aims to evaluate and compare the structural performance of tall reinforced concrete (R.C.) buildings using shear wall and outrigger systems under seismic loading. The methodology adopted involves modeling, analysis, and comparison of different structural configurations using advanced structural analysis software.

3.1 Description of Building Model

A regular plan high-rise R.C. building is considered for analysis. The building is modeled with the following specifications:

- Plan dimension: **35 m × 35 m**
- Number of storeys: **G + 29**
- Total height: **90 m**
- Storey height: **3 m**
- Structural system: Reinforced concrete moment-resisting frame

The building is assumed to be symmetric in both directions to eliminate torsional irregularities and to focus on the effect of lateral load-resisting systems.

3.2 Material Properties

The material properties used in the analysis are as follows:

- Concrete grade: **M30**
- Steel grade: **Fe500**
- Modulus of elasticity and density are taken as per IS 456:2000

3.3 Structural Components

The structural elements considered in the model include:

- Beams: Rectangular sections
- Columns: Varying sizes along height
- Slabs: 150 mm thick
- Shear walls: 150–300 mm thick
- Outriggers: Modeled as structural members connecting core and perimeter columns

3.4 Modeling Configurations

A total of multiple models are developed to compare the performance of different systems:

- Plan: 35 m x 35 m
- Bay size: 5#-5 m in both directions
- Providing shear wall and outrigger system in same R.C.C. building.
- No. of Story: G+9, G+19 and G+29
- Story height: 3 m
- Providing outrigger concept: conventional
- Location of outriggers: G+9, G+19, G+29
- Location of Shear wall: Centre of periphery wall
- Total no of models: 20 Models

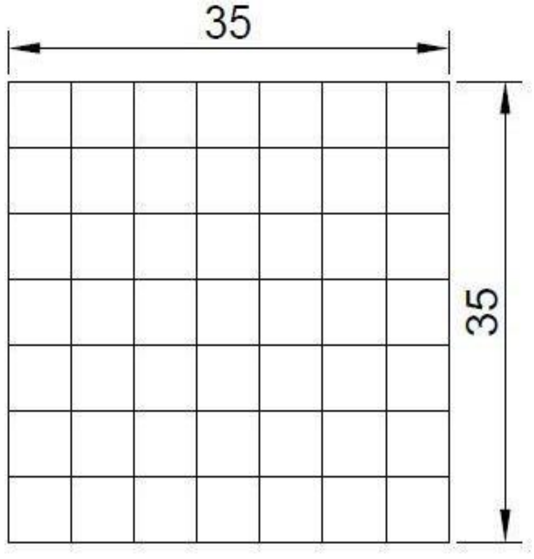


FIG.3.1 PLAN

FIG.3.2 ELEVATION

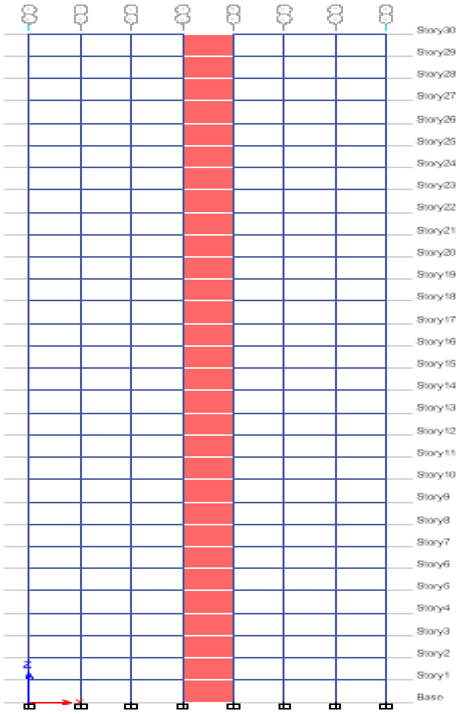


FIG.3.3. R.C. BUILDING WITH SHAER WALL

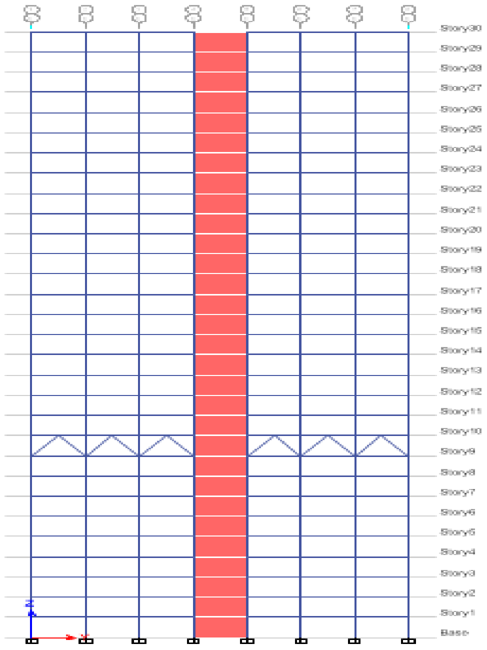


FIG.3.4.R.C.BUILDING SHEARWALL & OUTRIGGER AT 10^{TH} STOREY

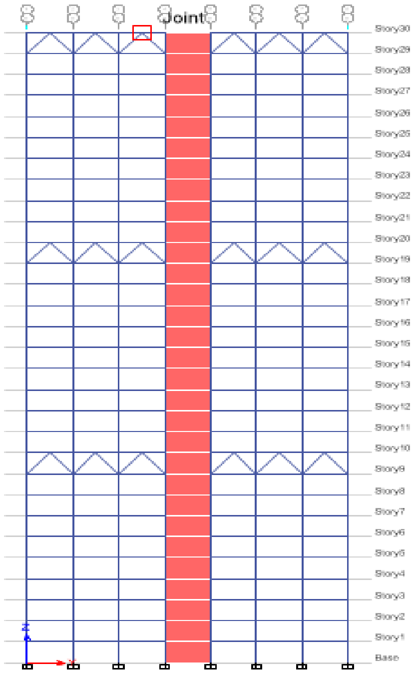


FIG.3.5.R.C.BUILDING SHEARWALL& OUTRIGGER AT 10 20 AND 30 STOREY

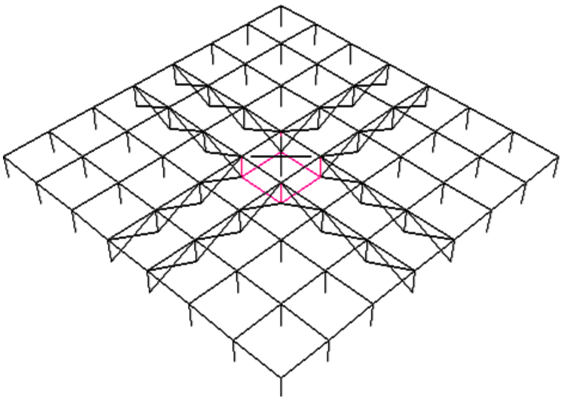


FIG.3.6. Perspective view of the model with central core and extended outrigger on all thefour sideswithout belt truss.

3.5 Loading Conditions

The structure is subjected to the following loads:

1. Dead Load (DL)

- Self-weight of structural components
- Floor finish load

2. Live Load (LL)

- As per IS 875 (Part 2)

3. Earthquake Load (EQ)

- As per IS 1893 (Part 1):2002
- Seismic Zones considered:
  - Zone III (Ahmedabad)
  - Zone V (Bhuj)
- Soil type: Medium soil
- Response reduction factor (R): 5

4. Wind Load

- As per IS 875 (Part 3)

3.6 Analysis Procedure

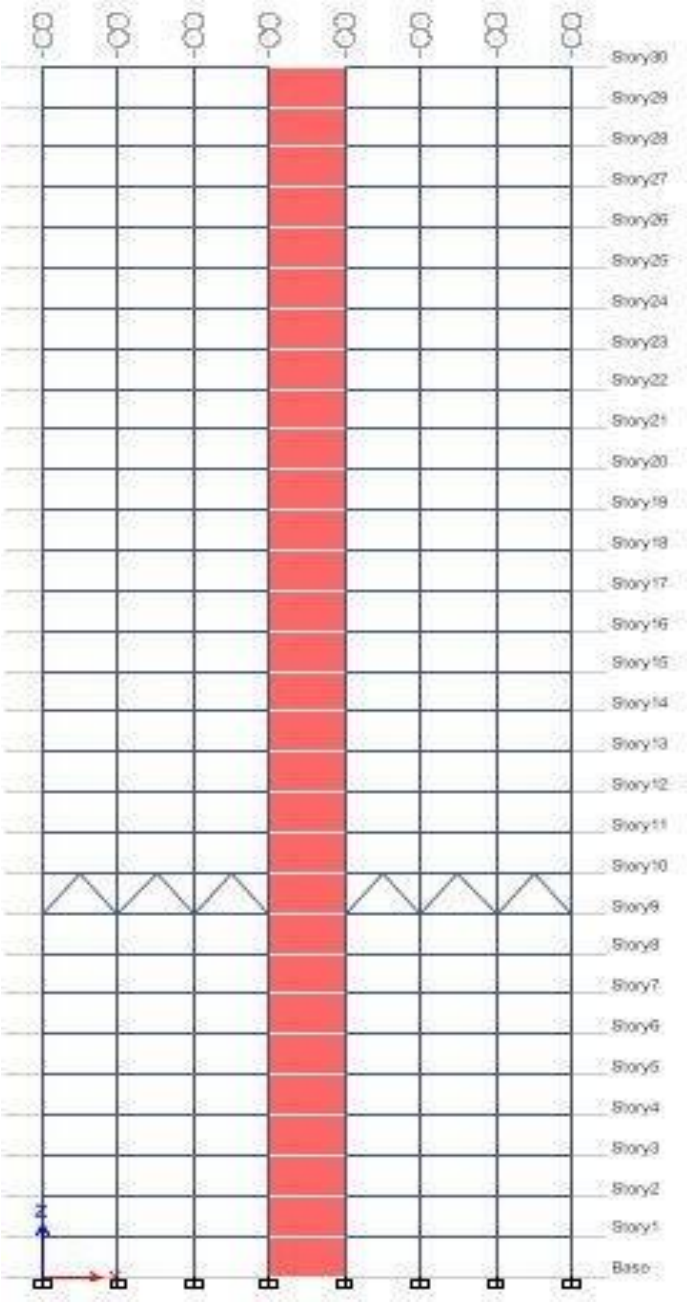
G+30 Building

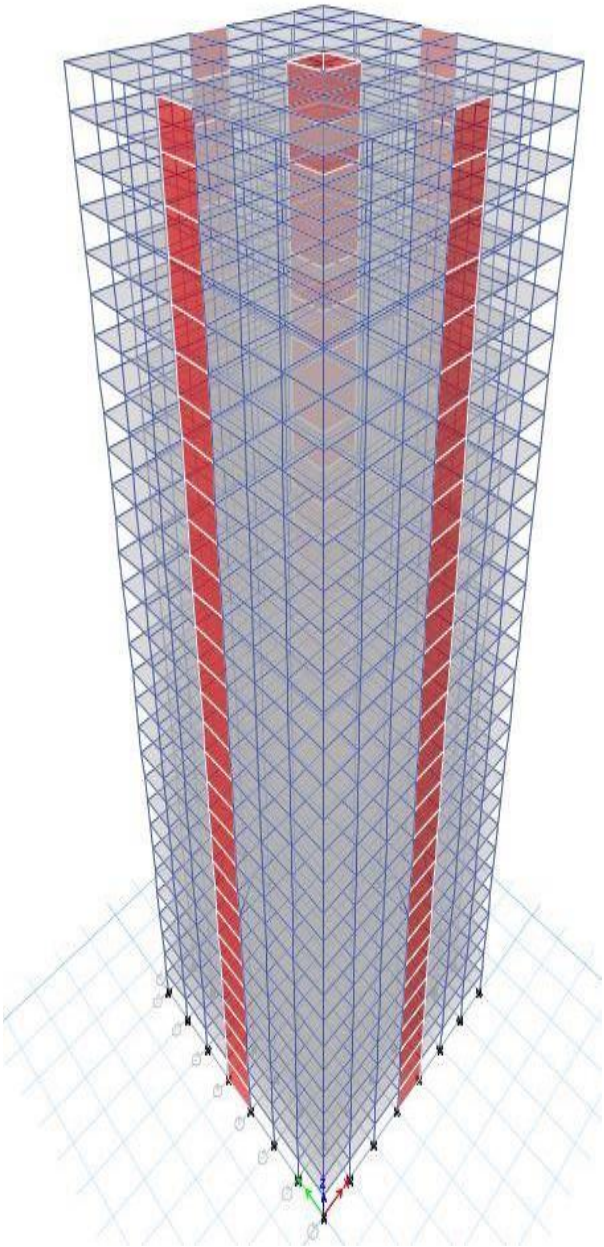
Zone	**Base Shear**
Zone III	**3482 kN**
Zone V	**7834 kN**

TYPE OF CASE	BASE SHAEAR (KN)
Bare Frame	7501.437

Base Shear (KN)	**Software**	**Problem**	**% Error**
	7566 KN	7501.437 KN	0.86%

4.0. Result and comparison





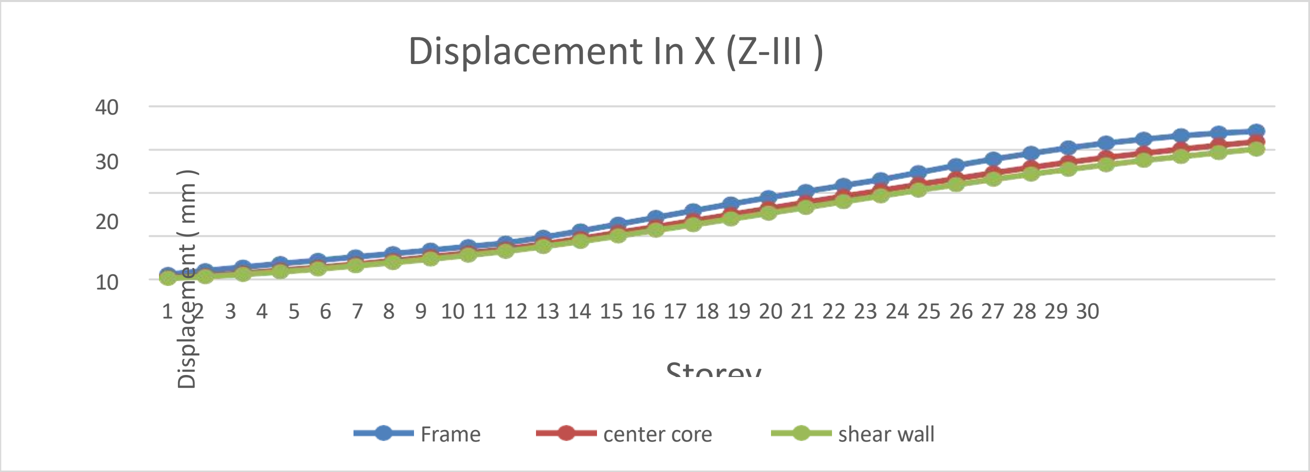


Fig 4.1: Story Displacement in X Direction For Z-III (A-B-C)

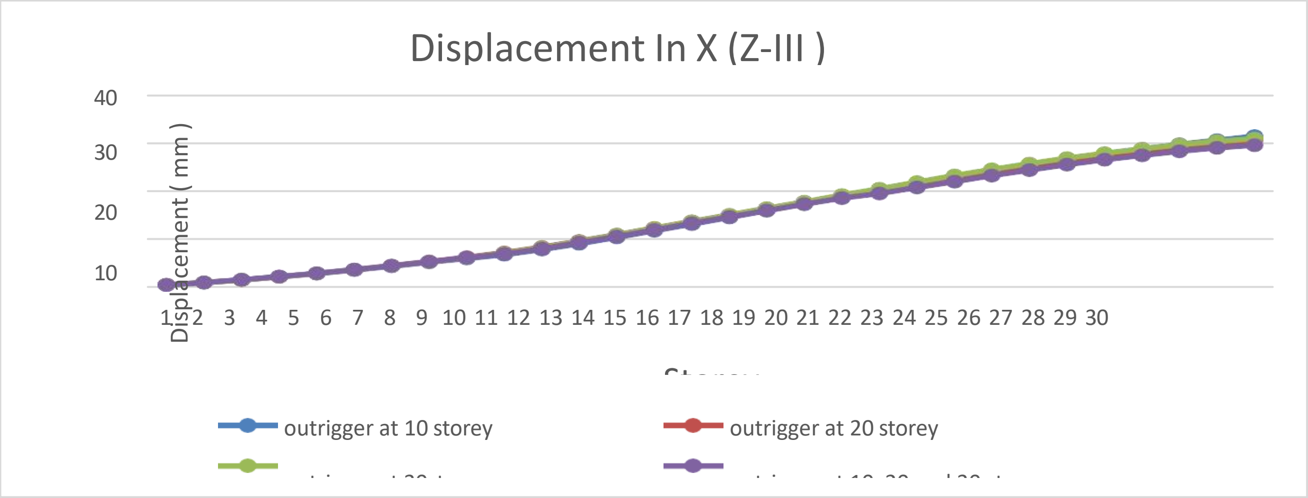


Fig 4.2: Story Displacement in X Direction For Z-III (D-E-F-G)

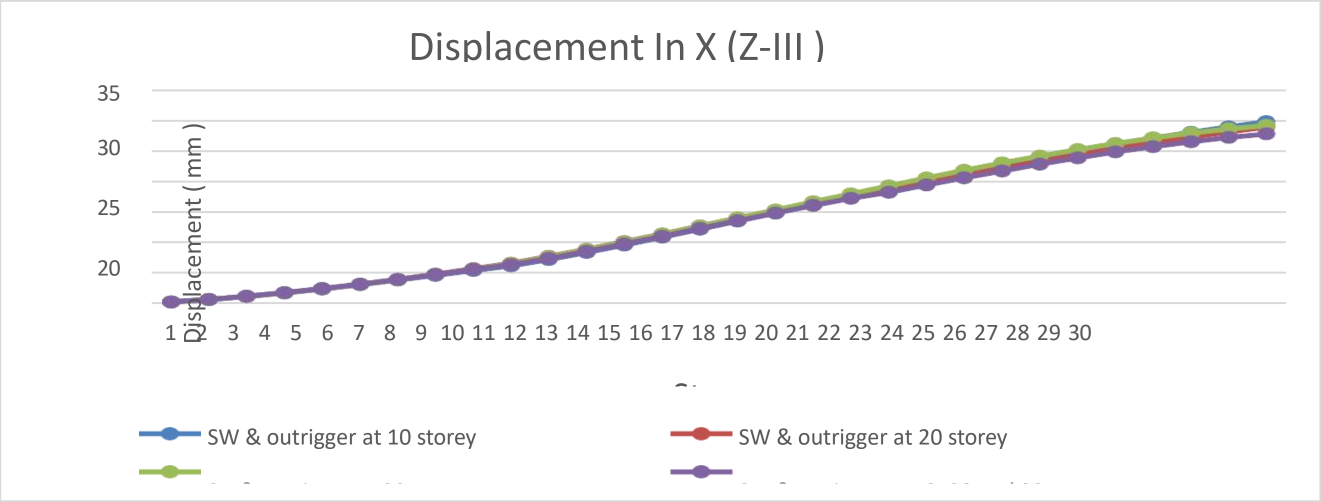
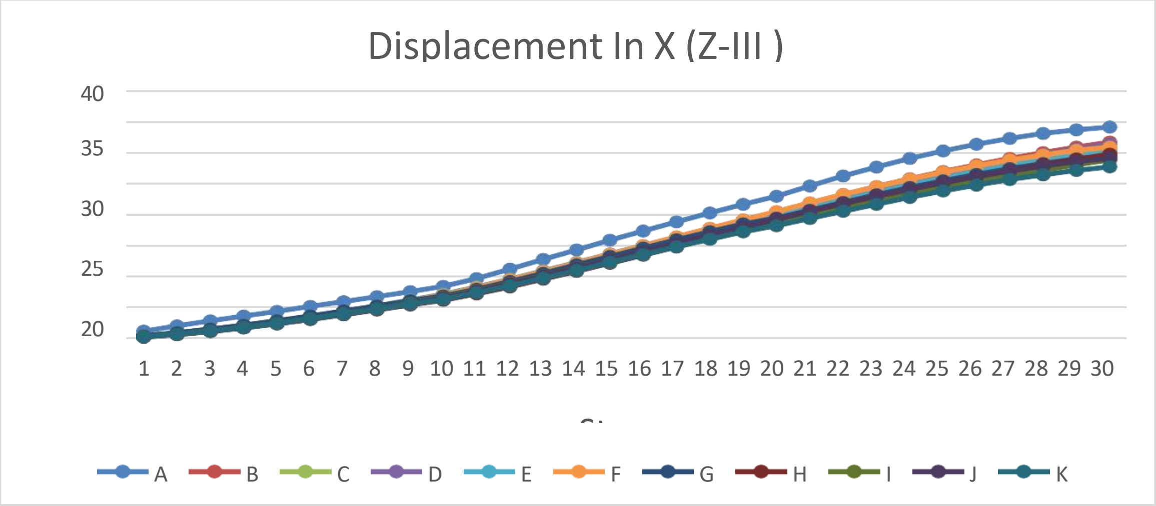


Fig 4.3: Story Displacement in X Direction For Z-III (H-I-J-K)



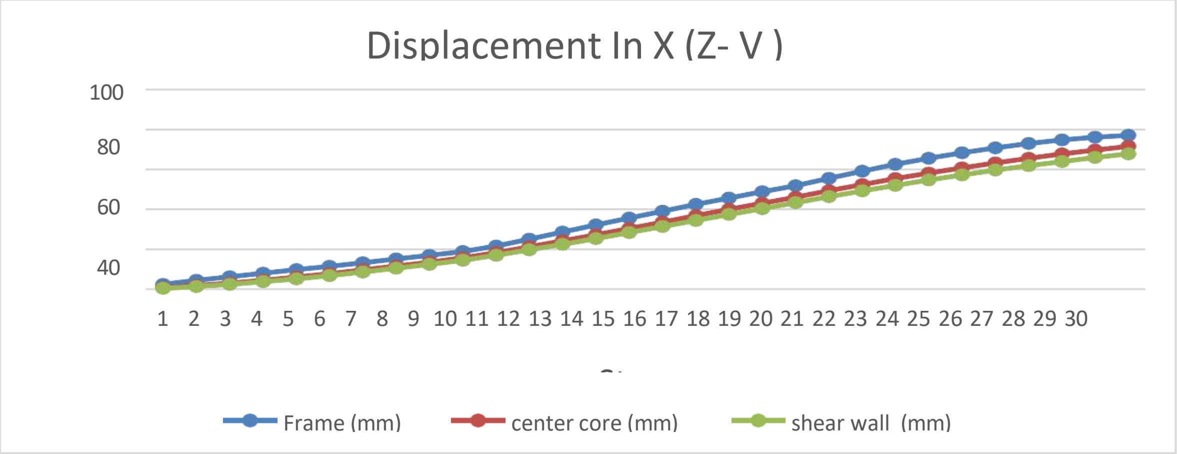


Fig 4.4: Story Displacement in X Direction For Z-V (A-B-C)

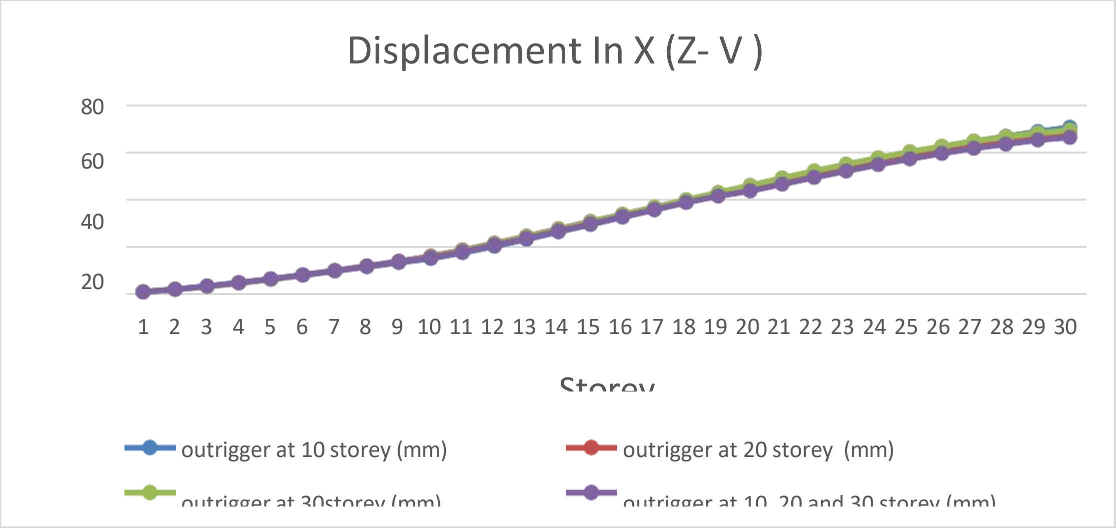


Fig 4.5: Story Displacement in X Direction For Z-V (D-E-F-G)

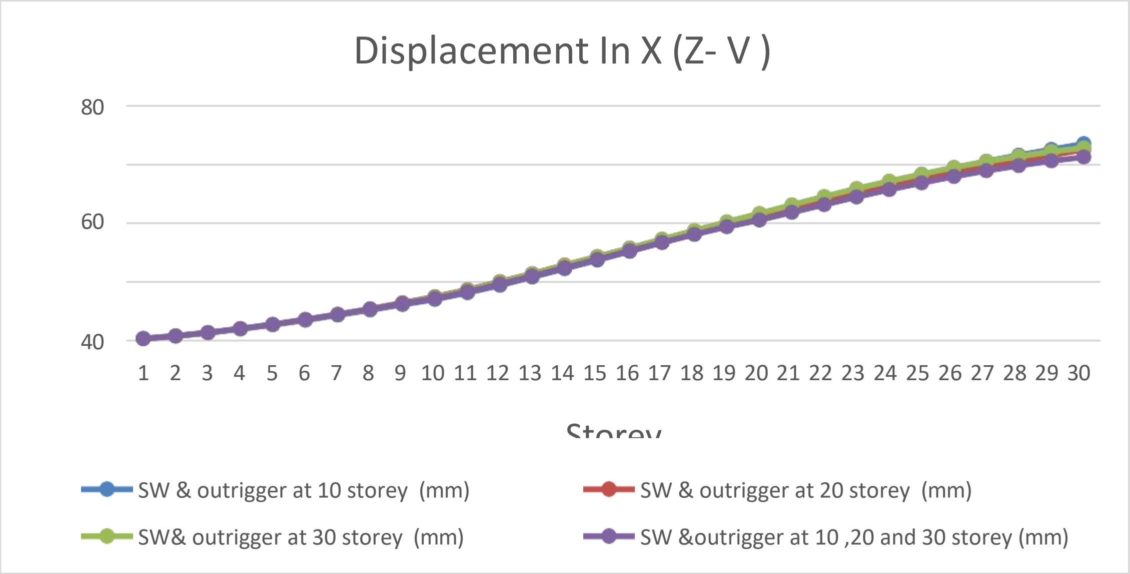


Fig 4.6: Story Displacement in X Direction For Z-V (H-I-J-K)

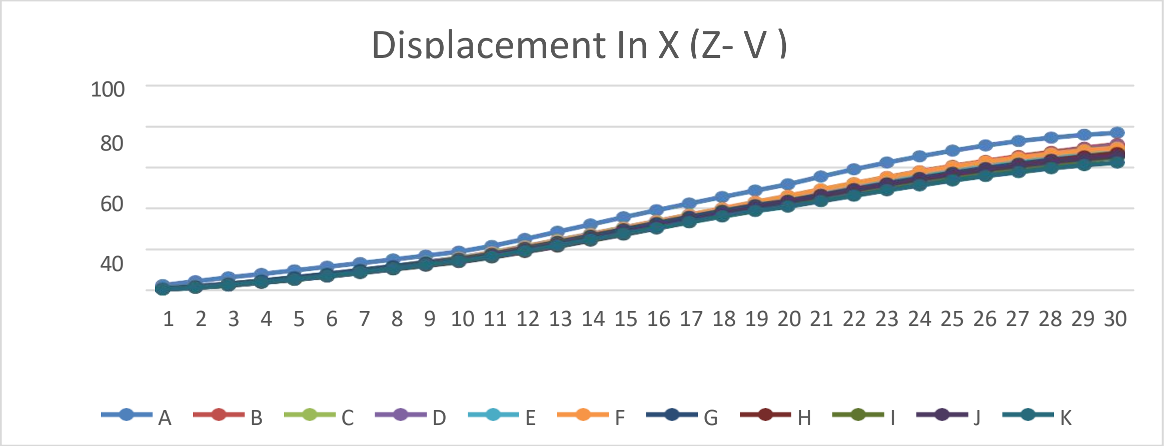


Fig 4.7: Story Displacement in X Direction For Z-V (A-B-C-D-E-F-G-H-I-J-K)

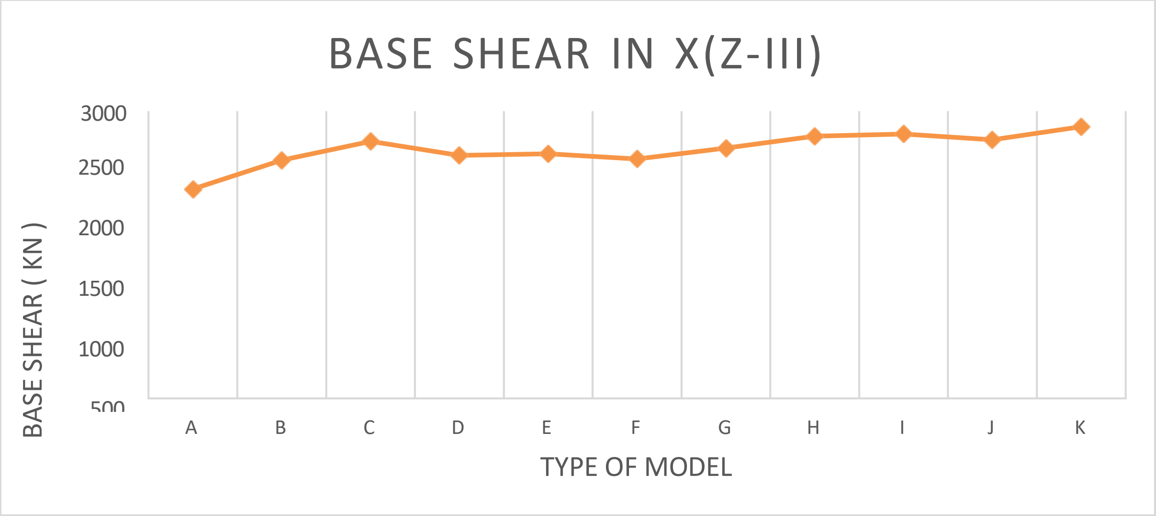


Fig 4.8: Base Shear in X Direction For Z-III (A-B-C-D-E-F-G-H-I-J-K)

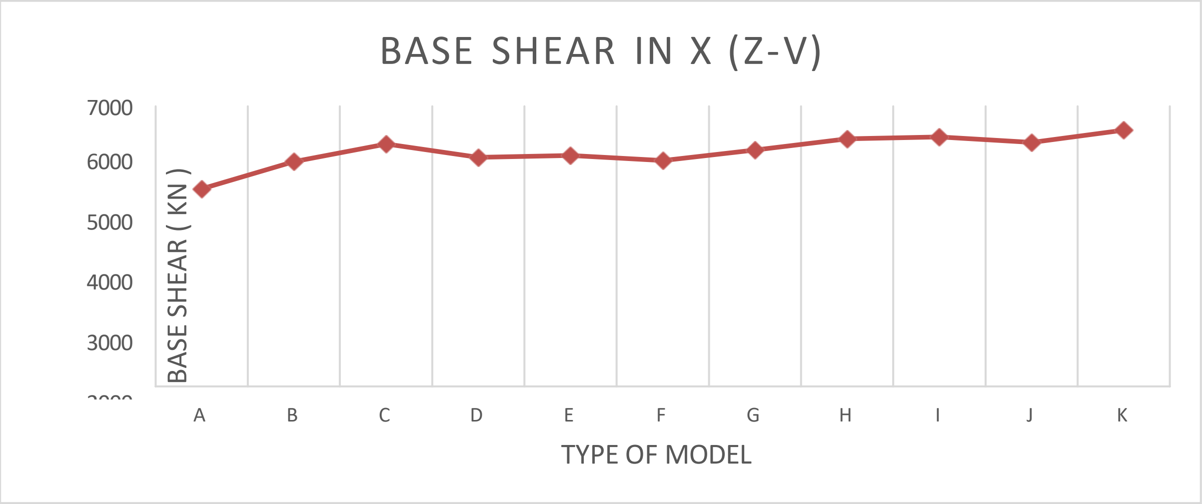


Fig 4.9: Base Shear in X Direction For Z-V (A-B-C-D-E-F-G-H-I-J-K)

6.0 CONCLUSIONS

- Using the shear wall and outrigger both in building reduces the storey displacement compare to shear wall and outrigger individual.
- Optimum location of outrigger is found at G+19 of building to better reduction of storey displacement and storey shear.
- Story displacement were decreased by 11.9% in shear wall ,13.54 % in outrigger, 18.80% in shear wall with outrigger in building as compared to Frame structure.
- Base shear were increased by 18.51%in shear wall,16.38 % in outrigger and 22.90% in shear wall with outrigger as compared to frame structure.

REFERENCES

[1] James Helal , Dario Trabucco , Dalibor Savovic" Embodied carbon premium for vanity height: A case for the exclusion of decorative spires in the design of tall buildings", Elsevier,2024.

[2]Maria Grazia Mallardi , Giuseppe D'Arenzo , Pier Francesco Giordano, Maria Pina Limongelli "Evaluation of optimal lateral resisting systems for tall buildings subject to horizontal loads", Science Direct, 2025.

[3]Giulia Angelucci , Fabrizio Mollaioli, omar Alshawa." Evaluation of optimal lateral resisting systems for tall buildings subject to horizontal load."Science direct, 2020.

[4]Zixiao Wang , komal rajana, Dan-Adrian corfar , Konstantinos Daniel Tsavdaridis "Automated minimum-weight sizing design framework for tall self-standing modular buildings subjected to multiple performance constraints under static and dynamic wind loads" Elsevier, 2023.

[5]Yogesh R. Carpenter, Vishal A. Arekar, Vimlesh V. Agrawal. "Seismic Analysis of Bundled Tall Building Connected with Outrigger System". IARJSET, 2023.

[6]Hussin Ahmad Hasrat, Wahidullah Qazi, Najeebullah Momand." Evaluation of Lateral Load Resisting Systems in High-Rise Buildings"IJCSRR, 2024.

[7]Suraj Sangtiani, Simon J, Satyanarayana J, Dheeraj Sangtiani"] PERFORMANCE OF TALL BUILDINGS UNDER LATERAL LOADS WITH DIFFERENT TYPE OF STRUCTURAL SYSTEMS"IJCIET, 2017.

[8]Vishvesh Jayswal, Aakash Suthar "A Review on Behavior of Connected Tall Buildings with Lateral Load Resisting Systems and Dampers Under Seismic Load" IRJET, 2024.

- IS 1893 (Part 1):2002 Indian Standard, "Criteria for earthquake resistant design of structure General provision and buildings, "Bureau of Indian Standard, New Delhi.
- IS 456: 2000, "Plain and reinforced concrete -code of practice" by Bureau of Indian Standard, New Delhi.
- IS-456, "Code of practice for plain reinforced concrete code of practice," Bureau of Indian Standards, New Delhi,2000.
- IS-875:1987, "Code for Wind load design of structures-general provisions for buildings", Part iii Bureau of Indian Standards, New Delhi.