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COMPARATIVE STUDY OF WIND ANALYSIS ON STRUCTURAL SHAPE WITH & WITHOUT SHEAR WALLS

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Abstract - *This research paper focuses on the recent advancements in building systems with a structural shape and vertical growth impact. A multi-story (G+25) structure with different shapes was modelled in the ETABS 2015 software to check its lateral load stability concerning wind loads. The study aims to identify the best suitable structural shape for stability in wind-prone areas. The analysis compared three different structural shapes: rectangle, square, and C-shape, focusing on three comparative parameters: story displacement, story drift, and base shear with and without shear walls. 2 distinct shear wall configurations were modelled across the 2 different shapes.*

The study found that the rectangular shape structure outperforms the square and C-shape structures in all three comparative parameters. This conclusion is consistent with earlier work in the construction industry, which suggests that rectangular-shaped structures are best suited for stability in wind-prone areas. Based on these findings, the rectangular shape is recommended as the preferred structural shape for high-rise buildings in such areas.

***Key Words*: Shear wall, Wind loads, ETABS, RCC structure, High rise multi story structure, Wind analysis**

1. INTRODUCTION

In this paper high-rise multi-story buildings are more vulnerable to wind lateral stresses than other types of buildings. Although the RCC (Reinforced Cement Concrete) Structure has a lot of rigidity, it cannot withstand wind because of its ineffective resistance. A particular arrangement must be made to make the high-rise structure wind resistant in order for it to endure the larger wind pressure.

Wind is air that is moving. Buildings and other topographic features in the path of the wind deflect or stop the wind, turning its kinetic energy into potential energy of pressure, causing wind load.

1.1 Vortex shedding

Vortex shedding is a common phenomenon in fluid dynamics, which occurs when wind or fluid flows around a body, such as a building or structure. The alternating vortices formed on both sides of the object, detach periodically from the body, and create unsteady and fluctuating pressures. This process can result in destructive vibrations or resonance, which can cause damage or failure to the structure.

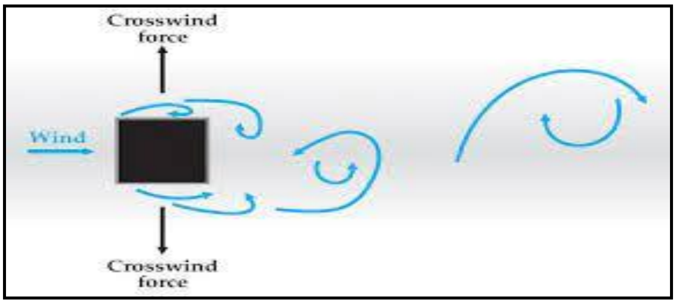

Fig -1: Vortex shedding

1.2 Importance of Wind Loads on the Tall Buildings

The flow pattern created around a building while wind is approaching it is complicated by the mean flow distortion, the flow separation, the vortex generation, and the wake development. A tall building's top floors may shake due to wind, which a passer-by would not notice but may worry individuals who live above. A tall building's top floors may shake due to wind, which a passer-by would not notice but may worry individuals who live above. As we are all aware, the requirement for vertical structure expansion is owing to the limited amount of available land, and this has exposed us to the idea of towering buildings on a huge scale. A tall building typically experiences several effects from wind:

1. It first applies forces and moments to the building's cladding.

2. It primarily distributes "wind" throughout and around the building.

1.3 Wind analysis

Wind analysis is the process of studying and evaluating the behavior of wind on tall buildings. The analysis can be used for various understanding of the wind effects on the environment and design of structure. Wind analysis includes measuring and interpreting wind patterns such as wind direction, speed and even to make weather predictions.

There are actually three types of wind forces that would be exerted on a building:

i) Uplift Wind Load is an upwards force of the wind that would affect roof structures or similar horizontal structures in a building, such as canopies or awnings. The wind flow under a roof structure pushes the roof upwards; the wind flow over the horizontal structure pulls the roof upwards.

ii) Shear Wind Load is a horizontal pressure or force that can cause walls or vertical structural elements to tilt or crack, causing a building to tilt.

iii) Lateral Wind Load is another horizontal wind pressure that can make a structure move off its foundations or overturn.

1.4 Static and Dynamic wind pressure

Static wind pressure is the term used to describe the force that wind exerts on a stationary object or structure. Static wind pressure refers to the force exerted by wind on a stationary structure, such as a building.

Dynamic wind load gives rise to vertical motion, creating oscillations in any direction. Like the breaking of an overused violin string, oscillations are vibrations that can cause a bridge to fail.

i) Story drift refers to the lateral displacement of one story or floor of a building relative to the adjacent floor or story due to wind loads. In other words, story drift measures the horizontal movement between adjacent floors of a building caused by wind-induced lateral forces.

ii) Story displacement refers to the absolute horizontal movement of a building due to wind loads. It is the total distance that a building moves horizontally due to wind-induced lateral forces.

iii) Base shear refers to the lateral force created at the base of a structure due to wind loads. It is the force required to keep the structure from sliding or toppling over. The base shear is proportional to the mass of the building and the acceleration caused by the wind.

1.5 Shear wall

A shear wall is a structured element used in building construction to resist lateral load such as those caused by wind and earthquake or other external forces. A vertical plate like a reinforced concrete wall starting from foundation level and extending up to the full height of the building to form a vertical cantilever is called a shear wall.

It works the best when they are placed symmetrically within or around a building's central axis point. There are two types of alignment for shear walls:

Shear walls along the periphery: Shear walls are provided along the periphery if the possibility of twisting of the building is considerably high. This needs more material for construction.

Shear wall provided as a core to the building, known as shear core. Compared to peripheral shear walls, shear core needs less material and hence economical. But the shear core cannot resist the twisting moment induced by wind loads.

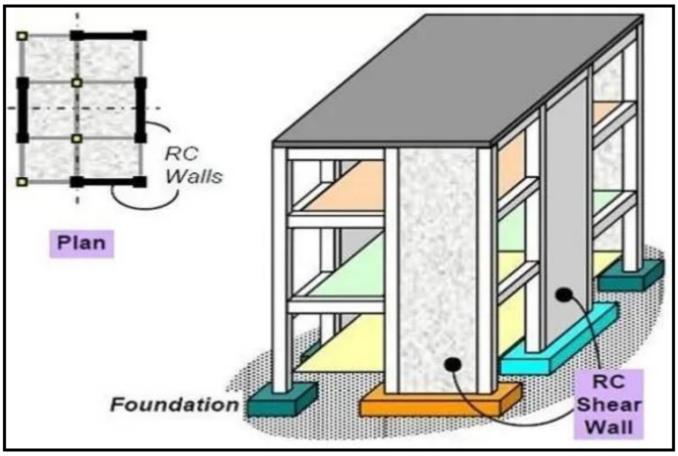

Fig -2: Shear wall

Shear walls can be classified on basis of material that is used and the various materials used for a shear wall are:

Reinforced concrete shear walls are widely used shear walls for residential buildings. The reinforcement is provided in both horizontal and vertical directions. But at the end of each wall, bars are closely spaced and anchored.

Steel shear wall consists of a steel plate wall, boundary column and horizontal floor beam. The action of the steel shear wall is more like a plate girder.

2. DESCRIPTION OF ANALYTICAL MODEL

In addition, computer-based simulations and modelling tools are available and may provide more accurate and efficient assessments of wind effects on objects, making them a preferable alternative to manual methods. Designing a G+25 RCC frame structure model in E-tabs involves several steps, including building geometry, material properties, member design, load application, analysis and results, design verification, final design, construction, and testing. E-tabs provide a powerful toolset for modelling and analyzing complex building structures and can help ensure that the final design meets the required performance criteria.

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Table-1: General Specification of Building for ETABs modelling:

Grade of Concrete	M25
Grade of Reinforcing steel	Fe 415
Density of Concrete	25 KN/m^3
Density of Brick masonry	20 KN/m^3
Damping ratio	5%
Shear wall thickness	250 mm
(G+25)	86 M
Storey Height	3.1 M
Bottom Storey Height	2.5 M
Thickness of wall	230 mm

These are the general description of the analytical model that contents general specification of the structure about its grade and density of steel and concrete, damping ratio, thickness of the shear wall, thickness of walls, and general height of the structure.

This detail where used while modelling the structure in ETABS software to obtain the results occurring because of the wind acting on the structure.

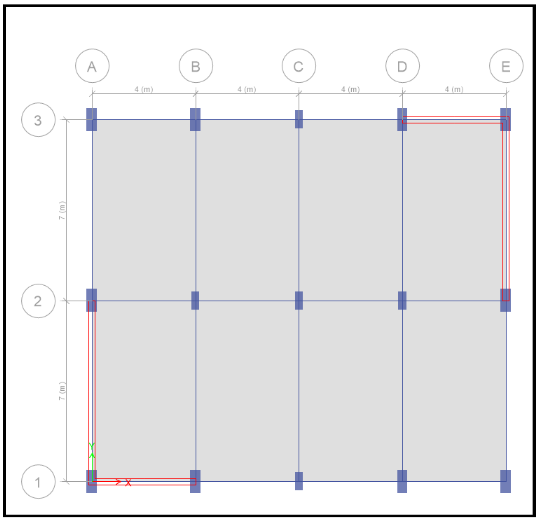
Table-2: Specification of loading & sizes of beam column at different level:

Floor load	1 KN/m^2
Live load	4 KN/m^2
Wall load	12 KN/m^2
Structural class	B
Basic wind speed	50 m/s
Risk coefficient (K1)	1
Topography factor (K3)	1
Wind design code	IS 875:1987 (Part 3)
RCC design code	IS 456:2000
Steel design code	IS 800:2007

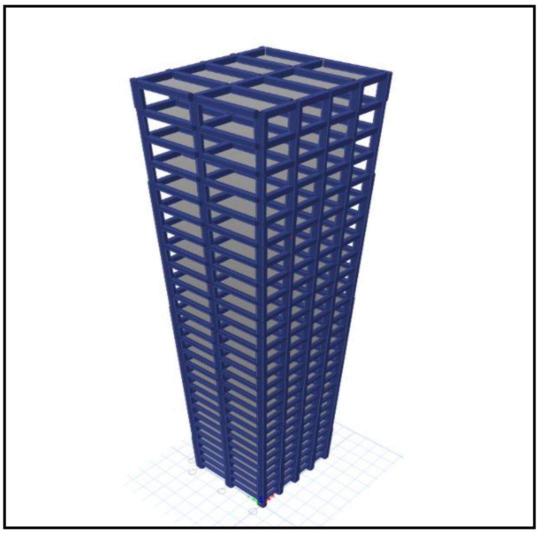
Table-3: the following table represents the dimension of the beam and reduction in the sizes of column: -

RCC	Section
Beam	350X700
Column up to 16th story	
Column 1	900x1100
Column 2	700x1100
Column 3	500x1000
Column from 16th to 25th story	
Column 4	450x1000
Column 5	400x900
Column 6	300x700

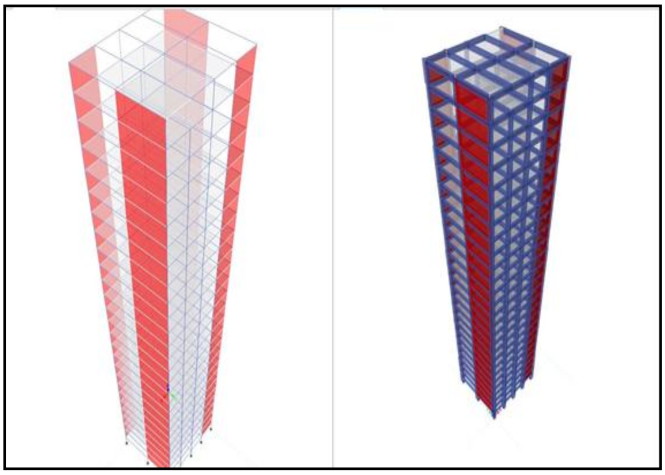
Step 1 - Modelling & Analysis of Rectangle Shaped RCC Model of G+ 25 Storeys:



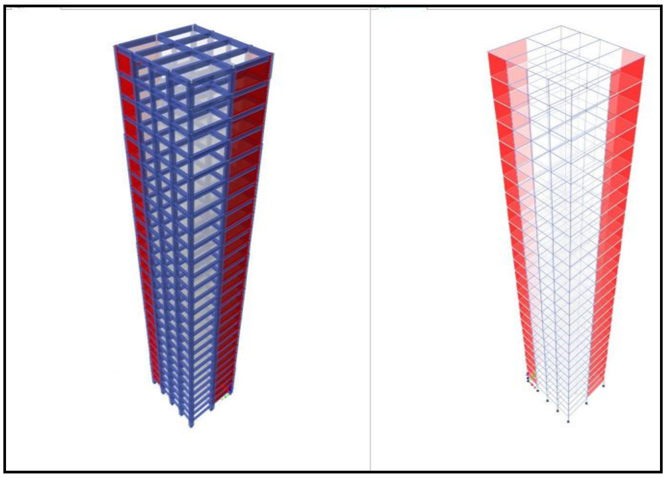
2D Plan view of rectangular shape structure



Case 1: 3D analytical model of rectangular shape Structure without shear wall.

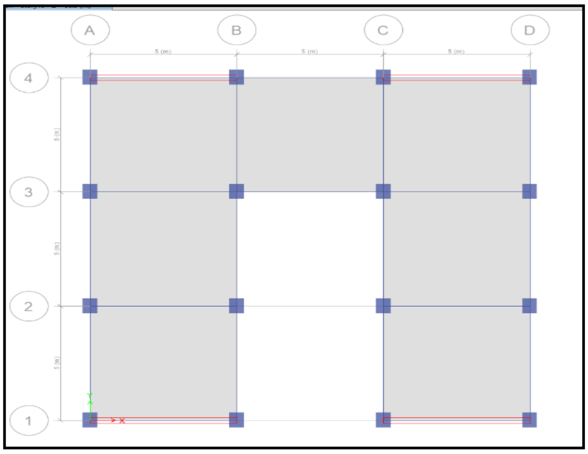


Case 2: 3D views of rectangular-shape Structure with shear wall.

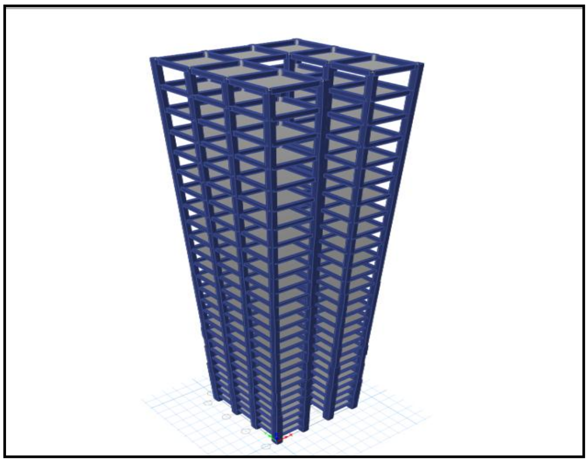


Case 3: 3D views of rectangular-shape Structure with shear wall.

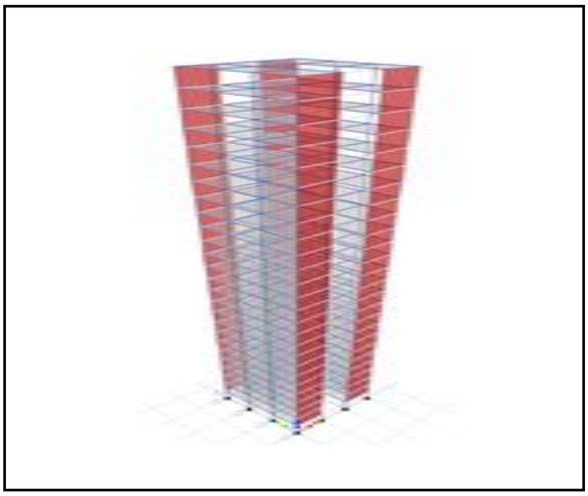
Step 2 - Modelling & Analysis Of C Shaped Model RCC Model Of G+25 Storeys:



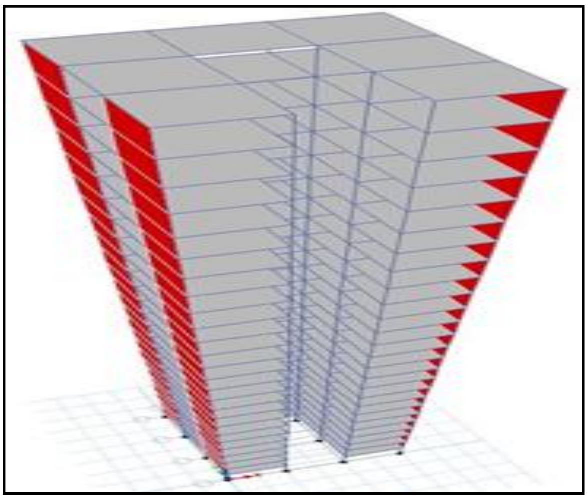
2D Plan view of H shape structure.



Case 1: 3D analytical model of C shape structure without shear wall.

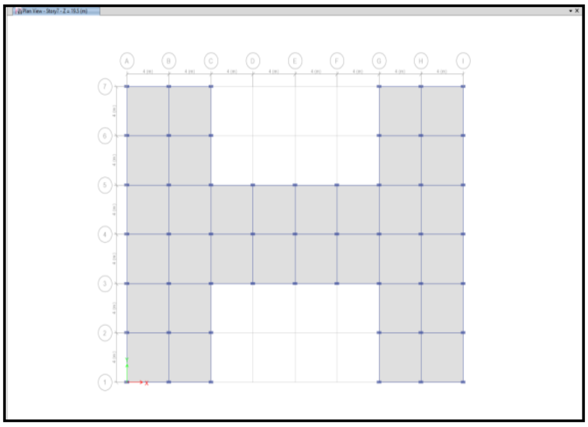


Case 2: 3D views of C-shape Structure with shear wall. Along Z axis.

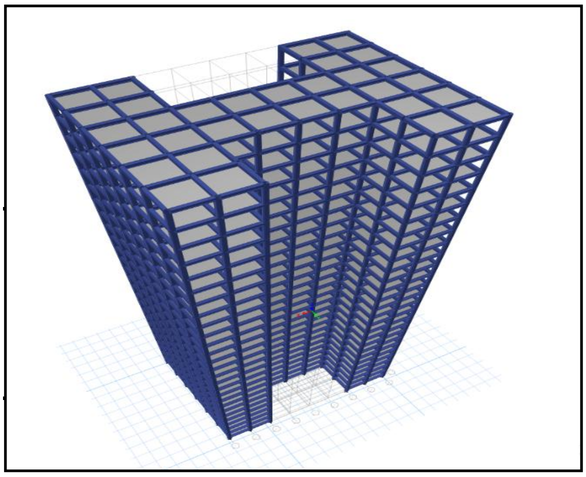


Case 3: 3D views of C-shape Structure with shear wall. Along x axis.

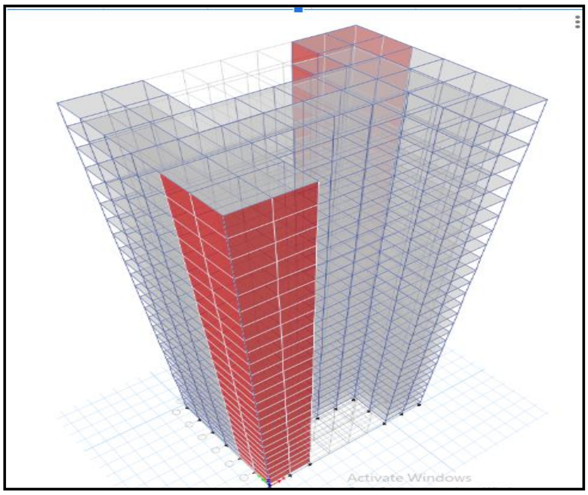
Step 3 - Modelling & Analysis Of H Shaped Model RCC Model Of G+25 Storeys:



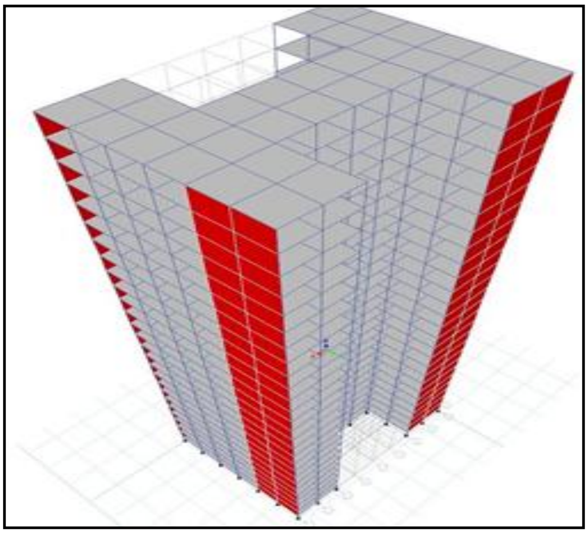
2D Plan view of C shape structure



Case 1: 3D analytical model of H shape structure without shear wall.



Case 2: 3D views of H shape Structure with shear wall.



Case 3: 3D views of H shape Structure with shear wall.

3. OBSERVATIONS

In total we have modelled and analyzed 3 cases for each shape, and then to save complexity and to maintain a simpler understanding only taken the minimum values from each case to compare them against each other.

3.1. Results of story drift:

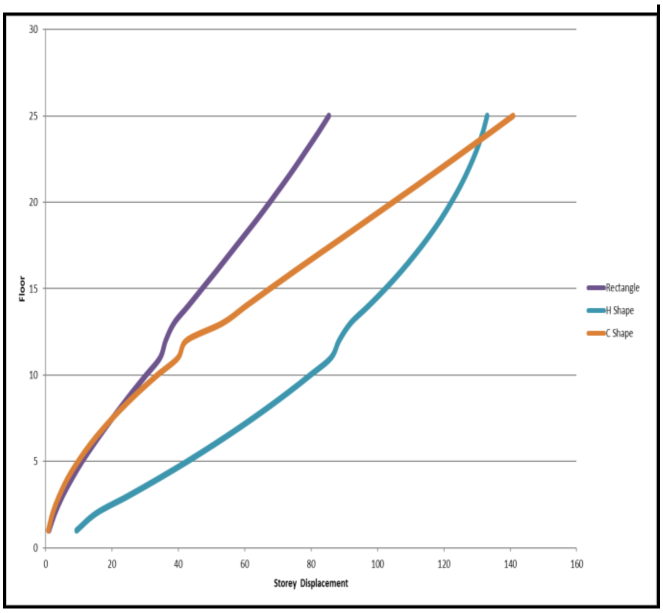


Chart -1: Story drift

The story drift of the Rectangle shape is consistently lower than both H-shape and C-shape. The difference becomes more significant as the building gets taller. For example, at story 25, the story drift for the Rectangle shape is 28% lower than the H-shape and 58% lower than the C-shape. The H-shape provides better control over building sway than the C-shape. The difference becomes more significant as the building gets taller.

3.2. Results of Base Shear Reactions

H shape			Rectangle			C Shape		
Case	**Fz - kN**	**Mx kN- m**	**Case**	**Fz - kN**	**Mx kN- m**	**Case**	**Fz - kN**	**Mx kN- m**
L Shape	405338	4864053	L Shape	185952	1301666	L Shape	221855	1552992
4 Way	428843	5145220	4 Way	202571	1417997	4 Way	236115	1652813
No Shear Wall	428731	5144770	No Shear wall	202396	1416024	No shear wall	236055	1652396

3.3. Results of story displacement

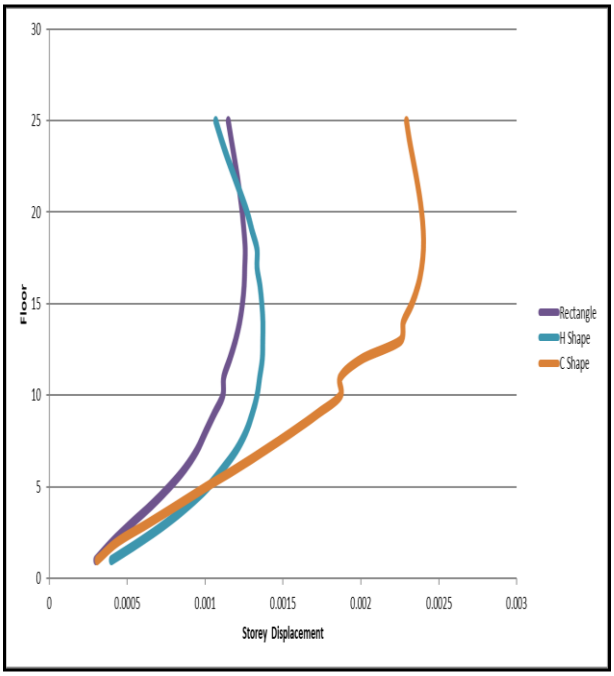


Chart -2: Story Displacement

The story drift of the Rectangle shape is consistently lower than both H-shape and C-shape. The difference becomes more significant as the building gets taller. For example, at story 25, the story drift for the Rectangle shape is 28% lower than the H-shape and 58% lower than the C-shape. The H-shape provides better control over building sway than the C-shape. The difference becomes more significant as the building gets taller

4. CONCLUSION

Displacement: Rectangle model performs better than H and C shape models with % differences of 88% and 19% respectively at the highest story, indicating higher resistance to lateral loads and lower displacements.

Story Drift: Rectangle model exhibits better results in story drift than H and C shape models with % differences of 34% and 21% respectively at the highest story, meaning it is more stable and can resist lateral loads better.

Base Reaction: Rectangle model outperforms L shape, T shape, and 4-way models in base reactions with % differences of 54%, 54%, and 46% respectively in Fz and % differences of 59%, 47%, and 48% respectively in Mx, implying it can handle higher loads and moments at the base, making it more stable.

Shear Wall: Rectangle model has better shear wall design efficiency than other models and requires the least amount of shear walls to meet the target drift limits, leading to minimal use of resources and materials.

Cost-Effective: The rectangle model emerges as the most cost-effective option due to better performance with less material usage and reduced construction costs.

Overall, the rectangle model is a better choice for high-rise building design based on the % difference in displacement, story drift, base reaction, shear wall design efficiency, and cost-effectiveness.

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