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Analysis of Multi-Storey Building for Efficient Location of Outrigger and Wall-Belt Support System in Earthquake Zones

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Abstract: With the growing need for vertical expansion in modern cities, high-rise buildings must be designed to withstand lateral forces, especially those resulting from seismic events. Outrigger and wall-belt systems have emerged as effective structural solutions to enhance the performance of tall buildings under such loads. This study presents a detailed investigation into the optimal location of a single outrigger and wall-belt support system in a G+20 storey reinforced concrete building situated in Seismic Zone III of India. Using CSI ETABS software, six different structural configurations (OTS1 to OTS6) were modeled and analyzed to evaluate parameters such as lateral displacement, base shear, bending moments, and axial forces. The results demonstrate that placing the outrigger and wall-belt system at the third floor level significantly improves the building's lateral load resistance. The findings offer valuable insights for structural designers aiming to enhance the seismic resilience of tall buildings.

Keywords: Outrigger system, Wall-belt support, Seismic load resistance, High-rise building, Lateral displacement, ETABS analysis

I. INTRODUCTION

The increasing demand for high-rise buildings has introduced new challenges in structural engineering, particularly in ensuring stability against lateral loads due to wind and seismic forces. In seismic zones, the effects of earthquakes on tall structures can be catastrophic if not properly addressed during the design phase. A structure is considered safe and acceptable when it performs satisfactorily under the combined action of gravity and lateral loads without exceeding permissible limits of deformation or instability. Conventional systems like shear walls, braced frames, and moment-resisting frames have limitations in taller structures. To overcome these, structural systems such as outrigger and belt truss systems have been developed. These systems improve the lateral stiffness and strength of tall buildings by engaging peripheral columns in resisting overturning moments induced by lateral loads. The location and configuration of outriggers significantly influence their effectiveness. This research investigates the performance of a G+20 storey reinforced concrete frame building using various outrigger and wall-belt placements. The analysis helps identify the most efficient configuration for reducing lateral displacement and optimizing internal forces in columns and beams under seismic conditions.

Outriggers

Outriggers are defined as the members who consist of the beams or contact plates from the center to the outside of the posts on both sides that block the structure and operation of the connecting links. The core was provided as a detachable bar holding the entire structure firmly to accommodate loads and moving equal loads out of poles. Greater stiffness is accomplished in this type of structure than conventional frame. An outrigger combines the two elements adding a strong solid that interferes with emergency power. If an outrigger-reinforced building under wind or seismic loads deflection, the outrigger connects the main wall to and away from the posts, a unit to resist lateral loads is act on replaced the full structural system.

Belt Supported System

The best technique used in huge-story houses is to maintain the body whether it is a bar belt or a truss belt system. Its representatives to the structural nodal points & communicate through it. They are termed as belt support systems the reason is the belt is usually made of trusses or bolts, connecting the structure line. The load departs from each member being distributed equally housing. In order to adapt to the force of the wave and to maintain the stability of the structure, the outer straps and straps are used. The Policy is that the outer poles are fitted with the center of the bar with the braces and straps in one or more positions. The truss straps are attached to the outside pillar of the house while the outside holds them to the main or central vertical wall. The reason behind is this approach due to reduction value is occurs in interference structure with respect to the conventional method.

II. OBJECTIVE

The primary objectives of the research include:

- 1.To analyze the lateral behavior of a G+20 storey structure under seismic loads using Response Spectrum Analysis.
- 2.To investigate the effectiveness of a single outrigger and wall-belt support system at various heights.
- 3.To evaluate the structural performance through parameters such as displacements, base shear, axial forces, bending moments, and shear forces.

III. MODELLING APPROACH

3.1 Modeling of Structure and Assigning property

The space frame has been modeled in E-Tabs software. The descriptions of the structure, single outrigger and wall belt specifications are listed in Table 3.1. The connections between all the members are assumed to be fixed. The arrangement idealization and member segment property details of all cases are shown in Table 3.1. Various plans and 3D views are shown in subsequent figures. Since when using E-Tabs software, user has to define the properties to tell the software that which material is going to use with its size in a particular model. Such properties which are used in this work are mentioned below: -

Table 3.1: Description of parameters taken for analysis

Building configuration	G + 20
Building type	Commercial Apartment
Building Length	6m @ 5 bays
Building Width	5m @ 6 bays
Height of building from footing	82m
Depth of footing	4 m
Beam dimensions	550 mm x 400 mm with M25 grade
Column dimensions	600 mm x 550 mm with M25 grade
Outrigger Thickness	0.135m (M30)
Wall Belt Thickness	0.130m (M30)
Slab thickness	150 mm
Staircase waist slab	145 mm
Shear wall thickness	155 mm

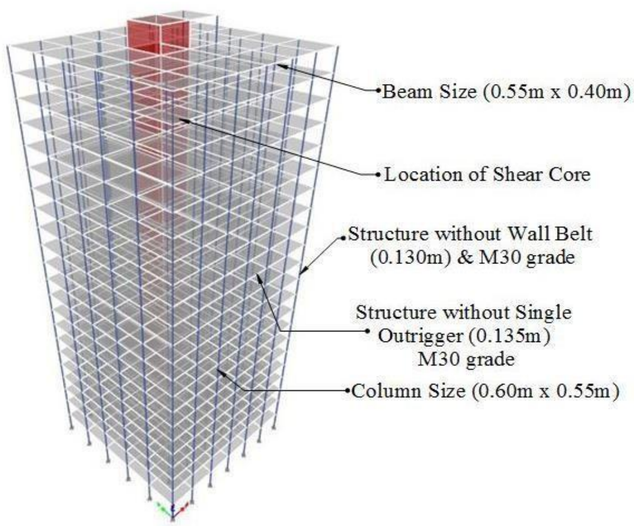

Figure 3.1: Case OTS1: Regular Structure with no Outriggers and Belt Supported system

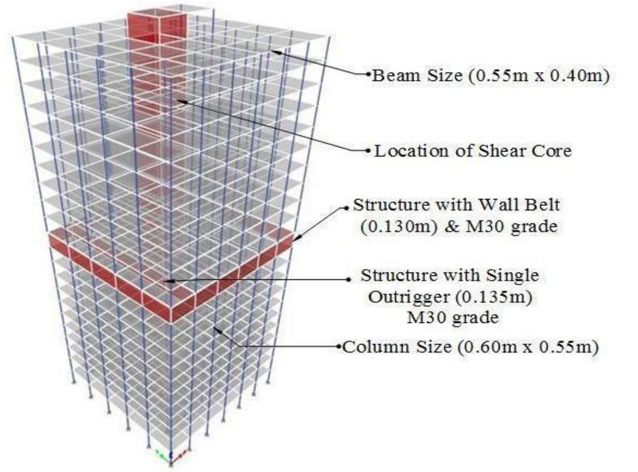

Figure 3.2: Case OTS2: Single Outrigger and Wall Belt Supported System at B1with Dual Core

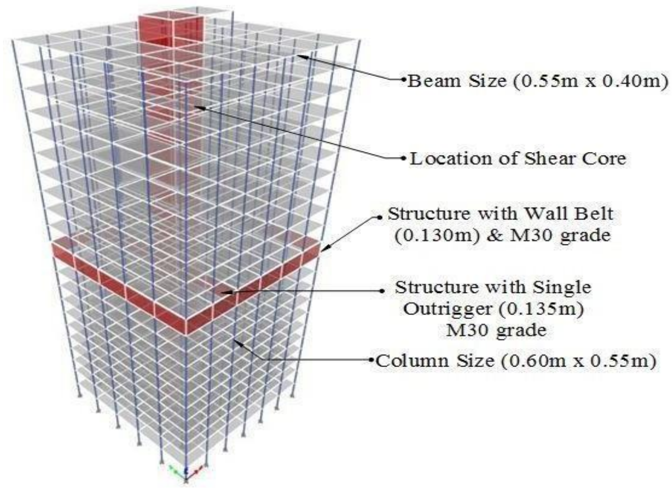

Figure 3.3: Case OTS3: Single Outrigger and Wall Belt Supported System at C1with Dual Core

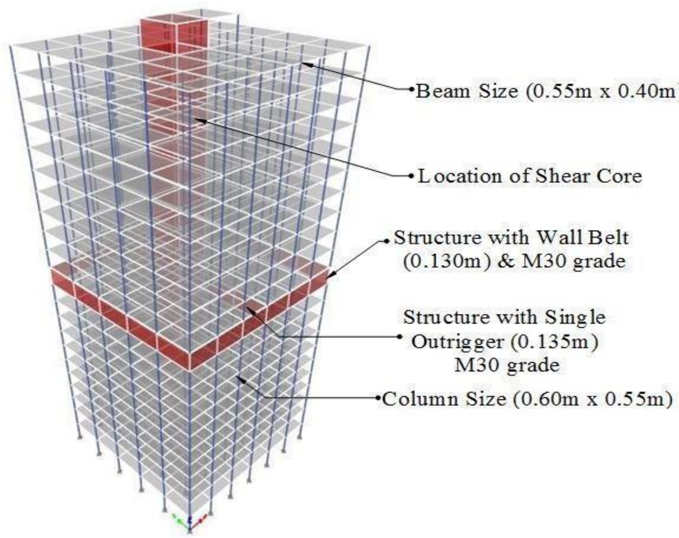

Figure 3.4: Case OTS4: Single Outrigger and Wall Belt Supported System at D1with Dual Core

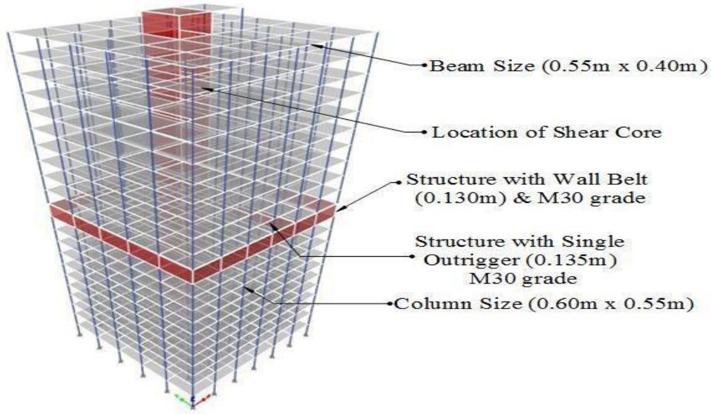

Figure 3.5: Case OTS5: Single Outrigger and Wall Belt Supported System at E1with Dual Core

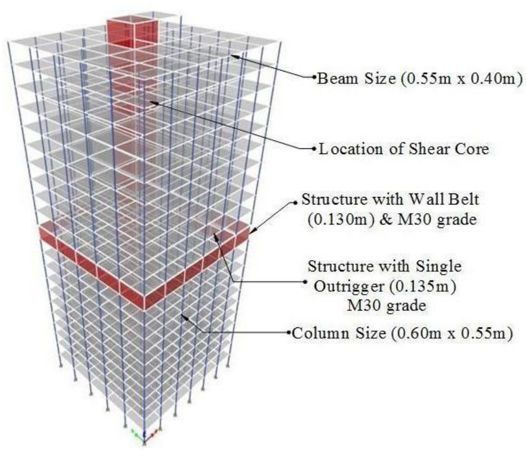

Figure 3.6: Case OTS6: Single Outrigger and Wall Belt Supported System at F1with Dual Core

IV. RESULT AND DISCUSSION

4.1 Displacement

Table 4.1 Displacement in X and Z direction for Outrigger and wall belt supported system at different level

Cases	**Displacement (mm)**	
	For X Direction	**For Z Direction**
Case OTS1	284.688	269.734
Case OTS2	246.908	211.959
Case OTS3	246.221	195.675
Case OTS4	247.135	190.66
Case OTS5	246.61	207.583
Case OTS6	246.286	212.696

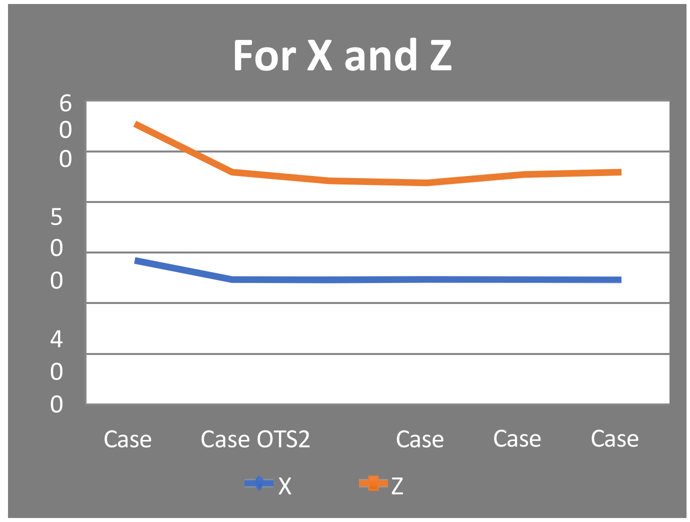

Fig. 4.1: Graphical Representation of Displacement in X direction for Outrigger and wall belt supported system at different level

4.2 Axial Force

Table 4.2: Axial Forces in Column for all for Outrigger and wall belt supported system at different level

Cases	**Column Axial Force (KN)**
Case OTS1	7913.5328
Case OTS2	7188.1145
Case OTS3	7122.2883
Case OTS4	7077.9609
Case OTS5	7158.6939
Case OTS6	7220.0373

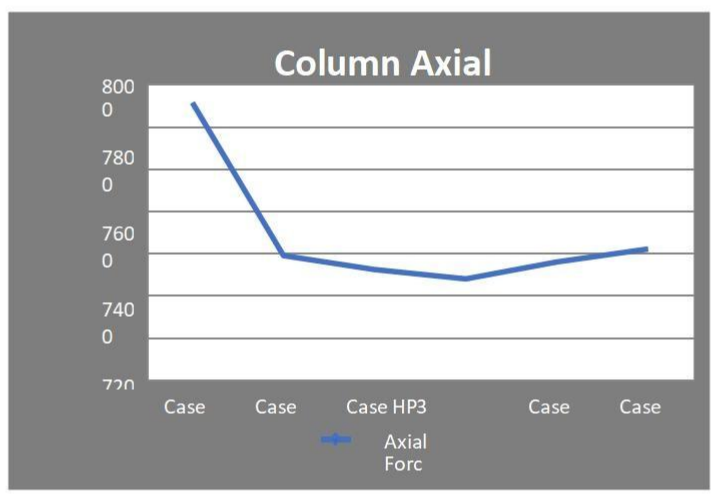

Fig. 4.2: Graphical Representation of Axial Forces in Column for all for Outrigger and wall belt supported system at different level

4.3 Base Shear

Table 4.3: Base Shear in X and Z direction for all for Outrigger and wall belt supported system at different level

Cases	Base Shear (KN)	
	X direction	Z direction
Case OTS1	5321.9388	5321.9352
Case OTS2	5389.3595	5389.356
Case OTS3	5384.4732	5384.4728
Case OTS4	5384.4729	5384.4747
Case OTS5	5387.1615	5387.1619
Case OTS6	5387.1612	5387.1582

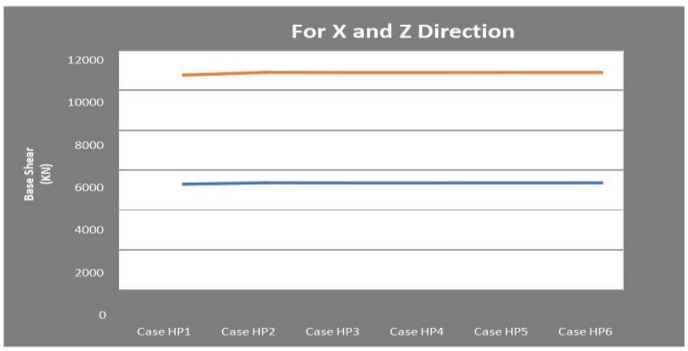

Fig. 4.3: Graphical Representation of Base Shear in X direction for all for Outrigger and wall belt supported system at different level

4.4 Shear Force

Table 4.4: Shear Force in Column for all for Outrigger and wall belt supported system at different level

Cases	Column Shear Force (KN)	
	Shear along Y	Shear along Z
Case OTS1	137.4636	136.0902
Case OTS2	180.9536	196.1098
Case OTS3	183.4581	188.5578
Case OTS4	181.9816	189.0116
Case OTS5	181.3896	176.9272
Case OTS6	180.4866	193.1373

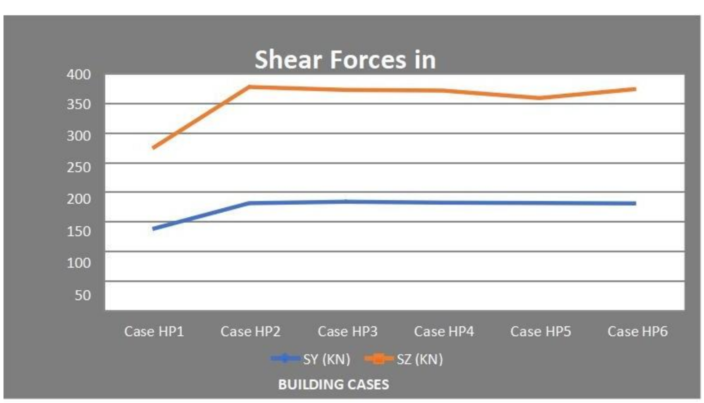

Fig. 4.4: Graphical Representation of Shear Force in Column for all for Outrigger and wall belt supported system at different level

4.5 Bending Moment

Table 4.5: Bending Moment in Column for all for Outrigger and wall belt supported system at different level

Cases	Column Bending Moment (KN m)	
	Moment along Y	Moment along Z
Case OTS1	208.4792	239.2556
Case OTS2	462.0692	404.54
Case OTS3	434.764	411.8289
Case OTS4	436.8066	409.866
Case OTS5	411.9202	408.6063
Case OTS6	447.5797	403.877

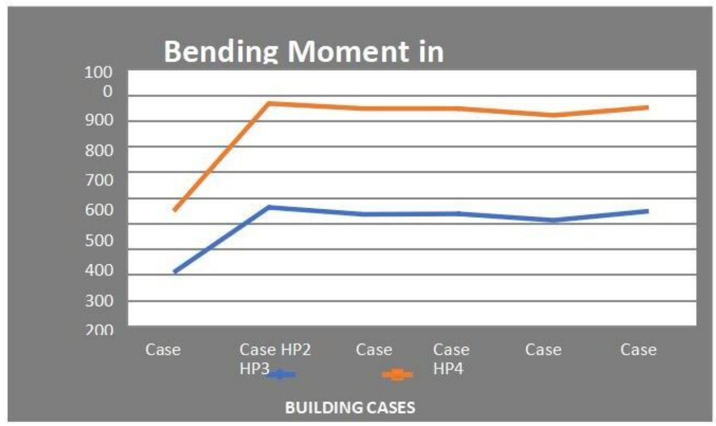

Fig. 4.5: Graphical Representation of Bending Moment in Column for Outrigger and wall belt supported system at different level

V. CONCLUSION

1. Lateral displacement was significantly reduced in the outrigger-supported models. The most effective configuration was found in Case OTS4, where the displacement in the Z-direction was reduced by approximately 40.41% compared to the base model (OTS1), clearly indicating better resistance to lateral movement.

2. Axial forces in columns showed notable improvement with the inclusion of the outrigger system. Specifically, Case OTS4 recorded an 11.18% reduction in axial force compared to the basic structure, demonstrating improved load distribution.

3. In terms of base shear, models with outrigger supports (especially OTS4 and OTS3) experienced a slight improvement of around 1.27%, indicating better stability under seismic conditions.

4. For shear forces in columns, Cases OTS5 and OTS6 showed substantial reductions—up to 44.10%—which implies a lower internal force demand on structural elements, improving safety and durability.

5. Similarly, the bending moments in columns were considerably lower in outrigger-supported structures. Case OTS5 and OTS6 showed reductions of up to 121.64% and 69.08% respectively compared to the base case.

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