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Enhancing Seismic Performance of Semi-Commercial Apartment having Telecommunication Tower at Roof

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Abstract: When studying the impact of seismic activities on a structure, we focused on the efficient case and didn't consider the worst-case scenario. If a telecommunication tower is planned on a multistoried building in the future, and the tower is in the worst possible location, certain measures need to be taken to stabilize it and adjust the parametric values.
In this research, we analyzed a total of 5 semi-commercial apartment building cases with G+19 floors, each having different telecommunication tower locations.
After the analysis, we identified the worst case and implemented an outrigger system, as discussed in the graphical representations in the discussion section. In conclusion, we compared parametric results and observed that Case TTD is very efficient, while Case TTA is the worst among all the cases.
We also improved the stability of the worst-case TTA and transformed it into Case TTO through the implementation of the outrigger system, as indicated by our results and discussions.
Keywords: Seismic activities, Multistoried Building, Response spectrum method, telecommunication tower

I. INTRODUCTION

When considering the safety of human civilization, earthquakes emerge as a major threat, causing harm to lives, structures, and property. Worldwide, ongoing experimental efforts aim to address this issue and create environments that can withstand earthquakes, ensuring a secure and hassle-free life. Modern structures are designed with special techniques to withstand earthquake forces, often at a higher manufacturing cost.

In India, the common practice for constructing tall buildings is using a reinforced concrete frame. The country is divided into earthquake zones (Zone II, III, IV, and V), and structures in these zones need to be analyzed and designed with extra stiffness and ductility to minimize damage. Steel bracing arrangements within the frame structure are used to reduce lateral effects, providing strength, stiffness, and architectural appeal. Bracings are crucial for resisting movement in structures.

Another element to enhance stiffness in construction is the shear wall, typically located around the lift area in what is known as the core-type shear wall system. Shear walls not only increase stiffness but also enhance stability against overturning and reduce lateral effects. Following Taranath's approach, shear walls can serve as an outrigger system to minimize deflection and mitigate the worst effects of lateral forces.

This system can be implemented at 0.466 of the structural height, combining shear wall outriggers with shear core to form a comprehensive outrigger system.

II. PROCEDURE AND 3D MODELLING OF THE STRUCTURE

An earthquake analysis was conducted on a G+19 storey semi commercial apartment using a software-based approach. Five different models were created in the software, initially placing the tower in various positions atop the apartment. Subsequently, the most efficient and worst-case scenarios were identified, and optimization measures were applied to the parameters of the worst-case using an Outrigger system.

The analysis involved assessing the impact on the building under different loads, including dead load, live load, and lateral loads such as those from earthquakes and wind, using the software's mechanisms. Seismic data conforming to IS 1893(PART1):2016 standards was utilized, and the analysis employed the response spectrum analysis method to evaluate the building's behavior.

Table 1: Descriptions of different models

S. No.	Buildings framed for analysis	Abbreviation
1	Semi commercial apartment with telecommunication tower at A	Case TTA
2	Semi commercial apartment with telecommunication tower at B	Case TTB
3	Semi commercial apartment with telecommunication tower at C	Case TTC
4	Semi commercial apartment with telecommunication tower at D	Case TTD
5	Semi commercial apartment with telecommunication tower at E	Case TTE
6	Semi commercial apartment with telecommunication tower at worst location with outrigger support system	Case TTO

Table 2: Data taken for analysis of structure

Constraint	Assumed data for all buildings
Soil used	Medium Soil
Zone factor Z	0.16
Importance factor I (For all semi commercial building)	1.2
Build up area of building	625 sq. m
Floors configuration	G + 19 (Semi-commercial Apartment)
Depth of foundation	4 m
Floor to floor height	GF-4 m, All floors-3.5 m each
Fundamental natural period of vibration (T_a)	$0.09*h/(d)^{0.5}$
Earthquake parameters	Zone III with RF 4 & 5% damping ratio
Period in X & Z direction	1.341sec. for both direction
Slab thickness	128 mm
Shear wall and Outrigger thickness	138 mm
Tower horizontal and Vertical elements	ISA 130x130x16
Tower bracing elements	ISA 100x100x15
Tower steel standing plate	25mm thick steel plate
Beam sizes	0 to 25.50m – 0.55m x0.40m 25.50 to 50m – 0.50m x0.35m 50 to 75.50m – 0.45m x0.30m
Column sizes	0 to 25.50m – 0.65m x0.60m 25.50 to 50m – 0.55m x0.50m 50 to 75.50m – 0.45m x0.40m
Material properties	M 30 Concrete Fe 415 grade steel

III. RESEARCH OBJECTIVES

To find the most efficient and worst location of telecommunication tower placements, following objectives have been decided for Semi commercial apartment building:-

1) To obtain the minimum values of Nodal Displacement and Base Shear in both X and Z direction
2) To determine Time period and Mass participation factor in both X and Z direction.
3) To find Maximum Axial Forces, Shear Force and Bending Moment in Column.
4) To compare Maximum Shear Forces, Bending Moments and Torsional Moments in beams parallel to X and Z direction.

To obtain the most efficient parametric case and worst case by comparing all and then to erect the worst one, following objectives have been decided for both Semi commercial apartment buildings:-

a) To obtain the minimum values of Nodal Displacement and Base Shear in both X and Z direction
b) To determine Time period and Mass participation factor in both X and Z direction.
c) To find Maximum Axial Forces, Shear Force and Bending Moment in Column.
d) To compare Maximum Shear Forces, Bending Moments and Torsional Moments in beams parallel to X and Z direction
e) To obtain the minimum values of Nodal Displacement and Base Shear in both X and Z direction
f) To determine Time period and Mass participation factor in both X and Z direction.
g) To find Maximum Axial Forces, Shear Force and Bending Moment in Column.

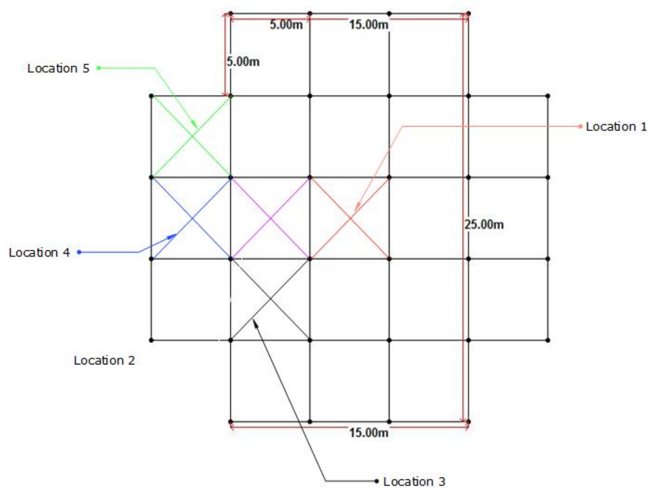

Fig. 1: Plan of different building telecommunication tower locations

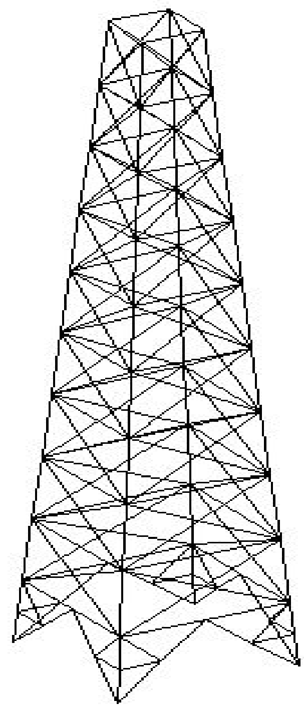

Fig. 2: 3D model of Telecommunication Tower

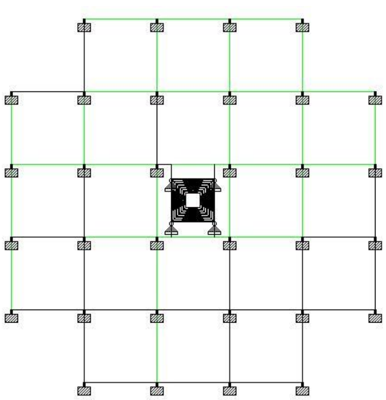

Fig. 3: Top view of Case TTA: Semi commercial apartment with telecommunication tower at A `

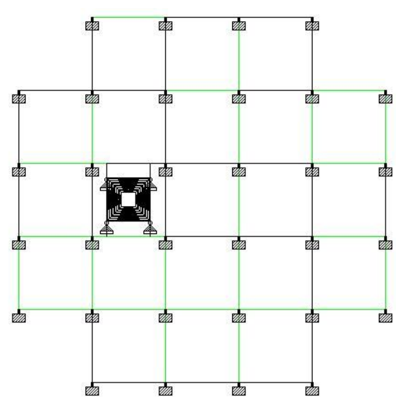

Fig. 4: Top view of Case TTB: Semi commercial apartment with telecommunication tower at B

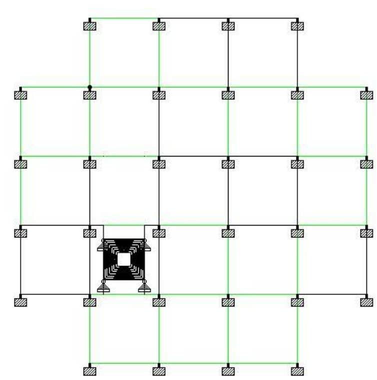

Fig. 5: Top view of Case TTC: Semi commercial apartment with telecommunication tower at C

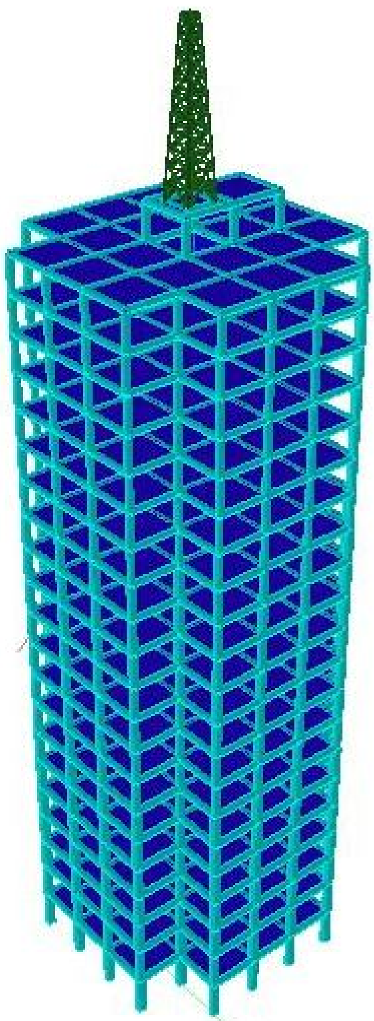

Fig. 6: 3D view of Case TTA: Semi commercial apartment with telecommunication tower at A

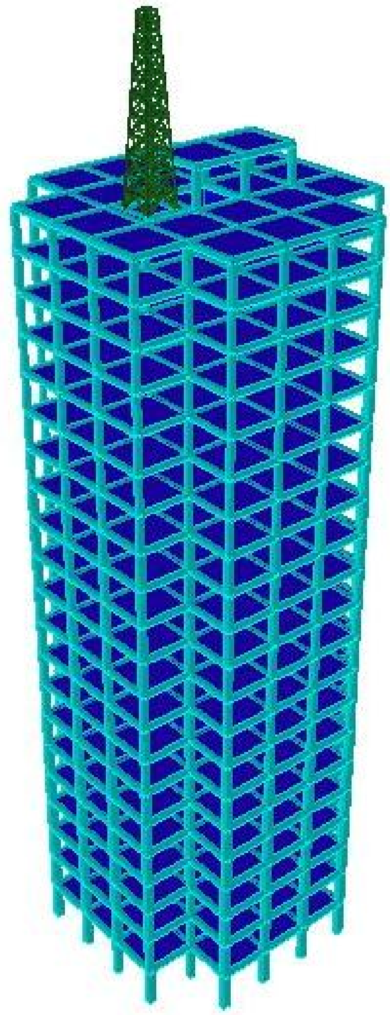

Fig. 7: 3D view of Case TTB: Semi commercial apartment with telecommunication tower at B

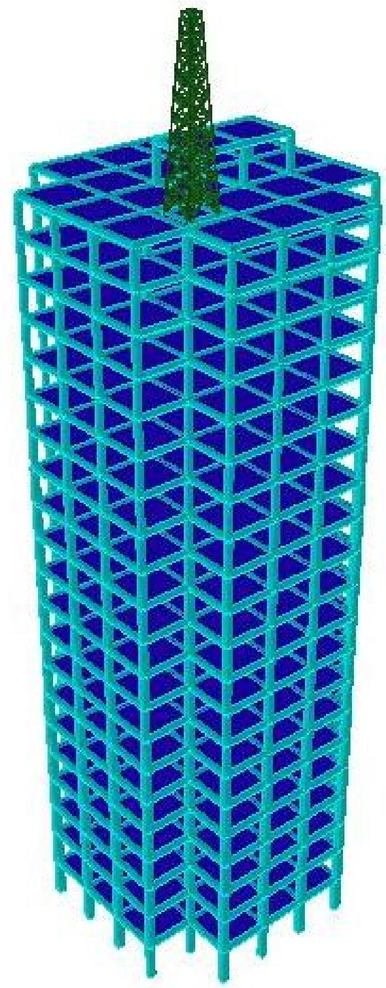

Fig. 8: 3D view of Case TTC: Semi commercial apartment with telecommunication tower at C

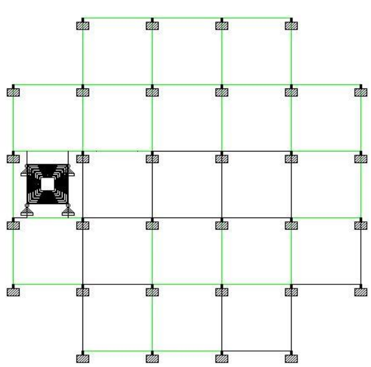

Fig. 9: Top view of Case TTD: Semi commercial apartment with telecommunication tower at D

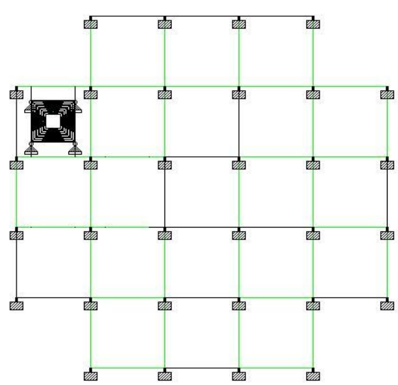

Fig. 10: Top view of Case TTE: Semi commercial apartment with telecommunication tower at E

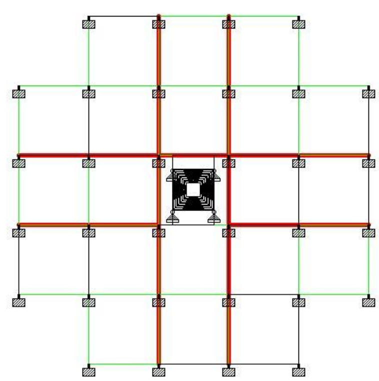

Fig. 11: Top view of Case TTO: Semi commercial apartment with telecommunication tower at worst location with outrigger support system

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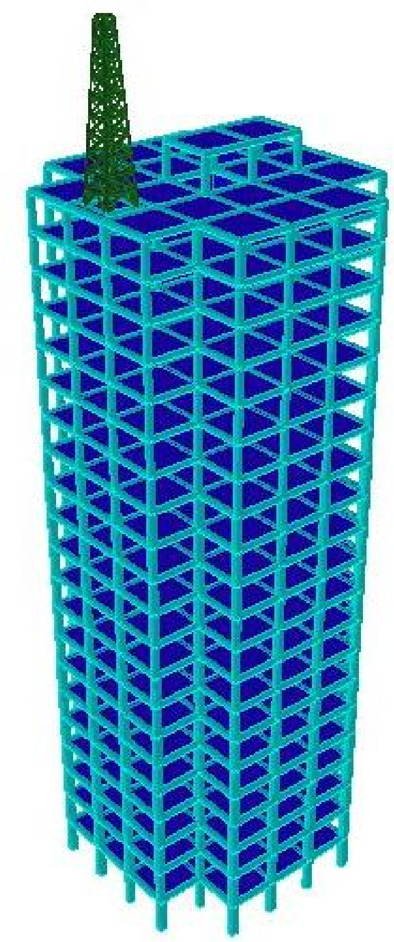


Fig. 12: 3D view of Case TTD: Semi commercial apartment with telecommunication tower at D

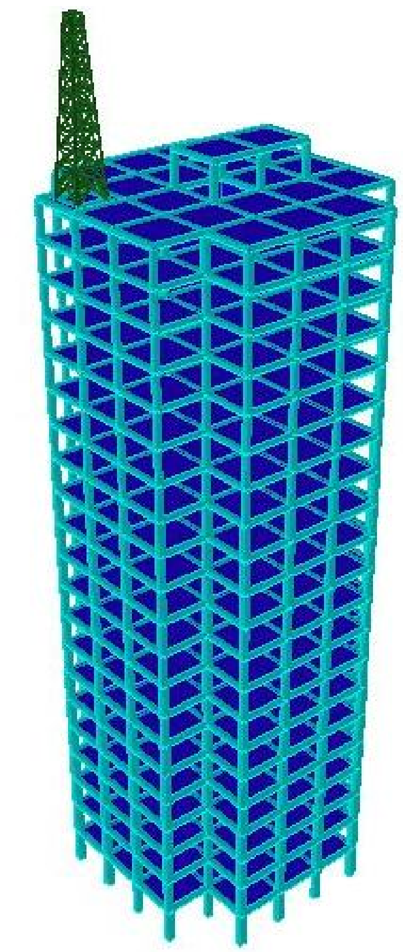


Fig. 13: 3D view of Case TTE: Semi commercial apartment with telecommunication tower at E

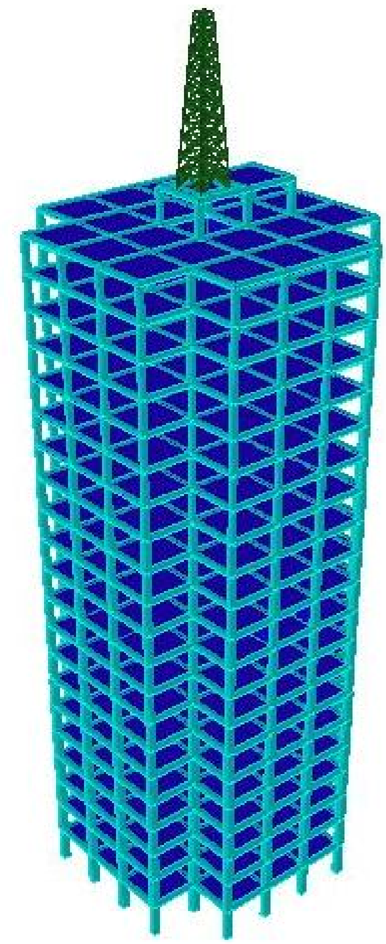
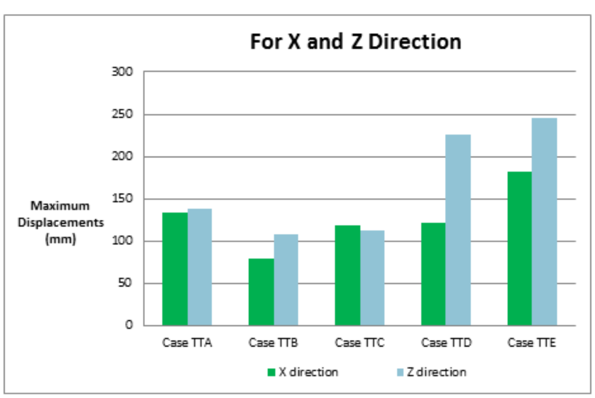


Fig. 14: 3D view of Case TTO: Semi commercial apartment with telecommunication tower at worst location with outrigger support system

IV. RESULTS ANALYSIS

The result parameters obtained by the application of loads and their combinations on various cases as per Indian Standard 1893: 2016 code of practice. Result of each parameter has discussed with its representation in graphical form below:-



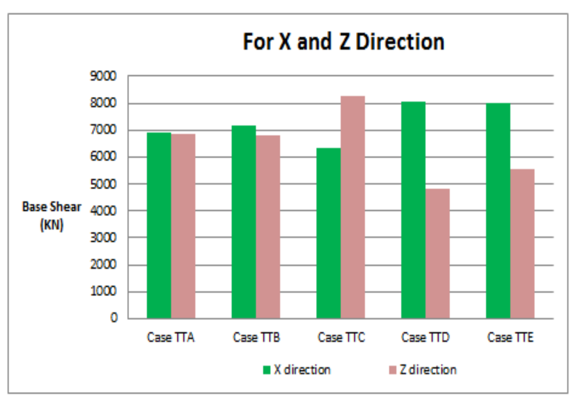


Fig. 15: Comparative representation of Maximum Displacement and Base Shear in X and Z direction obtained for all Cases

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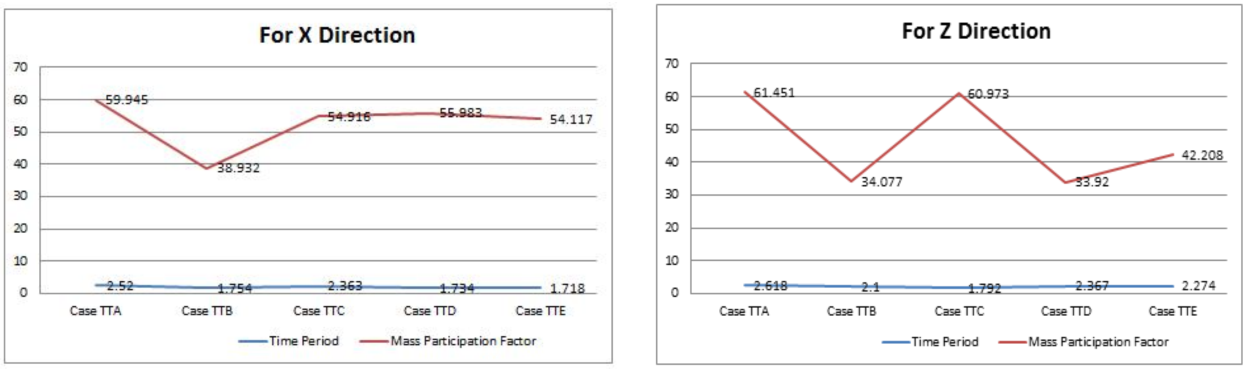


Fig. 16: Comparative representation of Time Period and Mass Participation Factor in X and Z direction obtained for all Cases

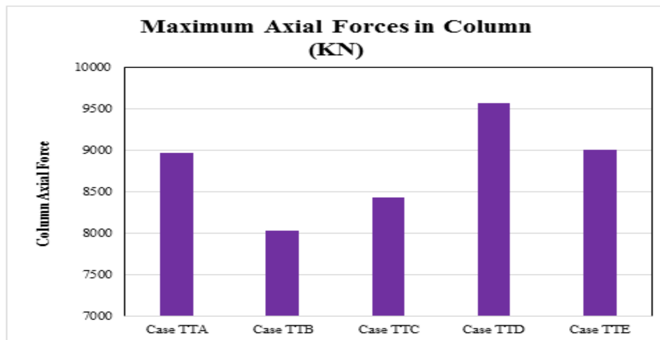


Fig. 17: Comparative representation of Maximum Axial Forces in Column obtained for all Cases

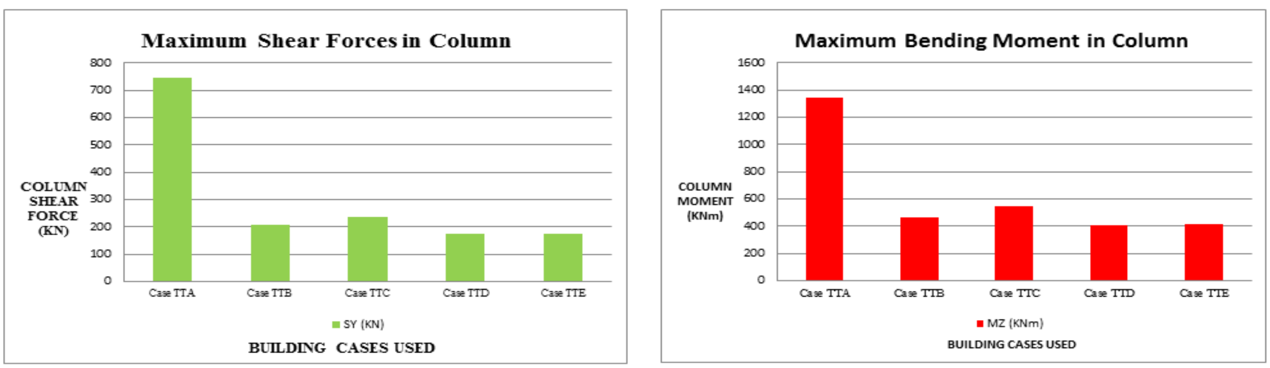


Fig. 18: Comparative representation of Maximum Shear Forces and Bending Moments in Columns obtained for all Cases

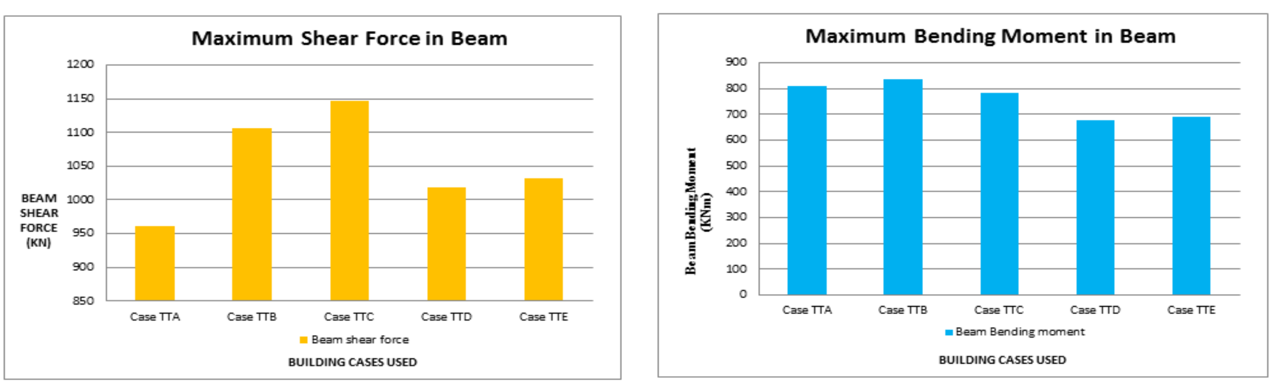


Fig. 19: Comparative representation of Maximum Shear Forces and Bending Moments in Beams obtained for all Cases

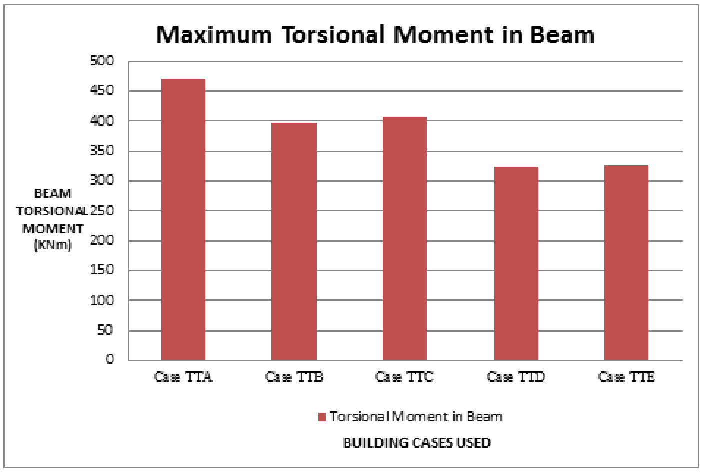
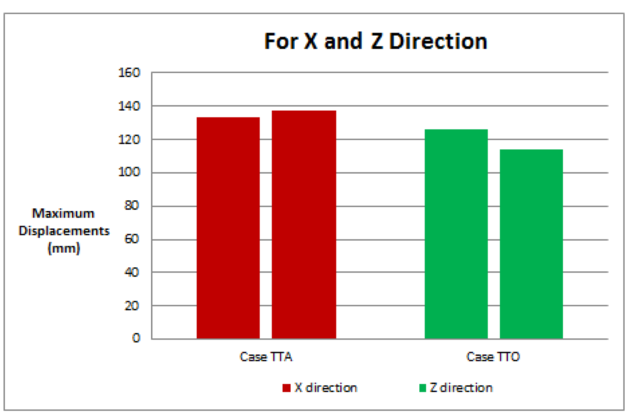


Fig. 20: Comparative representation of Maximum Torsional Moment in beams obtained for all Cases

Table 3: Comparative result of optimum and worst results observations

S. no.	Parameter	Optimum case observed	Worst case observed
1	Maximum Displacement in X direction	Case TTB	Case TTE
2	Maximum Displacement in Z direction	Case TTB	Case TTE
3	Base Shear in X direction	Case TTC	Case TTD
4	Base Shear in Z direction	Case TTD	Case TTC
5	Mass Participation Factor in X direction	Case TTB	Case TTA
6	Mass Participation Factor in Z direction	Case TTD	Case TTA
7	Axial Forces in Column	Case TTB	Case TTD
8	Shear Forces in Columns	Case TTD	Case TTA
9	Bending Moment in Columns	Case TTD	Case TTA
10	Shear Forces in Beams	Case TTA	Case TTC
11	Bending Moment in Beams	Case TTD	Case TTB
12	Torsional Moment in Beams	Case TTD	Case TTA

After looking at many cases and comparing them based on different factors, it was found that the best scenario is Case TTD out of a total of 6 cases, while the worst scenario is Case TTA out of a total of 5 cases. The same has mentioned in table 4.46 above. If it's not possible to place the tower in the best scenario, the plan is to put it in the worst scenario, as suggested by this research. In this case, an outrigger system will be added to make the tower more stable than before. The comparison between the worst-case and the case with the added outrigger system is shown below:



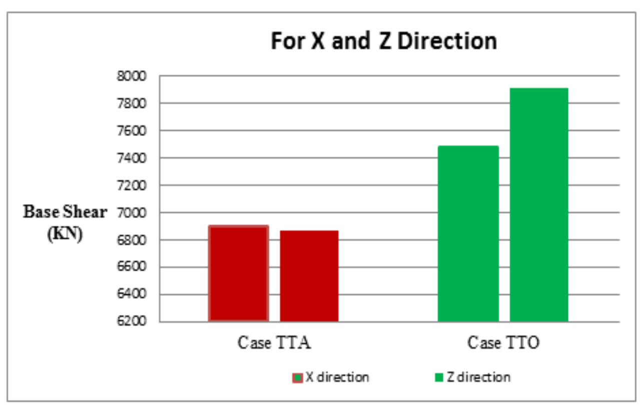


Fig. 21: Maximum Displacement and Base Shear in X and Z direction obtained in Worst Case and Erected Case

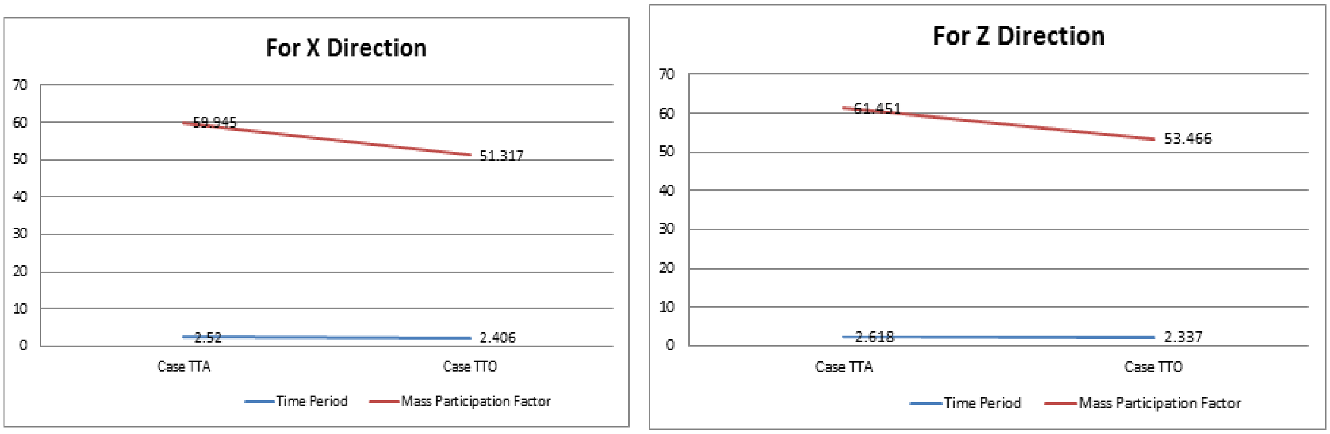


Fig. 22: Time Period and Mass Participation Factor in X and Z direction obtained in Worst Case and Erected Case

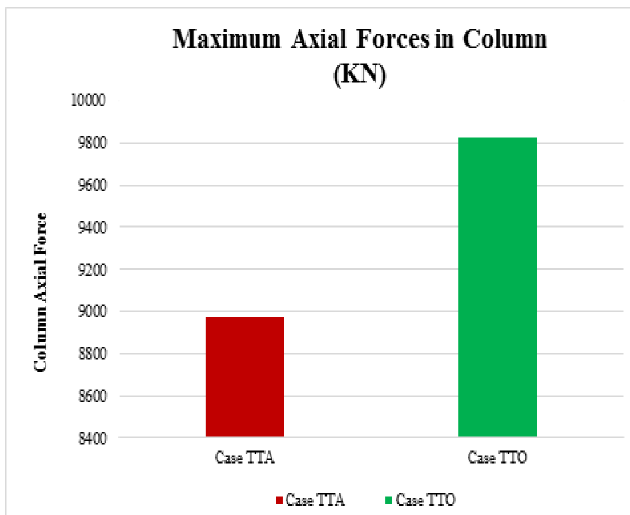


Fig. 23: Maximum Axial Forces in Column obtained in Worst Case and Erected Case

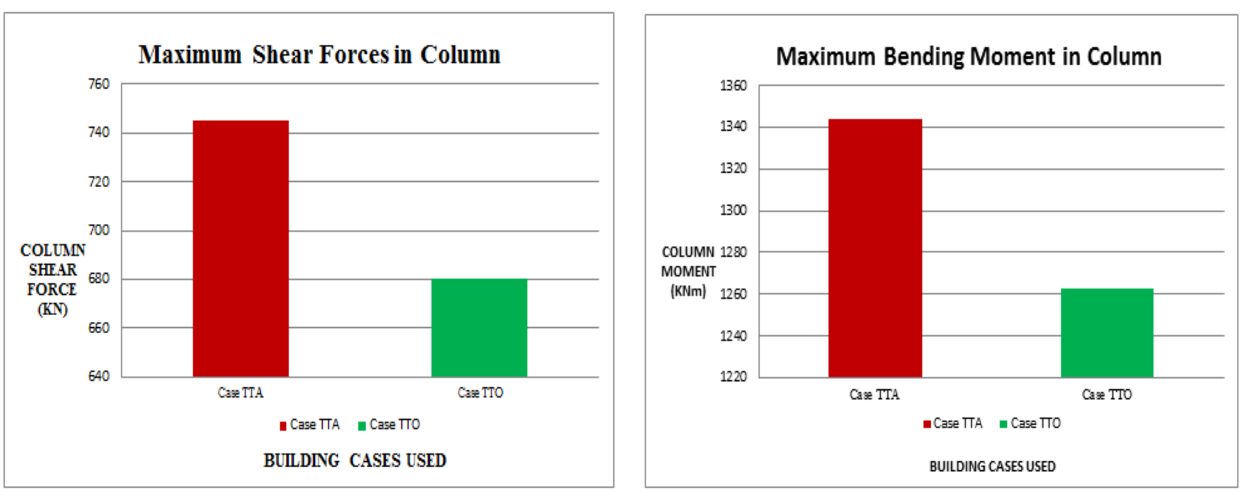


Fig. 24: Maximum Shear Forces and Bending Moment in Columns obtained in Worst Case and Erected Case

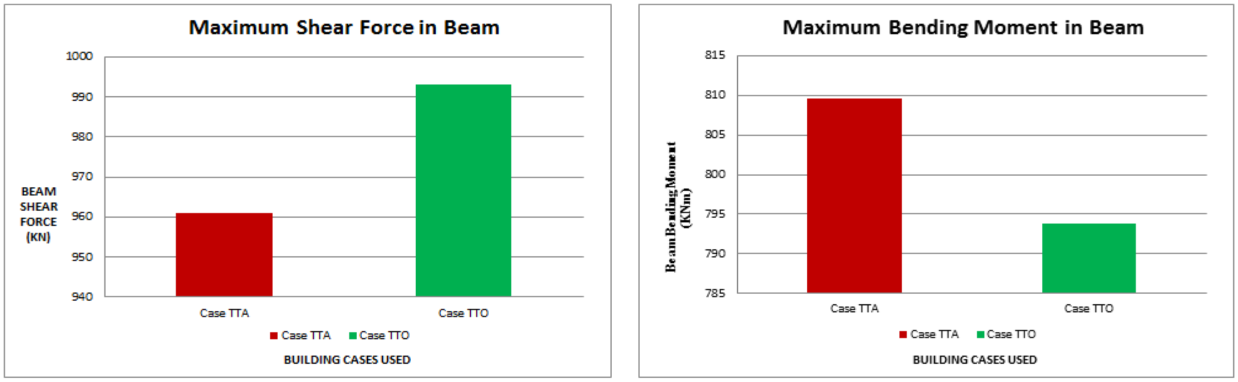


Fig. 25: Maximum Shear Forces and Bending Moment in Beams obtained in Worst Case and Erected Case

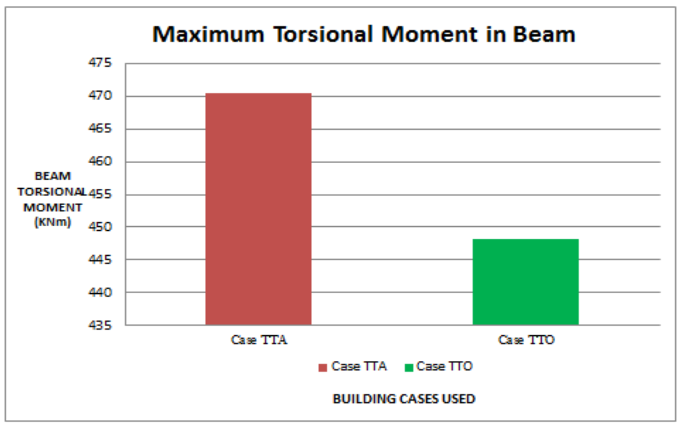


Fig. 26: Maximum Torsional Moment in beams obtained in Worst Case and Erected Case

As per comparison between the worst case and the erected case, it has been proved that if such kind of provision situation arises, provision of erection in the analysis phase should be performed before the construction to lessen the higher parametric values as discussed in this research.

V. CONCLUSIONS

The conclusion can be pointed out are as follows:-

1) The least nodal displacement for X and Z directions for the semi commercial apartment is observed in Model Case TTB.
2) When determining the Base Shear for both X and Z directions, the Base Shear values observed least in Case TTC for X and TTD for Z directions respectively.
3) When comparing the mass participation factor in both X and Z directions, the maximum mass over time is taken into account. The optimal case is Case TTB and Case TTD, while the worst case is Case TTA for both X and Z direction.
4) In Column Axial Forces, Case TTB performs the best, and Case TTD is the least favorable when compared among all cases.
5) In Column Shear Forces, Case TTD performs the best, and Case TTA is the least favorable when compared among all cases.
6) In Column Bending Moment, Case TTD performs the best, and Case TTA is the least favorable when compared among all cases.
7) In Beam Shear Forces, Case TTA performs the best, and Case TTC is the least favorable when compared among all cases.
8) In Beam Bending Moment, Case TTD performs the best, and Case TTB is the least favorable when compared among all cases.
9) In Beam Torsional Moment, Case TTD performs the best, and Case TTA is the least favorable when compared among all cases.

In general, it is noticed that Case TTD is the most efficient among all the cases. Additionally, we improved the stability of the worst-case scenario, Case TTA, based on our findings and discussions by adding an outrigger system.

Therefore, the most appropriate location for the tower had always been taken but the worst case if taken should be re-structured first, taking into account various result parameters, we attempted to reduce the adverse effects in certain parameters by incorporating outrigger walls and erected the worst case to TTO with better outcomes.

VI. ACKNOWLEDGEMENT

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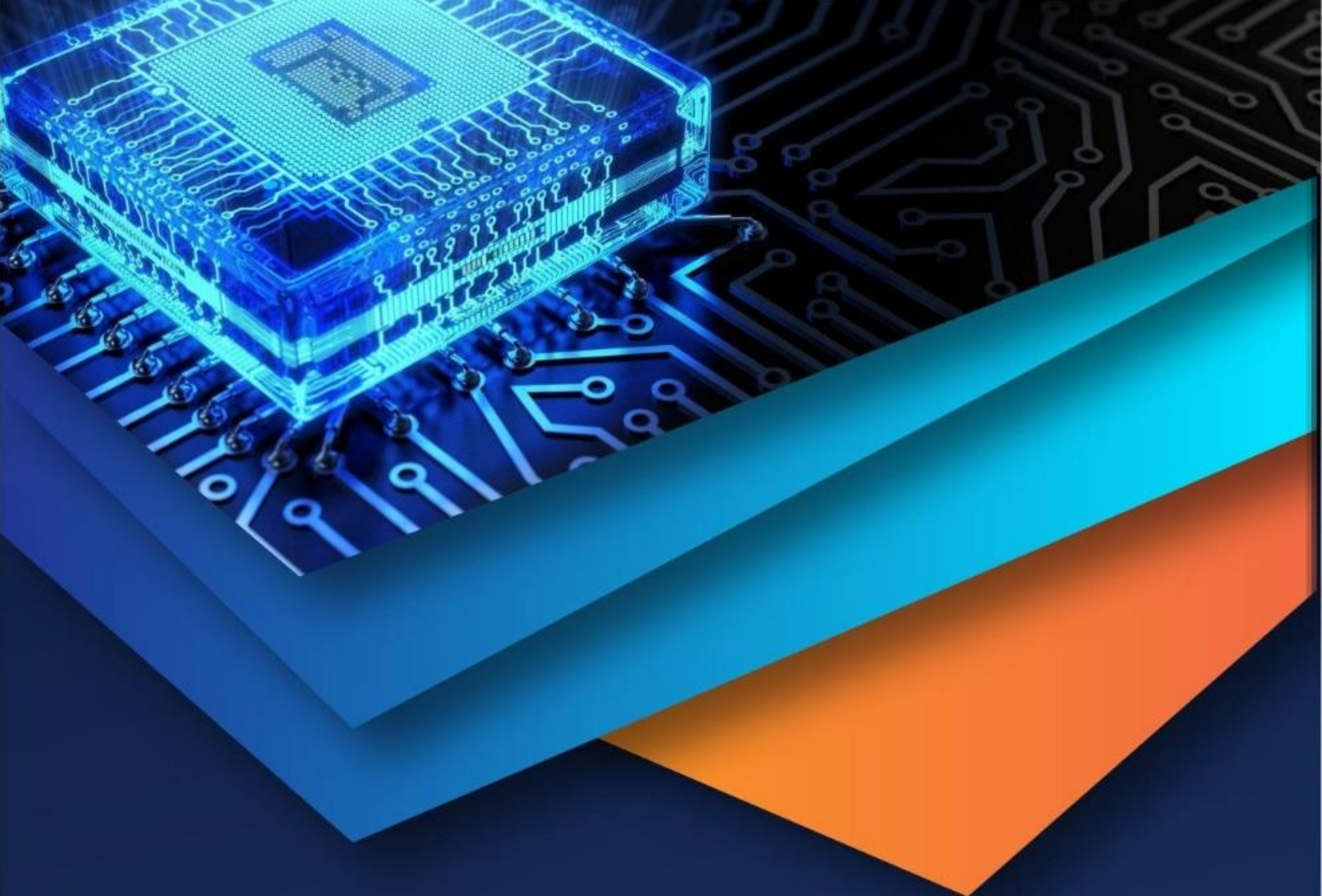

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