SSRG International Journal of Civil Engineering
ISSN: 2348-8352/ https://doi.org/10.14445/23488352/IJCE-V9I6P105

Volume 9 Issue 6, 47-61, June 2022

Original Article

Effect of Backstay on Tall Structures with Podium

Nirav Bhatu[1], Vishal B. Patel[2], Pratiti M. Bhatt[3]

[1,2,3]Structural Engineering Department, Birla Vishvakarma Mahavidyalaya, Gujarat, India.

Received: 16 March 2022 Revised: 25 May 2022 Accepted: 01 June 2022 Published: 22 June 2022

Abstract *- Structural engineering can be considered as the science of designing and building structures that are economical, long-lasting, and invulnerable to damage. To design and build such structures, visionary thinking following structural engineering concepts is required. The behaviour of structures during normal occupational use and under disastrous circumstances should be permissible and within the allowable limits per recent codal provisions. This research aims to learn modelling techniques for multiple towers with common podium-type structures. To comprehend the real and accurate behaviour of multiple towers with a common podium under horizontal forces while taking into account the backstay effect, as specified in IS:16700 (2017), is also one of the scopes of this research. Different models are prepared in this study by varying the podium height and the number of towers in the structure. A comparative study is also done on the single tower with a Podium and multiple towers with a common Podium with a shear wall at the periphery of the podium and without the shear wall at the periphery of the podium by changing the number of podium storeys and the number of towers in structure. The equivalent static method and Response spectrum method are used to analyze structures; ETABS is used in this study to analyse single towers with Podiums and multiple towers with common podium-type structures.*

Keywords *- Backstay effect, Equivalent static method, Podium, Response spectrum method, Seismic analysis.*

1. Introduction

Fig. 1.1 Tower with podium structure

Fig. 1.2a Bombay Stock Exchange Building

The demand for tall structures is increasing daily due to rising population and land scarcity in metropolitan regions. Tall structures are becoming more popular in developing nations, including India. After a certain amount of horizontal development, no more land is accessible for growth in any city, especially in metro cities. As a result, multistory towers became popular as a way to maximise land utilisation. High-rise buildings cannot be designed in the same manner that low and medium-rise structures are designed. Tall buildings are extremely complex engineering projects, so the most sophisticated design methods are required in tall structures. To satisfy the demand of increasing population as well as to satisfy the demand for the minimum parking space for such types of buildings under current bye-laws, Architects and Engineers proposed/put forward the new concept of Podium kind structures. The bottom few storeys have bigger plan dimensions than towers in many tall structures. These lower few stories of the building can be used for different purposes such as parking, retail shops, etc. A podium is a term used to describe the base of a tall building. Podium in architecture is any of various elements that form the foot or base of a structure and have a low wall supporting columns, or the structurally or decoratively emphasized the lowest portion of a wall. A building's basement story is sometimes used as a podium. In many multi-functional tall buildings, this type of configuration is seen.

A large number of basement floors most typically represent the condition of the podium. Still, the floors above ground can also serve as a podium if it has extra seismic features that do not extend up to the whole height of the structure. A podium may be authorized to be 1000 square meters or larger. According to DCPR 2034, a podium with a ramp may be approved in one or more levels if the total height of podium stories does not exceed 32 m above ground level.

The assembly of the tower-podium type of structure is shown in Figure 1.1. In Figure 1.2 Bombay stock exchange building is shown, which is also a (tower+podium)type building.

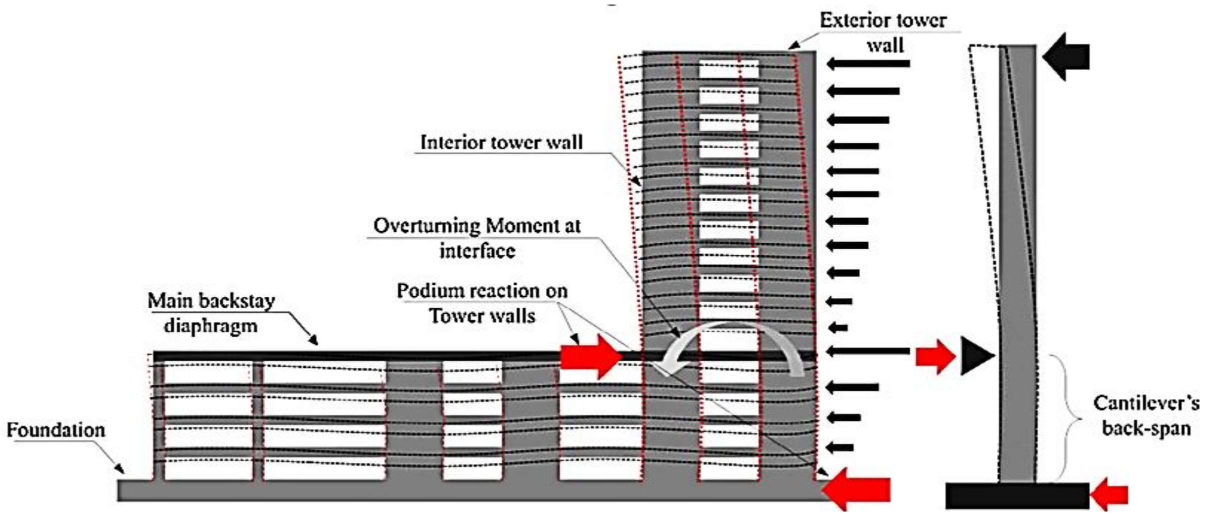

Fig. 1.2b Backstay action in a podium-tower sub-assemblage

- ❖ Following are the main structural elements of the podium:
- ➢ Supporting soil and foundation
- ➢ The RC peripheral walls at the below-grade levels
- ➢ Diaphragms at the ground and below-ground levels

- ❖ Following are the main functions of the podium slab :
- ➢ It works as a fire separation between different building occupancy categories.
- ➢ The podium slab serves as a diaphragm or the transfer slab for the transfer of lateral loads from the above superstructure and main lateral load resisting element in the tower to the structural walls and columns within the podium level.

The diaphragm is the horizontal system that transmits lateral forces to a vertical force-resisting element. A podium's floor and roof slabs are critical components. In shear and flexure, they act as diaphragms, which spread forces to the vertical components of the lateral load resisting system. Collectors in the diaphragms accumulate forces and aid in transferring forces to walls and frames by operating in axial tension and compression.

The stiffness of flat slab frames should now be neglected in horizontal load resistance in all seismic zones, according to IS 16700-2017, clause 7.3.11. i.e., In tall buildings, slabs are regarded as absolutely stiff, and horizontal force is transferred 100% to vertical elements of the structure without any deformation. So in slabs of tower construction, no planar stresses and out-of-plane bending moments have been observed. To accomplish this in structural analysis and design tool ETABS, the modelling type of Slab is defined as 'membrane,' and a 'Rigid' diaphragm is assigned to it.

Shear walls are generally considered as simple cantilever beams fixed at the bottom. For podium + tower structure, a more logical and valid correlation would be cantilever with

back span to include the consequences of large stiffness of Podium (Refer figure 1.3).

Backstay effects must be evaluated in the context of two seismic load paths, which are:-

(Refer to figure 1.4)

1. Direct load path: In this path, the overturning resistance is provided by the foundation beneath the seismic-force resisting components of the tower.

2. Backstay load path: In this path, the resistance is provided by planar forces in the podium diaphragms.

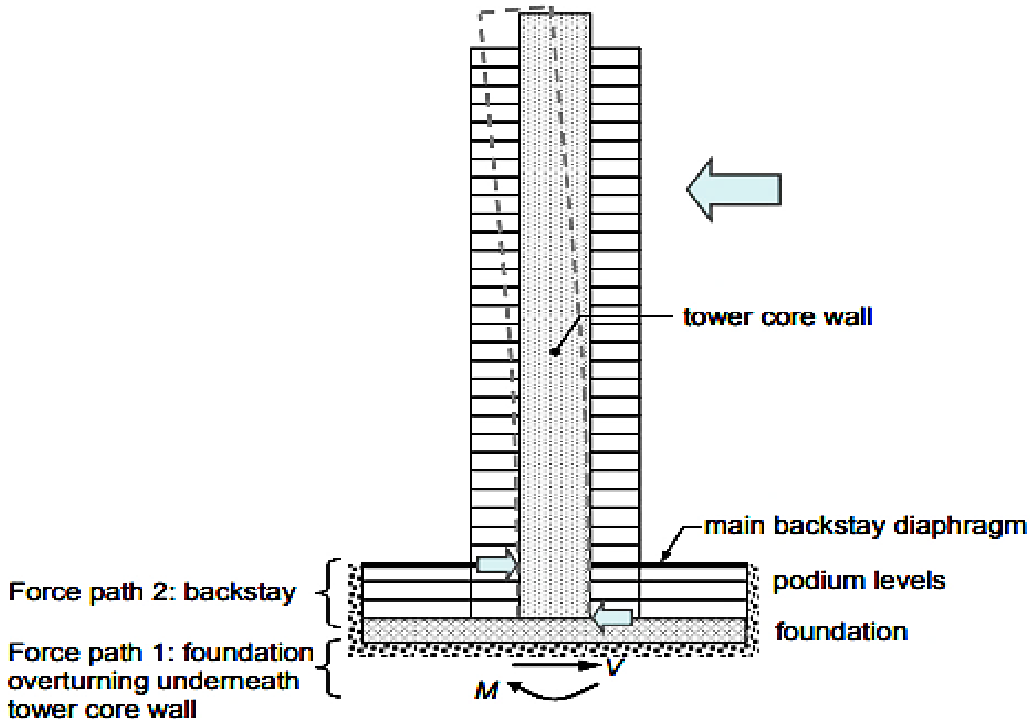

Fig. 1.3 Backstay action in a podium-tower sub-assemblage

It should be noted that Podium and backstay effects are not limited to tall buildings only, Low and mid-rise buildings can be subject to the same effects, and similar effects can occur wherever along with a building's height where the stiffness of lateral elements is reduced, such as a building setback or step backs.

❖ Objectives of current work are as follows:-

➢ To comprehend the phenomena of backstay observed in multiple towers with a common podium by referring to the guidelines in IS 16700: 2017.

➢ To carry out a comparative study on the single tower with a Podium and multiple towers with a common Podium with a shear wall and without a shear wall at the periphery of the podium by changing no. of podium storeys and no. of towers.

➢ To investigate the effect of increasing the number of podium storeys on backstay effect and behaviour of buildings.

➢ To investigate the effect of changing the number of towers in a structure on the backstay effect and on behaviour of buildings.

2. Numerical Study

For the current work, the construction is a building with 15 stories. The plan dimensions of the tower are 25m x 25m, and the podium is 80m x 80m. The work is done on different structural formations of tower-podium construction by varying the number of podium storeys/podium height and the number of towers in the structure. 16 different models are prepared and analysed in the structural analysis and design tool ETABS. Structures are analysed by Static earthquake analysis and Response spectrum analysis. The sectional properties, and Loads & seismic factors are given in table-2.1 & table-2.2

Table 2.1 Sectional properties of the model

SECTIONAL PROPERTIES	
Size of Beam	230mm X 450mm, 300mm X 550mm
Size of Column	400mm X 400mm, 500mm X 500mm
Core wall thickness	350mm
Shear Wall thickness	150mm
Slab thickness	125mm, 150mm
Grade of concrete	M30, M40
Grade of Steel	Fe550

Table 2.2 Loads and seismic factors of Models

LOADS AND SEISMIC FACTORS	
Dead Load	1.5 kN/m^2
Live Load	5 kN/m^2, 3 kN/m^2
Wall Load	14.03 kN/m
Parapet Wall Load	4.6 kN/m
Seismic Zone	III
zone factor	0.16
Response Reduction factor	5
Importance Factor	1.2
Soil Conditions	Medium

❖ The following 16 Models are prepared for the Present Study:-

1) Model: 1:- **(1t+1p+ps)**: Single tower with 1 storey podium with Shear wall at the periphery of Podium
2) Model : 2:- **(1t+2p+ps)**: Single tower with a 2-storey podium with a Shear wall at the periphery of the Podium
3) Model :3:- **(1t+3p+ps)**: Single tower with a 3-storey podium with a Shear wall at the periphery of the Podium
4) Model: 4:- Single tower without Podium
5) Model : 5:- **(4t+1p+ps)**: 4 towers with a common 1-storey podium with a Shear wall at the periphery of the Podium
6) Model : 6:- **(4t+2p+ps)**: 4 towers with a common 2-storey podium with a Shear wall at the periphery of the Podium
7) Model : 7:- **(4t+3p+ps)**: 4 towers with a common 3-storey podium with a Shear wall at the periphery of the Podium
8) Model: 8:- **(4t+1p+wps)**: 4 towers with a common 1-storey podium without a Shear wall at the periphery of the Podium
9) Model : 9:- **(4t+2p+wps)**: 4 towers with a common 2-storey podium without a Shear wall at the periphery of the Podium
10) Model: 10:- **(4t+3p+wps)**: 4 towers with a common 3-storey podium without a Shear wall at the periphery of the Podium
11) Model : 11:- **(3t+1p+ps)** : 3 towers with a common 1-storey podium with a Shear wall at the periphery of the Podium
12) Model : 12:- **(3t+2p+ps)** : 3 towers with a common 2-storey podium with a Shear wall at the periphery of the Podium
13) Model : 13:- **(3t+3p+ps)** : 3 towers with a common 3-storey podium with a Shear wall at the periphery of the Podium
14) Model: 14:- **(3t+1p+wps)** : 3 towers with a common 1-storey podium without a Shear wall at the periphery of the Podium
15) Model : 15:- **(3t+2p+wps)** : 3 towers with a common 2-storey podium without a Shear wall at the periphery of the Podium
16) Model: 16:- **(3t+3p+wps)** : 3 towers with a common 3-storey podium without a Shear wall at the periphery of the podium

❖ Plan & 3D views of all 16 models are as follows:-

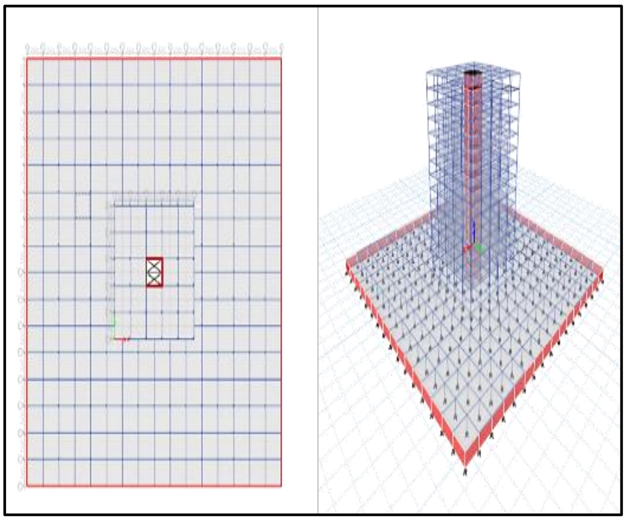

Fig. 2.1 1t+1p+ps

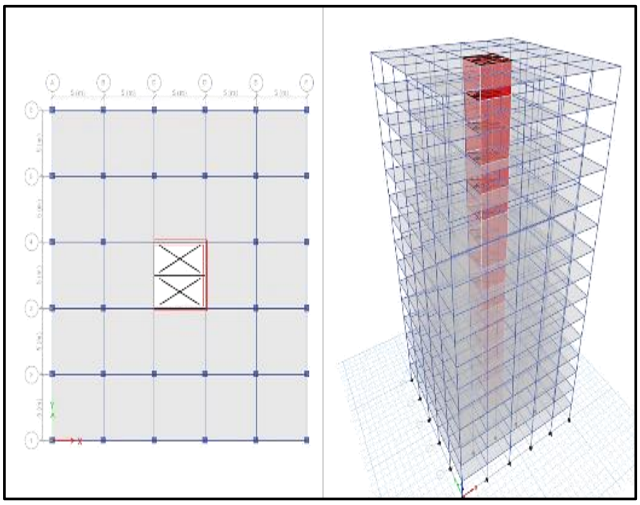

Fig. 2.4 Plan & 3D view of Single tower without podium

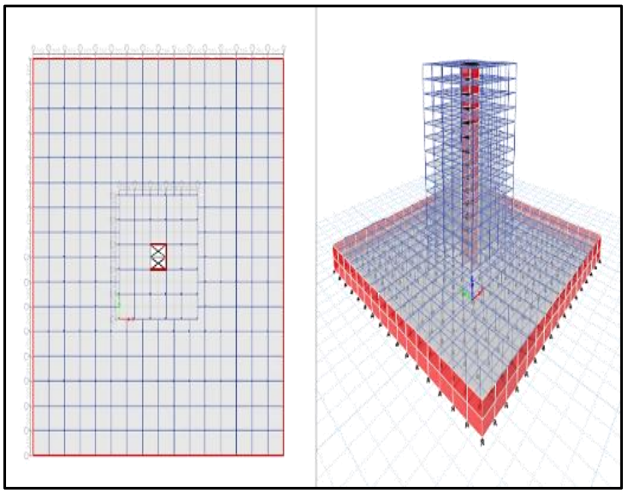

Fig. 2.2 1t+2p+ps

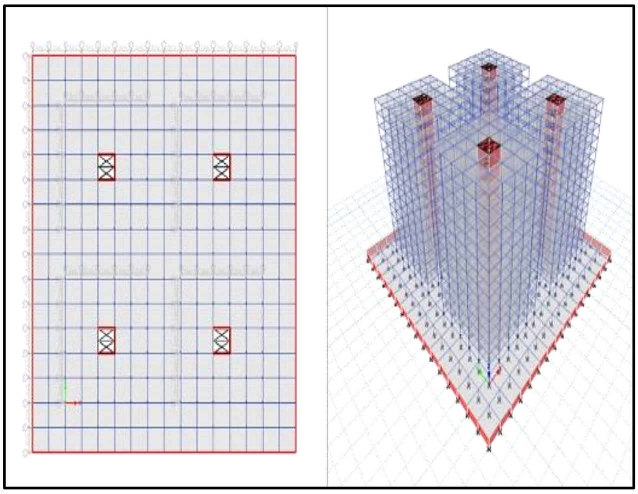

Fig. 2.5 4t+1p+ps

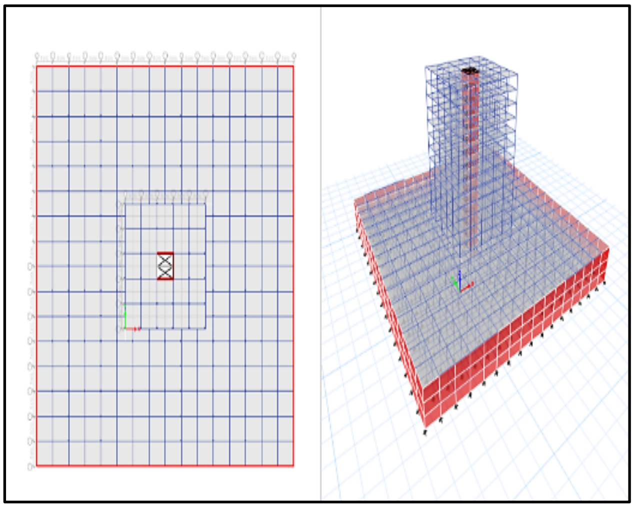

Fig. 2.3 1t+3p+ps

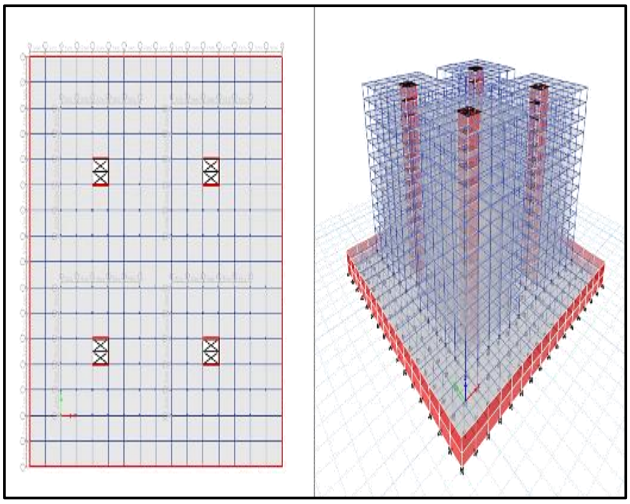

Fig. 2.6 4t+2p+ps

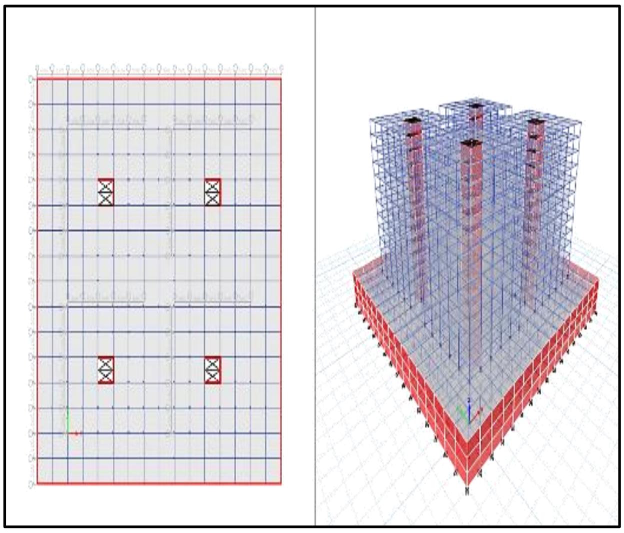

Fig. 2.7 4t+3p+ps

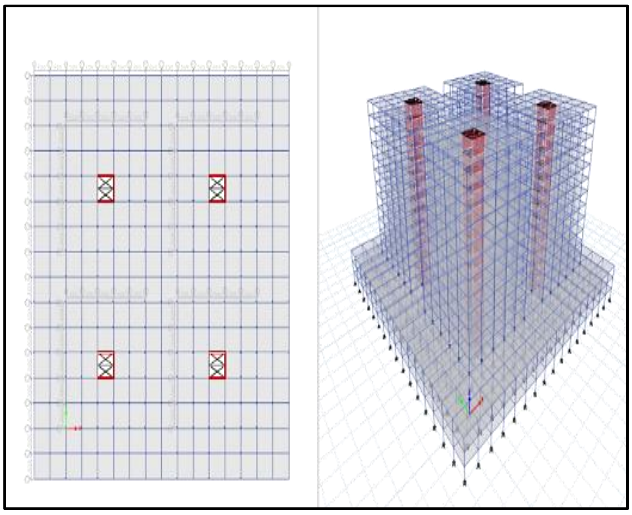

Fig. 2.10 4t+3p+wps

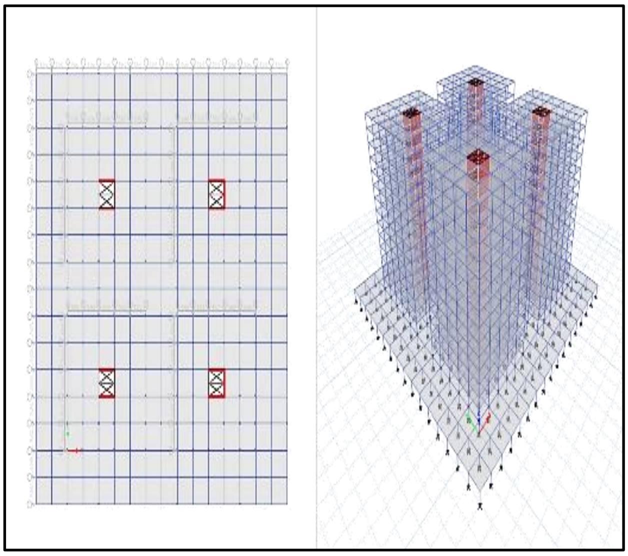

Fig. 2.8 4t+1p+wps

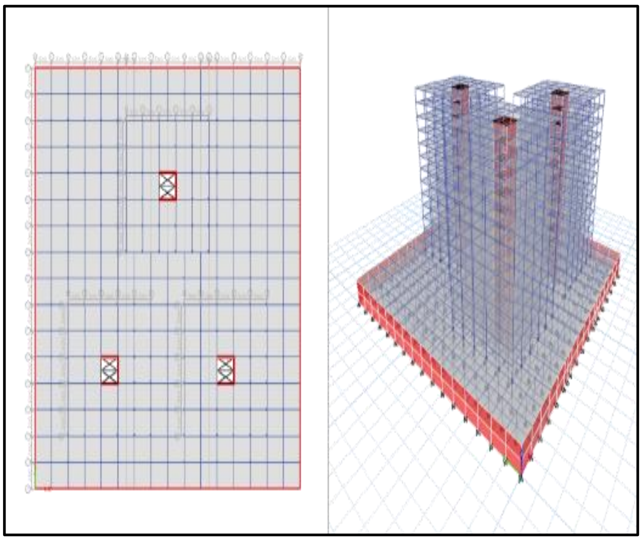

Fig. 2.11 3t+2p+ps

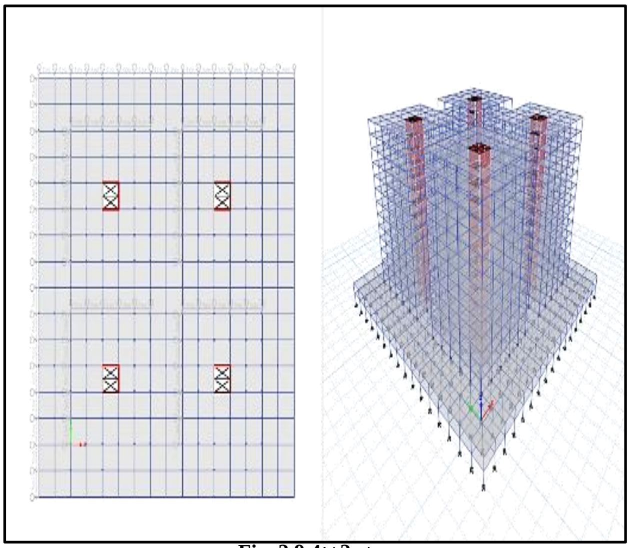

Fig. 2.9 4t+2p+wps

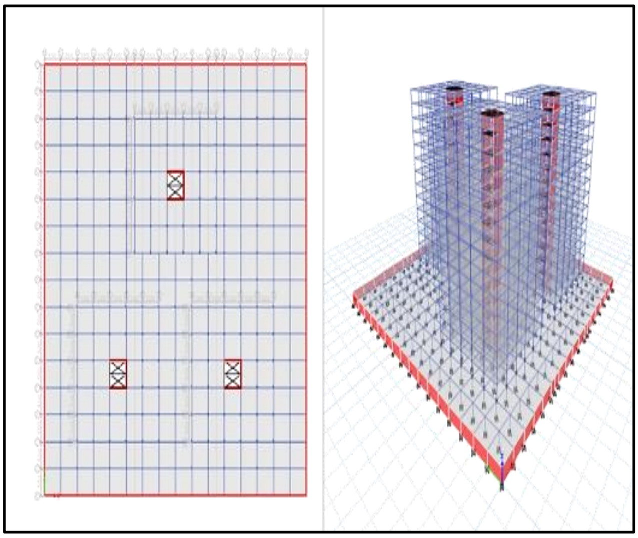

Fig. 2.12 3t+1p+ps

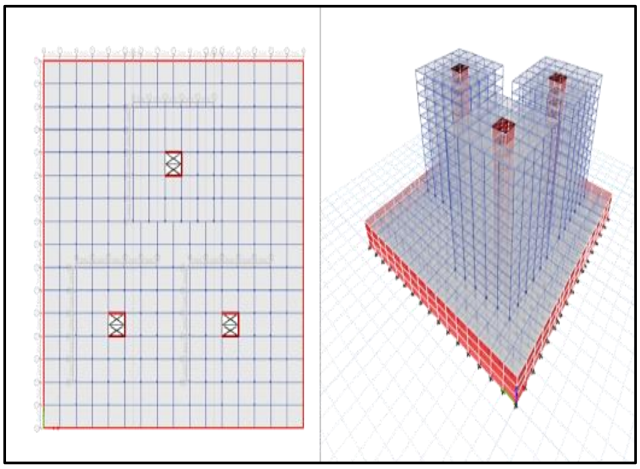

Fig. 2.13 3t+3p+ps

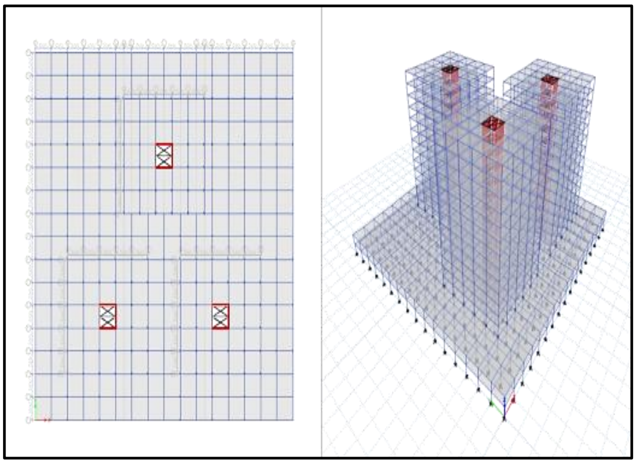

Fig. 2.15 3t+2p+wps

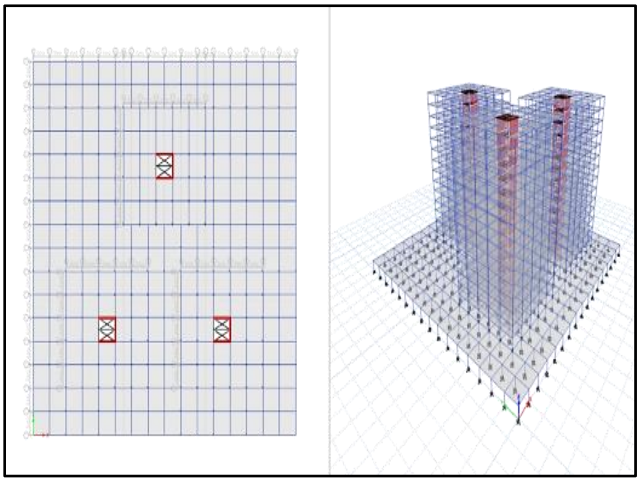

Fig. 2.14 3t+1p+wps

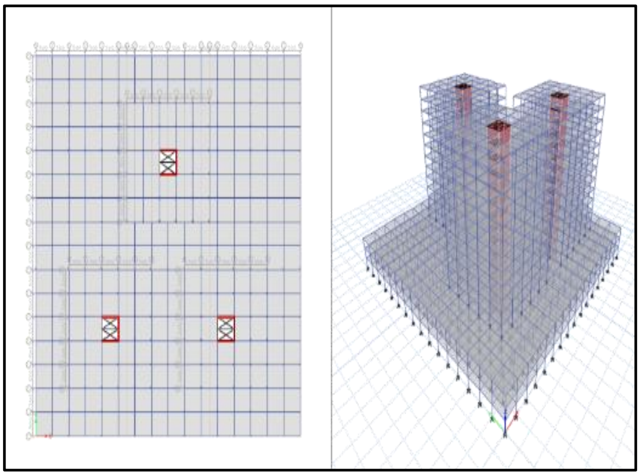

Fig. 2.16 3t+3p+wps

3. Result & Discussion

The results of the top storey displacement, Storey shear at the main backstay diaphragm level, Reversal of shear force at the main backstay diaphragm level, and Reduction in the overturning moment due to the Backstay effect are taken for each of the structural models prepared in structural analysis tool ETABS. The study outcomes are graphically represented after evaluating various parameters using the equivalent static technique and response spectrum approach.

3.1. Comparison of results of Top storey displacement for different models

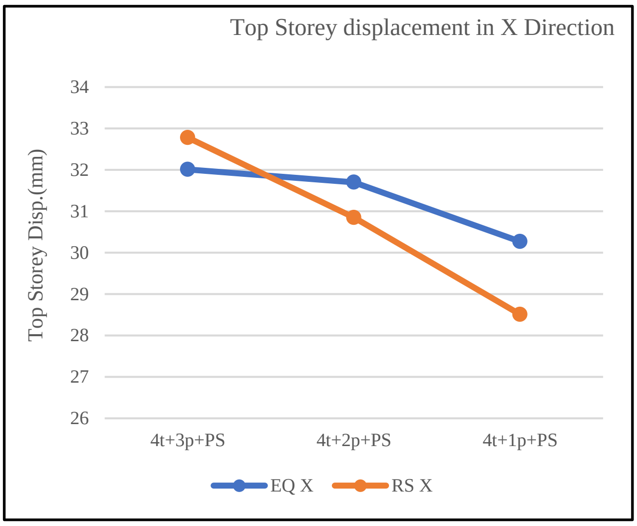

Fig. 3.1 Comparison of Top Storey Displacements For 4 Towers with common Podium type structures in X Direction

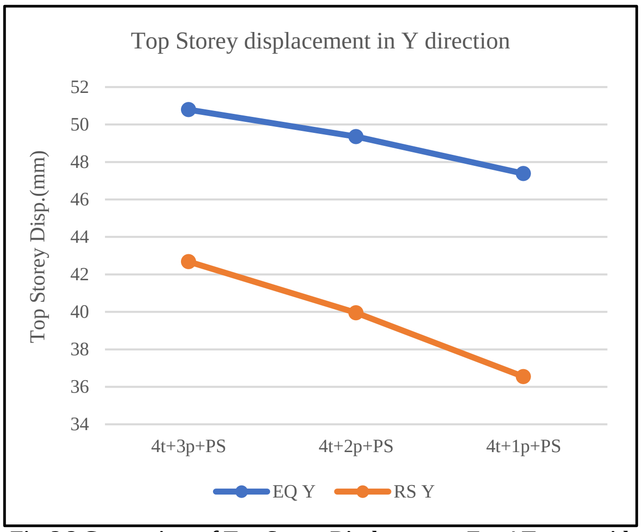

Fig. 3.2 Comparison of Top Storey Displacements For 4 Towers with common Podium type structures in Y Direction

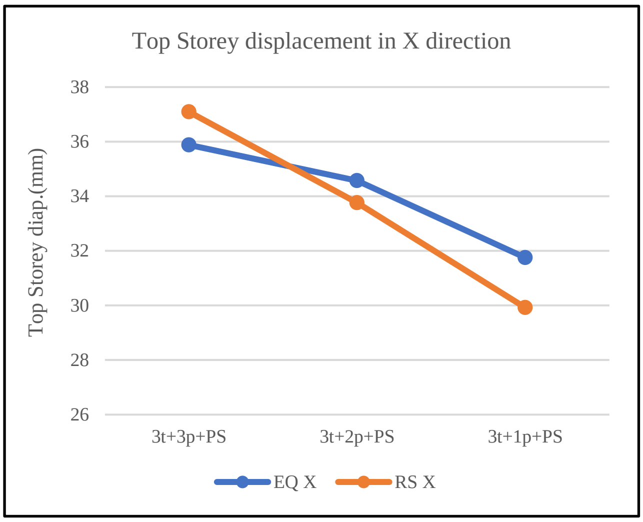

Fig. 3.3 Comparison of Top Storey Displacements For 3 Towers with common Podium type structures in X Direction

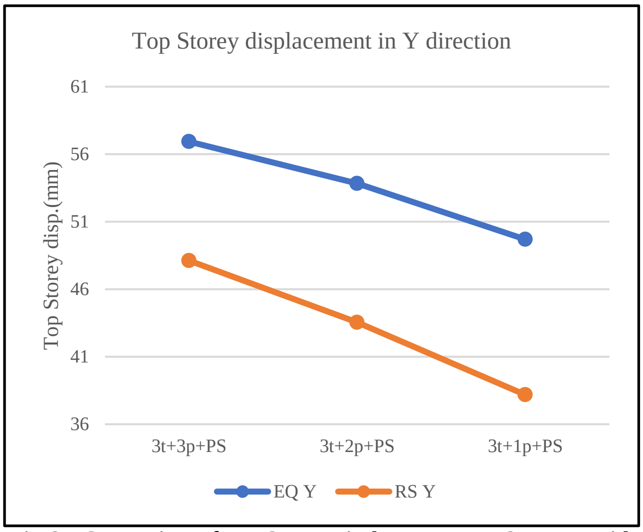

Fig. 3.4 Comparison of Top Storey Displacements For 3 Towers with common Podium type structures in Y Direction

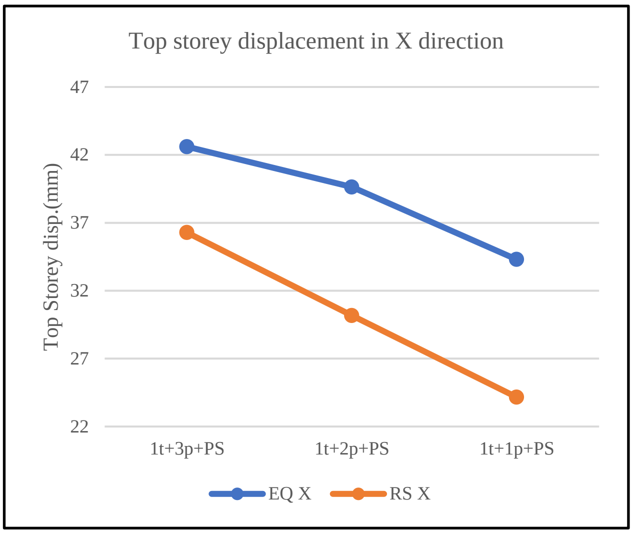

Fig. 3.5 Comparison of Top Storey Displacements For single Tower with Podium type structures in X Direction

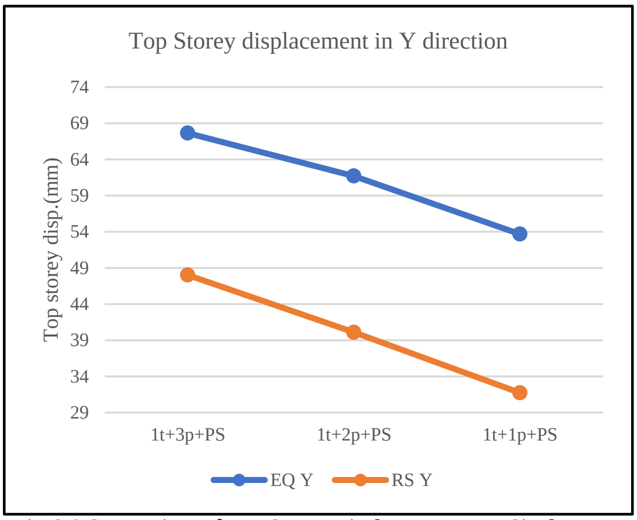

Fig. 3.6 Comparison of Top Storey Displacements For Single Tower with Podium type structures in Y Direction

As shown in the above figures, the top storey displacement in X-direction and Y-direction for both equivalent static and Response spectrum approaches are compared for 4 towers with the common podium, 3 towers with a common podium, and a single tower with podium-type structures.

As the no. of podium storey increases, the top storey displacement in X-direction and Y-direction increases for Equivalent Static and Response spectrum methods. Maximum top storey displacement is observed in structures with 3-storey podiums, and minimum top storey displacement is observed in structures with a single-storey podium.

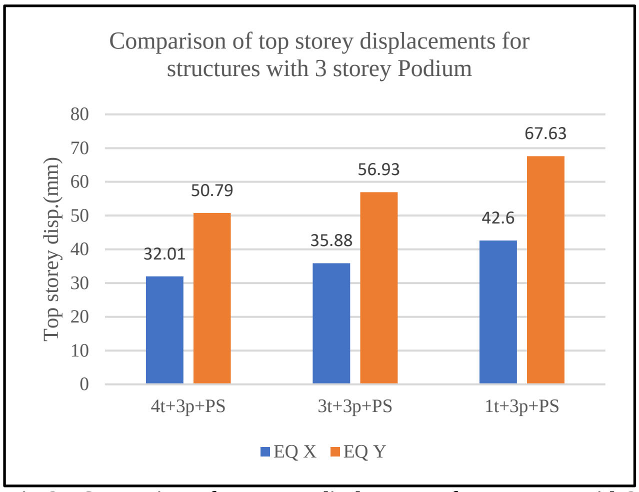

Fig. 3.7 Comparison of top storey displacements for structures with 3 storey Podium

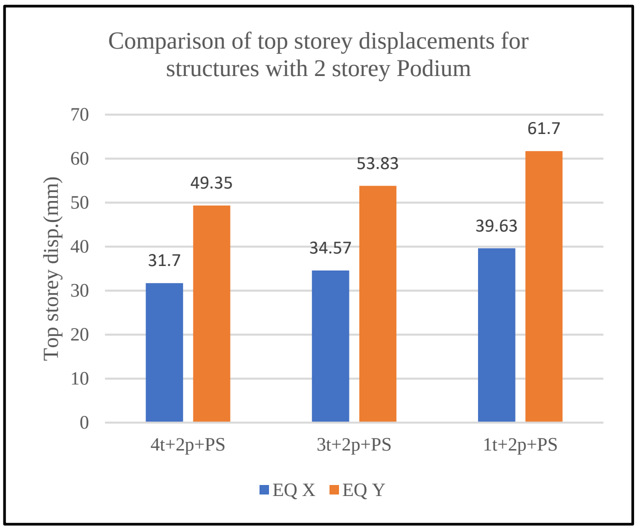

Fig. 3.8 Comparison of top storey displacements for structures with 2 storey Podium

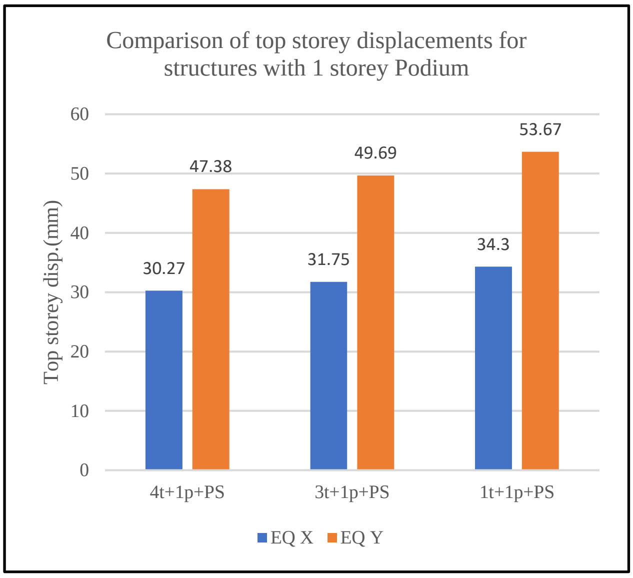

Fig. 3.9 Comparison of top storey displacements for structures with 1 storey Podium

As the no. of towers increases, the top storey displacement in X-direction and Y-direction decreases for the Equivalent Static method. Maximum top storey displacement is observed in structures with a single tower, and minimum top storey displacement is observed in structures with 4 towers.

3.2. Comparison of results of Storey shear at main backstay diaphragm level for different models

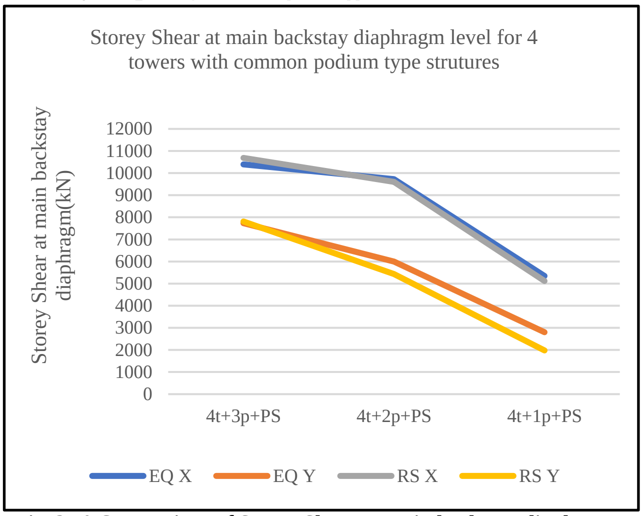

Fig. 3.10 Comparison of Storey Shear at main backstay diaphragm level for 4 towers with common podium type strutures (with shear wall)

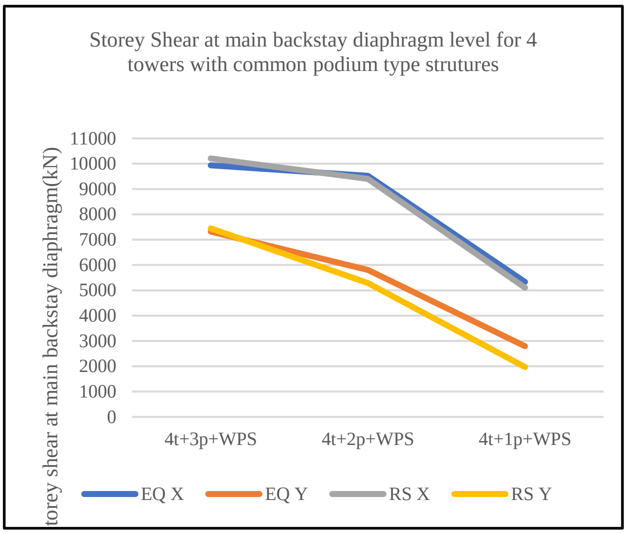

Fig. 3.11 Comparison of Storey Shear at main backstay diaphragm level for 4 towers with common podium type strutures (without shear wall)

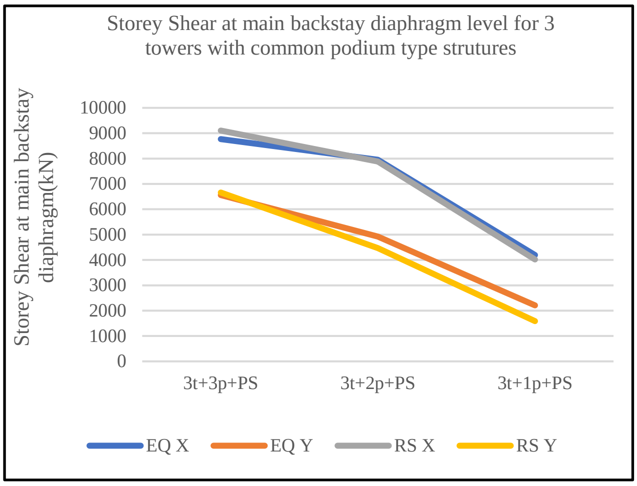

Fig. 3.12 Comparison of Storey Shear at main backstay diaphragm level for 3 towers with common podium type strutures (with shear wall)

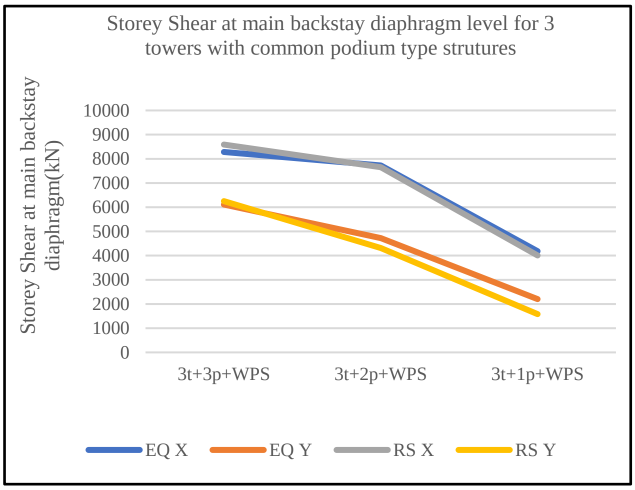

Fig. 3.13 Comparison of Storey Shear at main backstay diaphragm level for 3 towers with common podium type strutures (without shear wall)

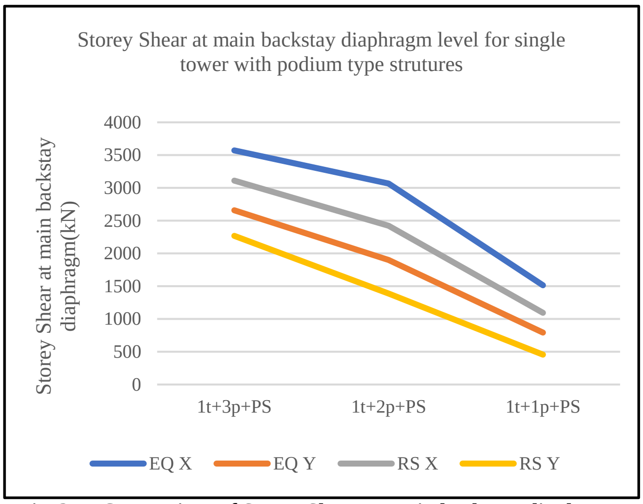

Fig. 3.14 Comparison of Storey Shear at main backstay diaphragm level for single tower with podium type strutures (with shear wall)

As the number of podium storey increases, the mass of the structure increases, which leads to a proportional rise in storey shear, it is observed that structures with 3-storey podiums have the maximum storey shear at the main backstay diaphragm level and structures with a single storey podium have the minimum storey shear at main backstay diaphragm level.

3.3. Comparison of results of Shear force reversed at main backstay diaphragm level for different models

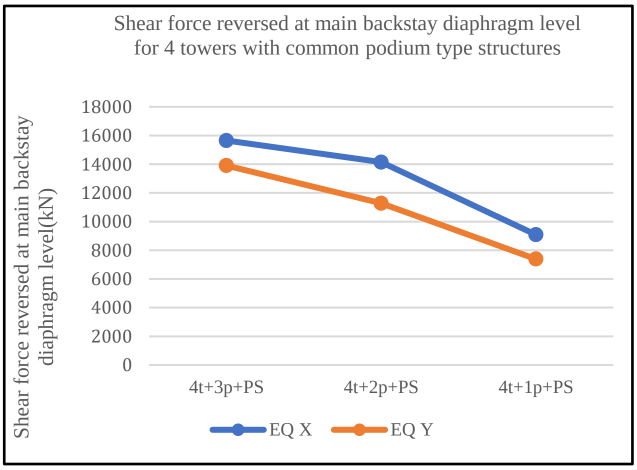

Fig. 3.15 Comparison of Shear force reversed at main backstay diaphragm level for 4 towers with common podium type structures (with shear wall)

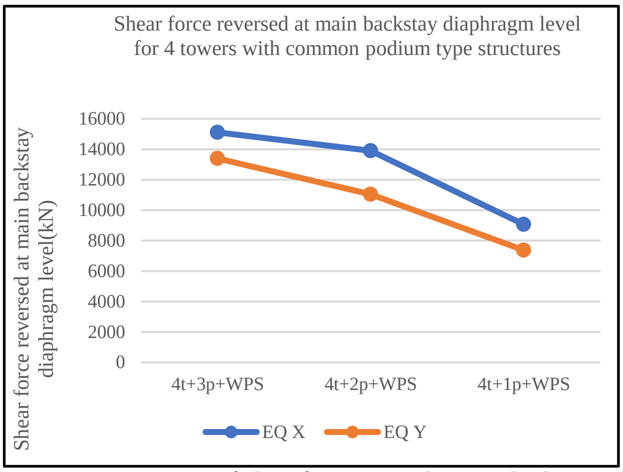

Fig. 3.16 Comparison of Shear force reversed at main backstay diaphragm level for 4 towers with common podium type structures (Without shear wall)

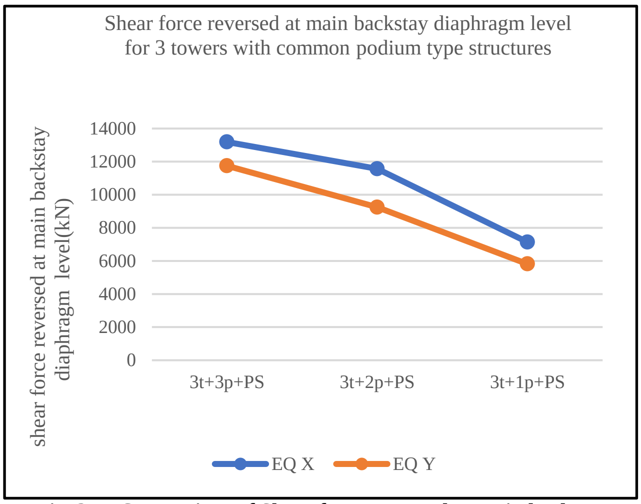

Fig. 3.17 Comparison of Shear force reversed at main backstay diaphragm level for 3 towers with common podium type structures(with shear wall)

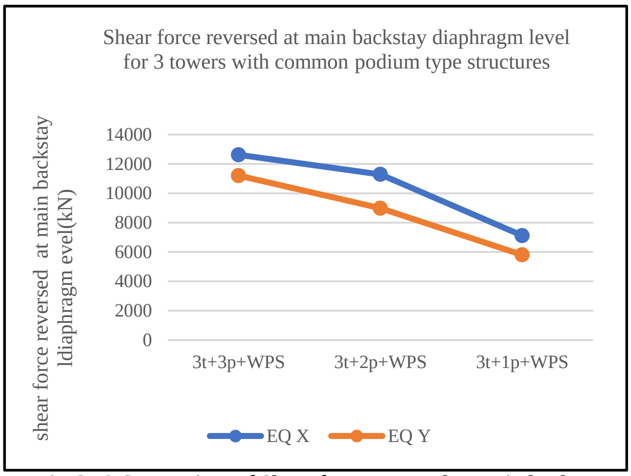

Fig. 3.18 Comparison of Shear force reversed at main backstay diaphragm level for 3 towers with common podium type structures(without shear wall)

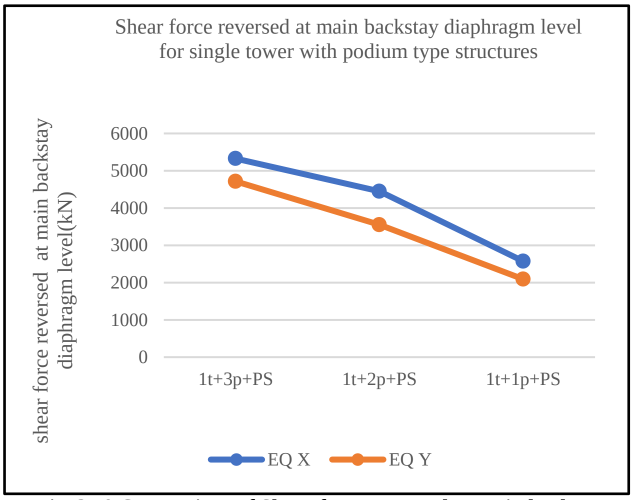

Fig. 3.19 Comparison of Shear force reversed at main backstay diaphragm level for Single tower with podium type structures(with shear wall)

As shown in fig, As the number of podium stories increases, Shear force reversed at the main backstay diaphragm level also increases. In the structures with 3 storey podium, the maximum shear force is reversed at the main backstay diaphragm levels observed. The minimum shear force is reversed at the main backstay diaphragm level in structures with a single-story podium.

3.4. Comparison of Shear force reversed at main backstay diaphragm level for 4 towers with common podium and 3 towers with common podium type of structures with and without shear wall:-

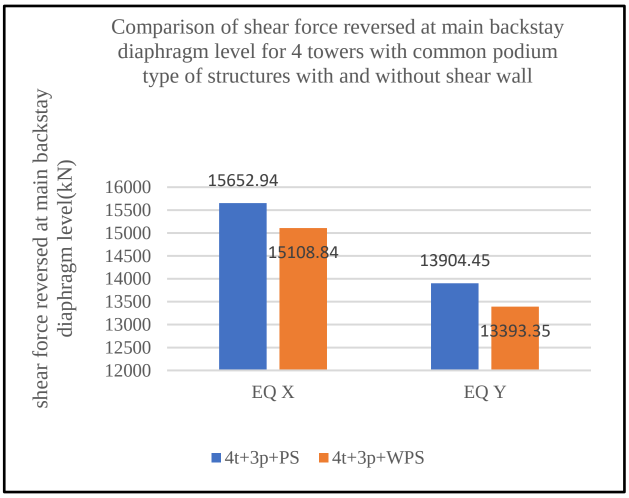

Fig. 3.20 Comparison of shear force reversed at main backstay diaphragm level for 4 towers with common 3 storey podium structures with and without shear wall

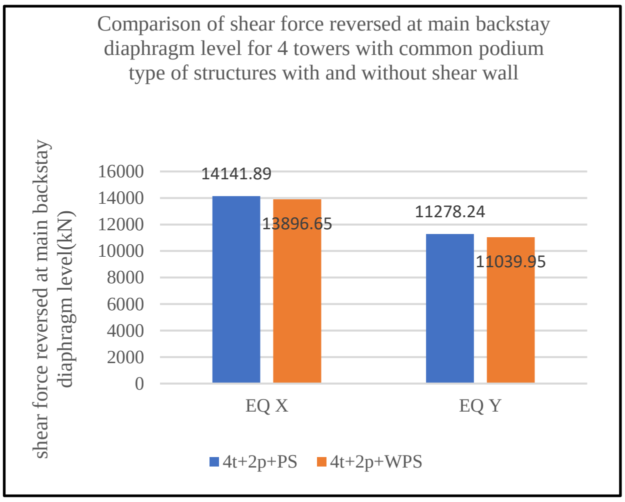

Fig. 3.21 Comparison of shear force reversed at main backstay diaphragm level for 4 towers with common 2 storey podium structures with and without shear wall

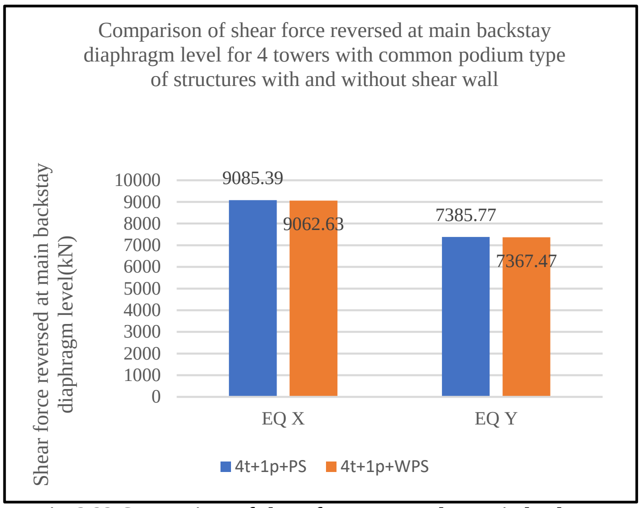

Fig. 3.22 Comparison of shear force reversed at main backstay diaphragm level for 4 towers with common single storey podium structures with and without shear wall

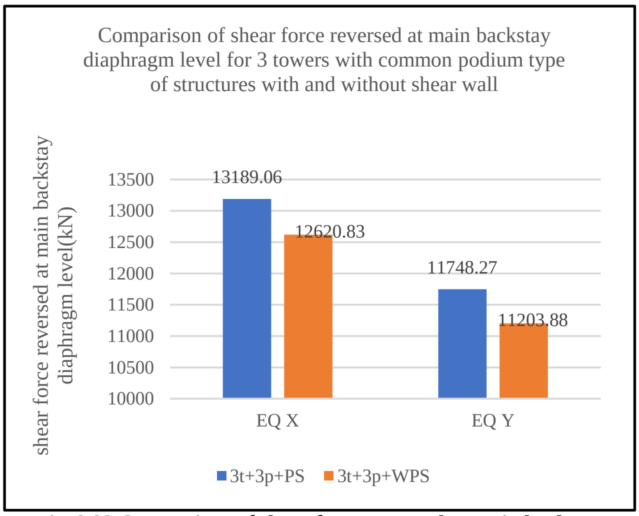

Fig. 3.23 Comparison of shear force reversed at main backstay diaphragm level for 3 towers with common 3 storey podium structures with and without shear wall

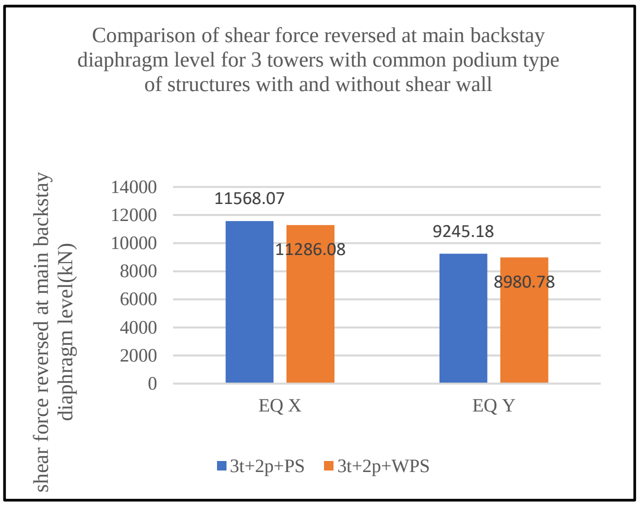

Fig. 3.24 Comparison of shear force reversed at main backstay diaphragm level for 3 towers with common 2 storey podium structures with and without shear wall

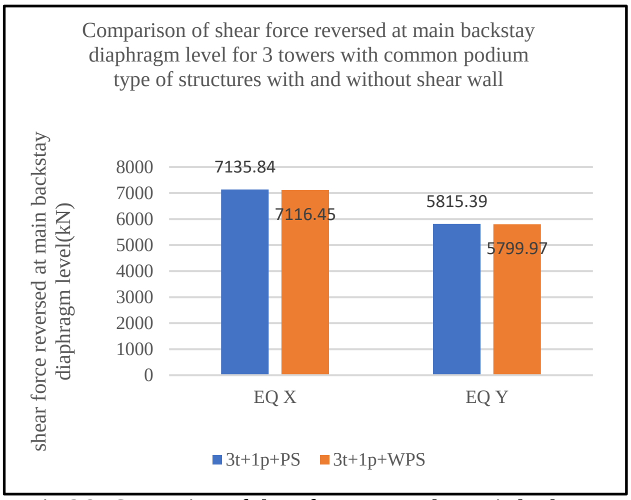

Fig. 3.25 Comparison of shear force reversed at main backstay diaphragm level for 3 towers with common single storey podium structures with and without shear wall

As shown in the above figures, in 4 towers with a common podium and 3 towers with a common podium with a shear wall and without the shear wall, a significant difference is not observed in shear force reversed at the main backstay diaphragm level. The difference in shear force reversed at the main backstay diaphragm level for structures with a shear wall and without a shear wall is very small such as (3 to 6%).

3.5. Comparison of Shear force reversed at main backstay diaphragm level for structures with 3 storey podium, 2 storey podium and single storey podium

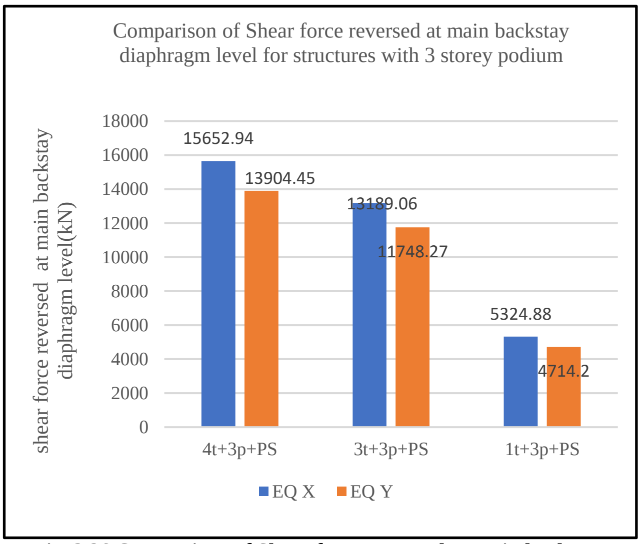

Fig. 3.26 Comparison of Shear force reversed at main backstay diaphragm level for structures with 3 storey podium

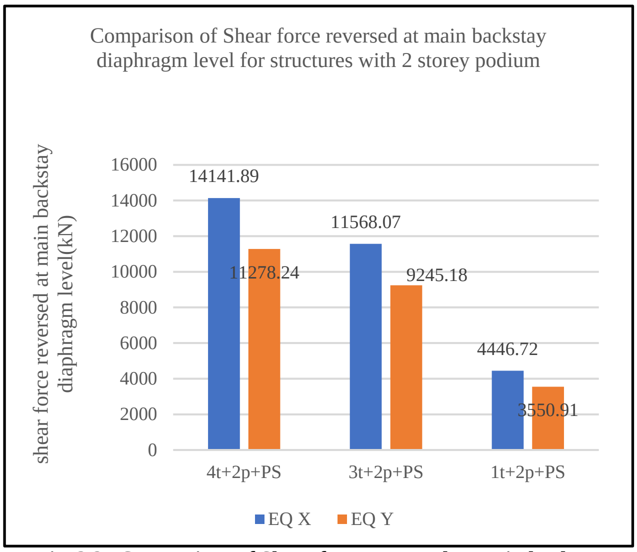

Fig. 3.27 Comparison of Shear force reversed at main backstay diaphragm level for structures with 2 storey podium

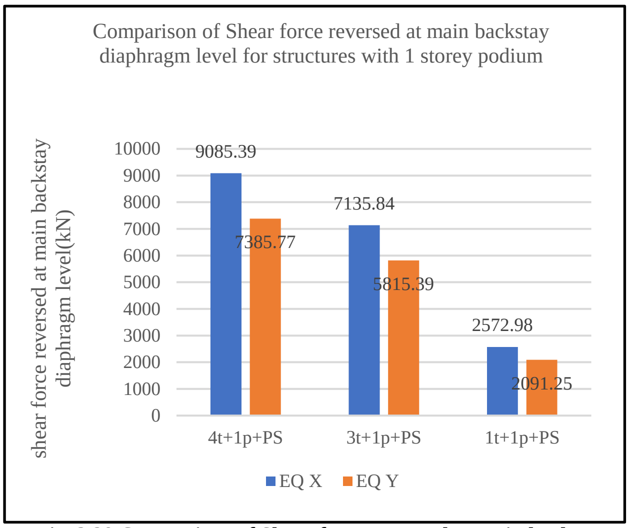

Fig. 3.28 Comparison of Shear force reversed at main backstay diaphragm level for structures with single storey podium

As shown in the above figures, As the number of towers increases, Shear force reversed at the main backstay diaphragm level also increases. It is observed that in structures with 4 towers, the maximum shear force is reversed at the main backstay diaphragm level. The minimum shear force is reversed in structures with a single tower at the main backstay diaphragm level.

3.6. Comparison of results of reduction in overturning moments due to backstay effect for different models

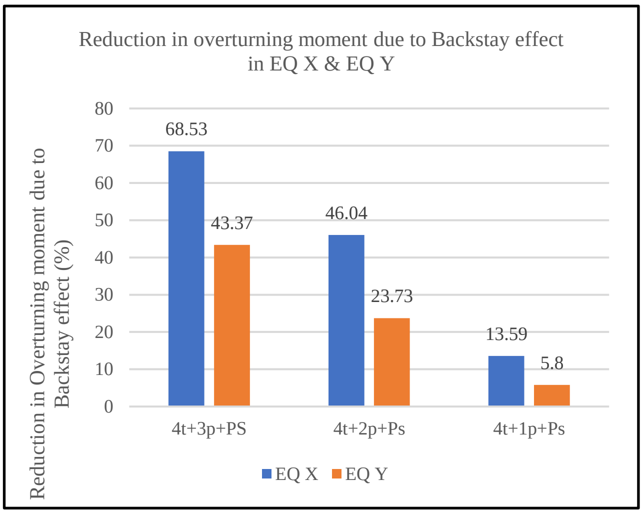

Fig. 3.29 Comparison of Reduction in overturning moment due to Backstay effect in EQ X & EQ Y

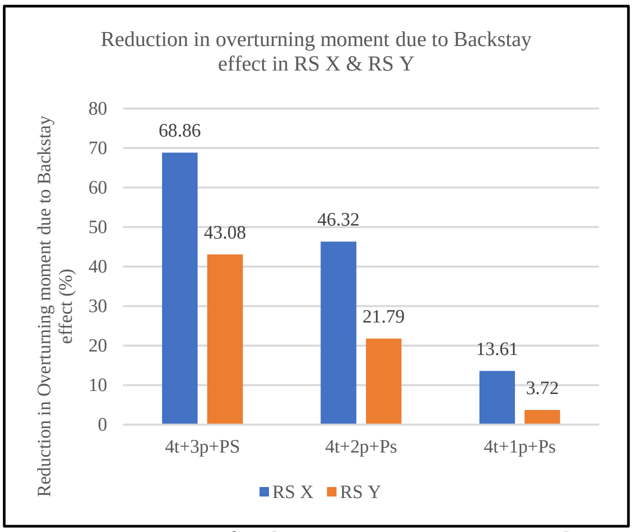

Fig. 3.30 Comparison of Reduction in overturning moment due to Backstay effect in RS X & RS Y

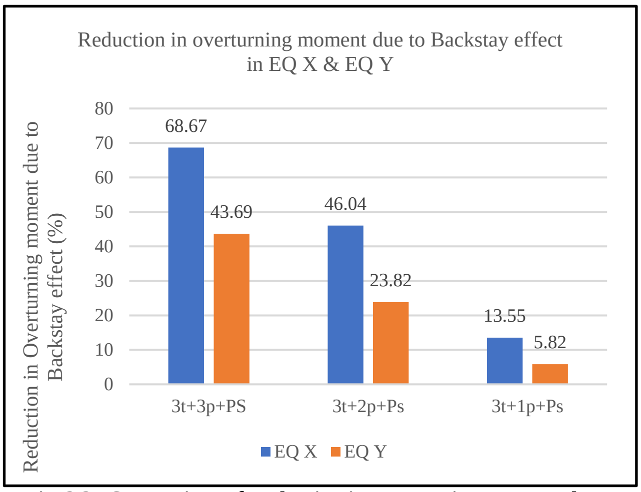

Fig. 3.31 Comparison of Reduction in overturning moment due to Backstay effect in EQ X & EQ Y

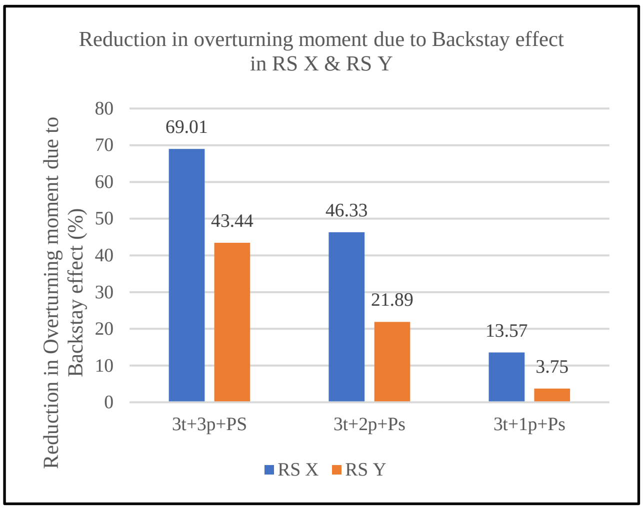

Fig. 3.32 Comparison of Reduction in overturning moment due to Backstay effect in RS X & RS Y

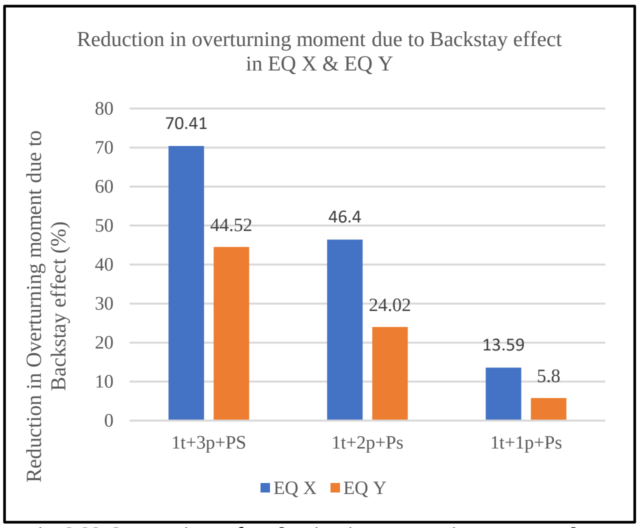

Fig. 3.33 Comparison of Reduction in overturning moment due to Backstay effect in EQ X & EQ Y

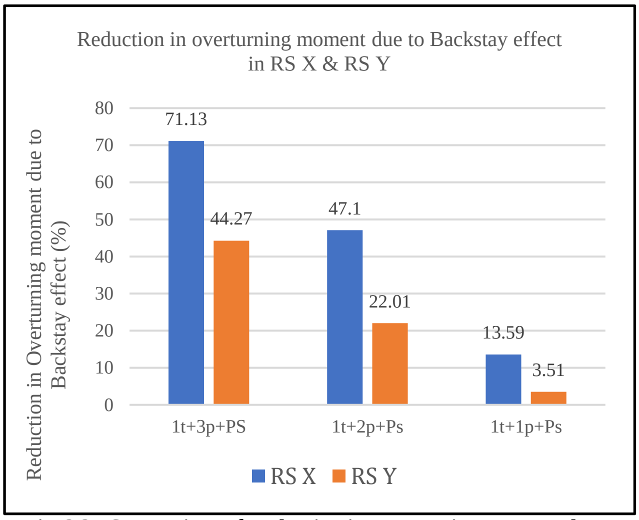

Fig. 3.34 Comparison of Reduction in overturning moment due to Backstay effect in RS X & RS Y

As shown in the above figures, As the number of podium stories increases, the reduction in the overturning moment due to the backstay effect increases. It is observed that in structures with 3 storey podium, the maximum reduction in the overturning moment due to the backstay effect is there, and in structures with a single-storey podium, the minimum reduction in the overturning moment is there. And in all cases, 4 towers with a common podium, 3 towers with a common podium, and the single tower with a common Podium, similar behavior is observed.

3.7. Comparison of reduction in Overturning moment due to backstay effect in 4 towers with the common podium, 3 towers with the common podium, and the single tower with podium type structures

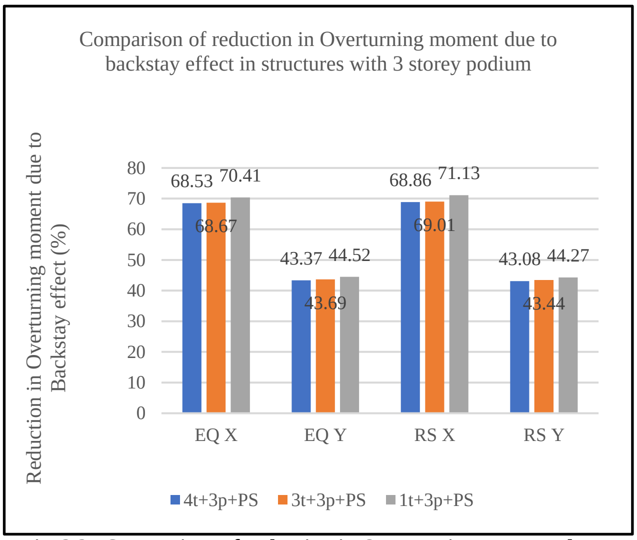

Fig. 3.35 Comparison of reduction in Overturning moment due to backstay effect in structures with 3 storey podium

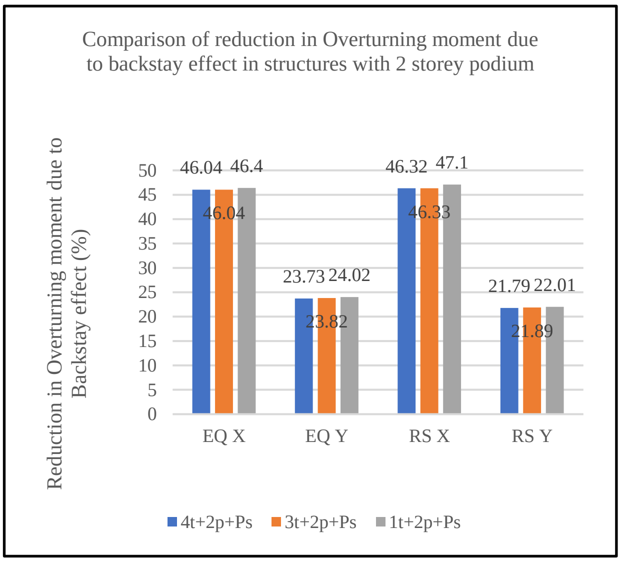

Fig. 3.36 Comparison of reduction in Overturning moment due to backstay effect in structures with 2 storey podium

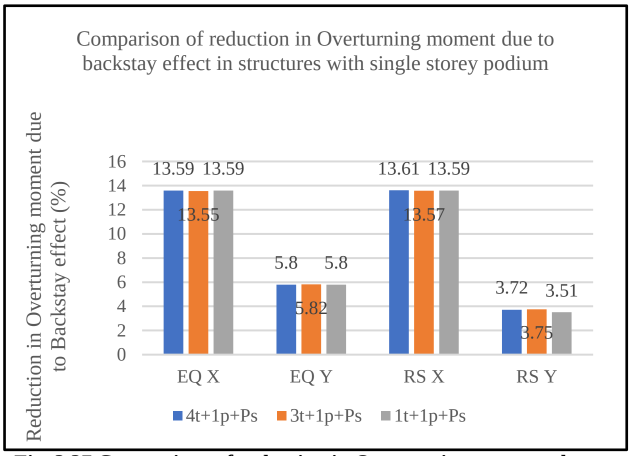

Fig. 3.37 Comparison of reduction in Overturning moment due to backstay effect in structures with single storey podium

As shown in fig, one interesting observation is that, for all the load cases, the reduction in the overturning moment due to the backstay effect is nearly the same for the structures with the same no. of podium stories. In other words, we can say that if the no. of podium stories is constant, then if we increase no. of towers, it will not affect the reduction in an overturning moment due to the backstay effect.

4. Conclusion

- With an increase in the height of the podium in the Tower-Podium configuration, the top Storey displacement of the structure increases in both X and Y directions.
- By increasing no. of towers from the single one with a podium to multiple towers with common podium-type structures, the top-storey displacement of the structure decreases.
- The increase in the height of podiums in towers with podium type of structures leads to an increase in Storey Shear at the main backstay diaphragm level.
- With an increasing number of podium stories, Reverse shear increases at the main backstay diaphragm level.
- It is observed that in Multiple towers with a common podium with a shear wall at the periphery of the podium and without a Shear wall at the periphery of the podium, the difference in Reversal of Shear is small such as (3 to 6)%.
- When the number of towers increases, the Reversal of Shear at the main backstay diaphragm level increases.
- When the number of podium storey increases, the reduction in an overturning moment due to the backstay effect increases.
- It is observed that the reduction in an overturning moment for all the load cases due to the backstay effect is nearly the same for the structures with the same number of podium stories.
- It is observed that the Ratio of Weights of structures and Ratio of Shear force reversed at the main backstay diaphragm level are the same. It shows that an increase in Reversal of shear is proportional to the increase in weight of the structure.

References

[1] IS:16700:2017, “Criteria for Structural Safety of Tall Concrete Buildings,” India, *Bureau of Indian Standards*, 2017

[2] IS 1893:2016, “Criteria for Earthquake Resistant Design of Structures, Part 1: General Provisions and Buildings,” *Bureau of Indian Standards*, New Delhi, pp. 1–44, 1893.

[3] IS 875(Part 1): “Indian Standard Design Loads (Other than Earthquake) for Buildings and Structures- Code of Practice,” 2015.

[4] IS 875(Part 2): “Indian Standard Design Loads (Other than Earthquake) for Buildings and Structures- Code of Practice,” 2015.

[5] Applied Technology Council, “Modeling and Acceptance Criteria for Seismic Design and Analysis of Tall Buildings,” *PEER Pacific Earthquake Engineering Research Institute/ATC-72-1*, 2010.

[6] Taranath B.S, “*Reinforced Concrete Design of Tall Buildings*,” Taylor & Francis Group, 2010.

[7] Tocci, Nat and Sanya Levi, “Backstay Effect Basement Modeling in Tall Buildings,” *Structure Magazine*, pp. 23–24, 2012.

[8] Ankit Purohit, and Lovish Pamecha, “Seismic Analysis of G+12 Multistory Building Varying Zone and Soil Type,” *SSRG International Journal of Civil Engineering*, vol. 4, no. 6, pp. 79-85, 2017. *Crossref*, https://doi.org/10.14445/23488352/IJCE-V4I6P113.

[9] Mehair Yacoubian, Nelson Lam, and John L. Wilson, “Effects of Podium Interference on Shear Force Distribution in Tower Walls Supporting Tall Buildings,” *Engineering Structures, Elsevier*, vol. 148, pp. 639-659, 2017. *Crossref*, https://doi.org/10.1016/j.engstruct.2017.06.075

[10] Babak Rajaee and Perry Adebar, “Seismic Design of High-Rise Concrete Walls: Reverse Shear Due to Diaphragms below the Flexural Hinge,” *ASCE Journal of Structural Engineering*, vol. 135, no. 8, 2009. *Crossref*, https://doi.org/10.1061/(ASCE)0733-9445(2009)135:8(916)

[11] Md Taqiuddin, and Dr. V Lakshmi Shireen Banu, "Numerical Study on Behavior of Non-Tower Building Attached with Tower,” *International Research Journal of Engineering and Technology*, vol. 6, no. 9, pp. 1412-1428, 2019.

[12] Geetha, and Kiran Kamath, “Seismic Performance of a Tall Multi Storey Tower Connected by a Large Podium,” *International Journal of Recent Technology and Engineering*, vol. 8, no. 2, pp. 3545-3551, 2019. *Crossref*, http://doi.org/10.35940/ijrte.B3065.078219

[13] Ankan Kumar Nandi, and Jairaj C, “Backstay Effect of Diaphragm in Tall Building,” *International Journal of Innovative Technology and Exploring Engineering*, vol. 9, no. 3, pp. 1578-1587, 2020. *Crossref*, http://doi.org/10.35940/ijitee.C8621.019320

[14] Kishan B. Champaneriya, Vishal B. Patel, and Atul N. Desai, “Effect of Backstay on Tall Structure with Podium Structure,” International *Journal of Advanced Research in Science, Communication and Technology (IJARSCT)* , vol. 7, no. 2, 2021. *Crossref*, http://doi.org/10.48175/IJARSCT-1724

[15] Kush Shah, Hiren Desai, and Dhara Shah, “Effect of Backstay on 3B+G+20 Storey RC Building,” *National Conference on Structural Engineering, NCRASE – 2020, 21-22 August 2020, National Institute of Technology Jamshedpur*, Jharkhand India, 2020.

[16] Nirav Bhatu, Vishal B. Patel, and Pratiti Bhatt, “Effect of Backstay on Tall Structures with Podium,” *International Research Journal of Engineering and Technology*, vol. 9, no. 4, pp. 529-532, 2022.