Effect of Backstay on Tall Structures with Podium

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Abstract - *Structural engineering is the art and science of creating structures that are safe, cost-effective, and durable. The entire exercise necessitates conceptual thinking based on structural engineering principles, as well as acceptable behavior and performance of the building during normal functional use and during extreme catastrophic events such as earthquakes, windstorms, and other natural disasters, all while adhering to the most recent codal provisions. The scope of this study is to study the modeling technique and to understand the realistic behavior of Multiple towers with common podium type structures under lateral loads considering the backstay effect as per IS:16700 (2017) "Criteria for Structural Safety of Tall Concrete Buildings". In this study, different models were prepared by changing the height of the podium and no. of towers in structure, and a comparative analysis is performed on the single tower with podium type of structures and multiple towers with common podium type structures by varying the height of Podium and no. of towers in Structure with shear wall and without Shear wall on the periphery of Podium. For the seismic analysis, Linear static and Response spectrum approaches are considered, and obtained results are represented and compared graphically. In this study, the analysis of Multiple towers with common podium type structures is done using the structural analysis tool ETABs.*

Key Words: **Podium, Backstay effect, multiple towers with common podium, seismic analysis, Equivalent static method, Response spectrum method**.

1. INTRODUCTION

Due to rise in population & land scarcity in urban areas, the need for tall structures is increasing day by day. Tall buildings are an evolving construction practice in developing countries including India. In any city, especially in metro cities, after certain horizontal development, no more land is available for development. So, to have optimum use of land, multistorey towers became popular. Due to the complexity of the structures, the most advanced engineering design techniques are needed in tall structures and to satisfy demand of larger commercial space near road level and make the building compliant with minimum parking space requirements for such mixed-use development according to prevailing bye-laws, Architects and Developers have come up with the unique idea of Podium type Buildings. Many tall structures have an arrangement in which the below few stories have a larger plan area than the towers above. A podium is the lowest level of tall building construction with a larger floor plan area and significantly higher seismic force resistance than the tower above. As compared to low and mid-rise buildings, the design criteria for high-rise buildings are different. Shear walls (lateral systems) have traditionally been viewed as simple cantilever beams fixed at the base. This analogy is reasonably correct for the above-grade structure, but for (podium + tower) type building, a more realistic and justifiable analogy would be a cantilever with a back span to take into account the effects of the relatively large lateral stiffness of the podium. Backstay effects are the transfer of lateral forces from the tower's seismic-force-resisting components to additional elements within the podium, usually via one or more floor diaphragms. A tall building's lateral force resistance and force transfer through floor diaphragms at these levels help it resist seismic overturning forces. Based on its similarity to the back span of a cantilever beam, This component of overturning resistance is referred to as the backstay effect. Sometimes it is also referred to as "Shear Reversal", because the shear in seismic load resisting elements can change its direction within the podium levels. BIS released the Code IS:16700 (2017) "Criteria for Structural Safety of Tall Concrete Buildings" in which various criteria for tall structures and detail regarding the analysis of the podium type tall structures with consideration of backstay effect is given. To account for the realistic behavior of the podium type tall structure, IS:16700(2017) also gives the sensitivity analysis approach. The details regarding modeling and accepted criteria for such a structural configuration and backstay effect are discussed in PEER/ATC 72-1 and Indian standard 16700-2017 "Criteria for the structural safety of tall concrete buildings". In IS: 16700 (2017), the details regarding sensitivity analysis of such structure by changing the stiffness parameters for elements within the podium level are given and in PEER/ATC 72-1 the instructions for the modeling of Podium Diaphragms, Collectors, and Backstay Effects are given.

1.1 Aim of study

To Study the backstay effect and shear reversal that occurs in the multiple tower with common podium type structures.

1.2 Objectives Of Study

Following are the objectives of the study:-

1. To study and understand the concept of backstay/Shear reversal observed in multiple towers with common podium type structures by considering the provisions given in the Indian standards (IS 16700: 2017).
2. To study the effect of the podium on the behavior of the tower.
3. To perform comparative Analysis on single tower with podium type structures and multiple towers with common podium type structures by varying height of Podium and no. of towers in Structure with shear wall and without Shear wall on the periphery of Podium.
4. To study the effect on shear reversal and backstay effect by changing the height of podium/no. of podium stories.
5. To study the effect on shear reversal and backstay effect by changing the no. of towers in the structure.
6. To study, interpret and compare the analysis results among the following structural systems:-

    a. Single tower with podium type of structures
    b. Three towers with common podium with Shear wall at the periphery of the podium.
    c. Three towers with common podium without Shear wall at the periphery of the Podium.
    d. Four towers with common podium with Shear wall at the periphery of the Podium.
    e. Four towers with common podium without Shear wall at the periphery of the Podium.

2. LITERATURE REVIEW

By focusing on writing audits from various authors, the following were completed:-

Mehair Yacoubian et al. (2017). Linear and non-linear analyses were done on a tall R.C.C podium-type building in this study. The structure was also tested by altering the podium height. The tower was also placed at a certain offset for the study. The diaphragms were modeled as semi-rigid to account for in-plane horizontal deformation. The author concluded that the dual-wall framing action can be affected by Diaphragm flexibility. At the podium tower interface, the maximum strutting forces in coupling beams were detected and at the podium tower interface level, shear force reversal was also detected. To reduce the podium restraint effects on the building, other design approaches such as expansion joints can be considered. It was also revealed that the conventional in-plane rigid diaphragm assumption leads to unconservative tower wall design.

Babak Rajaee et al. (2009). In this paper, the authors stated that The maximum bending moment (flexural plastic hinge) occurs above the diaphragms and the shear force reverses below the flexural hinge when a large amount of the overturning moment in the wall is transferred to the foundation walls by force couples in two or more stiff floor diaphragms. The reverse shear force below the flexural hinge may be substantially greater than the base shear force above the flexural hinge, depending on the stiffness of floor diaphragms and the shear and flexural rigidity of high-rise concrete walls. The maximum reversed shear force is related to the wall's bending moment capacity and inversely proportional to the accompanying base shear force, according to nonlinear dynamic studies. And based on this study, they gave several conclusions and recommended design procedures to deal with reversed shear Forces in high-rise tower walls connected to stiff base structures.

Md Taqiuddin et al. (2019). The in-plane strutting forces and in-plane floor deformation at the tower-podium contact were the main points of focus for this research. The reactive forces generated at the tower podium interface level and their impact on podium tower-type structures were discussed in this work. This research was conducted on two types of podium buildings: 1) 3B+G+50 and 2) 3B+G+9. In CSI ETABS, analysis sets were performed by changing the podium width while keeping the tower dimensions constant. Flat slabs/Flat plates were considered as diaphragms and they were modeled as semi-rigid. The study was also carried out by altering the column spacing. The findings were compared for the wind load impacts on the structure. On the basis of the outputs of the ETABS models of parameters such as displacements, drifts, axial forces, and shell stresses, a comparative study was performed. The assumption of a rigid diaphragm at the podium levels suppresses the in-plane forces generated at the diaphragm levels, according to this study. When the space between columns is lowered, the strutting forces produced in diaphragms increase. Tower displacements can be reduced by using podiums and the drift is unaffected by increasing the podium's size.

Geetha et al. (2019). In this study, buildings with different podium heights were analyzed to observe changes in back-stay effects on a podium-tower type building. A 36m x 36m tower and a 108m x 108m podium with varying heights were under consideration. The buildings were analyzed by equivalent static and response spectrum analysis. And results of bending moments, shear forces, and displacements were observed. The findings of the analysis in terms of parameters like shear force, bending moments, and top story displacement were compared to corresponding results for various structural configurations. In the case of the response spectrum approach, the top displacement decreases after incrementing at a certain point and then remains independent of the podium height. The backstay effect is imposed by the podium at the podium–tower interface level and so, the backstay forces at the tower and podium interface rise as the podium stories increase. They also observed that the behavior of the structure was more critical when the tower was offset from the center, as opposed to when the tower was in the center.

Ankan Kumar Nandi et al. (2020). In this study, the backstay effect was investigated, as well as the usage of a retaining wall to increase lateral stiffness, as stipulated in the latest tall building code IS:16700-2017 for low and high rise structures. Models with low to high rise stories and rigid and semi-rigid diaphragms were created for this study. By considering the podium floor diaphragm as a semi-rigid and rigid diaphragm, the influence of diaphragm flexibility on backstay forces at the tower and podium interface level was investigated. The effect of the placement tower at the center and corner on backstay forces was also investigated. Two structural cases were selected as 20 and 40-storey framed structures for a comparative study of rigid and flexible diaphragms situations. Both structural cases were analyzed using the structural analysis software ETABS. The findings were compared using factors such as base shear, story shear, top story displacement, and story drift. In addition, the tower structure with podium structures was compared to the bare frame structure. When the backstay effect was taken into account, there was a 35% reduction in top displacement in both 20-story and 40-story buildings when compared to the bare frame. The diaphragm drifted inside the allowed range due to the action of the backstay. The effect of backstay increases as the structure's weight increases, resulting in a corresponding increase in base shear. The authors concluded that when a tower was located at the center of the plot area, it produces better outcomes than when it was placed in the corner.

Kishan B. Champaneriya et al. (2021). The authors' goal in this research was to comprehend the realistic behavior of such structures under lateral loads while taking into account the backstay effect, as defined by IS: 16700(2017). To understand the variations in the shear force distribution among structural elements when the tower and Podium are modeled together, a sensitivity analysis was performed as per IS: 16700 (2017) considerations, taking into account the stiffness parameters given in the code & the variations in force distribution were compared to structures that did not have a backstay effect. It was concluded that by increasing podium height, the backstay forces can be increased. It was also concluded that by increasing the thickness of podium diaphragms and area of Podium, the backstay forces can be increased.

Kush Shah et al. (2020). In this paper, the authors' scope was to study the integrated modeling technique for a real-time 3B+G+20 storey building having a tower and below-grade podium to be able to forecast its behavior under earthquake loads in a realistic manner. The impact of a below-grade podium with a larger area and lateral stiffness than an above-grade tower on lateral load distribution, behavior, performance, and design philosophy of lateral load resisting systems, such as floor diaphragms at the intersections of below-grade podium and towers, was studied. When the tower and podium are modeled together, a set of Backstay Sensitivity analyses was performed on the structure to understand the behavior and changes in the force distribution among various structural elements and the impact of the overturning resistance provided by the backstay effect on the tower's behavior and performance was compared and analyzed against the behavior and performance of the tower without the effect. It was found that when we analyze and design below Grade Podium type towers considering the Tower and Podium separately and combined together, the magnitude and direction of the forces generated in the diaphragm, beams, shear walls, and columns change significantly.

3. CONCLUSIONS

Following are the conclusions from the review study:-

1. when we analyze and design below Grade Podium type towers considering the Tower and Podium separately and combined together, the magnitude and direction of the forces generated in the diaphragm, beams, shear walls, and columns change significantly.

2. Some structural engineers' current practice of modeling and designing towers and podiums separately or considering one or two bays surrounding the tower may result in several structural elements being over or under-designed, compromising the overall safety and serviceability of the structure, including the foundation.

3. By increasing podium height, the backstay forces can be increased.

4. With the increase in thickness of the podium, the backstay forces can be increased.

5. The backstay forces can be increased by increasing the Area of the podium.

6. Displacement of structure reduces with an increase in Backstay effects and when a tower was located at the center of the plot area, it produces better outcomes than when it was placed in the corner.

7. The behavior of the structure was more critical when the tower was offset from the center, as opposed to when the tower was in the center.

8. When the space between columns is lowered, the strutting forces produced in diaphragms increase and Tower displacements can be reduced by using podiums.

9. At the podium tower interface, the maximum strutting forces in coupling beams were detected and at the podium tower interface level, shear force reversal was also detected.

10. The conventional in-plane rigid diaphragm assumption leads to unconservative tower wall design.

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