A Review Study on Tall Structures with Altering Podium Height Inducing Backstay Effect With & Without Shear Wall

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Abstract — In a tall building, generally the building has a wider plan area and higher lateral resistance at the lower story level than the above story levels. So, the aim of this study is to recognize the actual behaviour of such structures under lateral loads considering the backstay effect as per IS: 16700. The present study focuses to understand the behaviour and effect on a tower connected by a podium at different levels with the consideration of several parameters under lateral load. The effect of backstay forces which is studied here are developed to resist the lateral overturning actions at the junction of tower interacted with podium from where the lateral load has been transferred. The critical effect of podium on the force distribution at and above junction is observed and on the basis of these parametric previous studies, one can easily understand the actual behaviour and do the necessary consideration in such conditions.

Keywords: RC Building, Seismic Analysis, Backstay Effect, Podium, Tower, Shear wall

I. INTRODUCTION

The demand for tall structures is increasing due to rising population and land problems 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, multi storied 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 government rules with the proper efficiency, the concept of Podium kind structures is introduced. The bottom few storeys have bigger plan dimensions than the towers in many tall structures and can be used for different purposes such as parking, retail shops, etc and can be considered as a podium for the tall building with the tower above. 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 storey sometimes used as a podium. In many multi-functional tall buildings, this type of configuration is seen. The assembly of the tower-podium type of structure is shown in picture below.

One of the critical aspects of modelling building structures is dealing with at and below-grade components of the structure. The main aim of this research is commonly referred to as the backstay effect. Conventionally, tall buildings have been viewed as simple cantilever beams fixed at the base. While this resemblance is reasonable for the above-grade structure, a more accurate correlation would also include the effects of the below-grade structure, which behaves like a back span to the cantilever. In this phenomenon, the lateral system is considered as a beam overhanging one support, where that support is created by the diaphragm and foundation walls at the level where backstay forces have been developed. This effect is not limited to control at the grade level. It can also see at setbacks with changes to the lateral system, the most common example being lower level podiums. They are often very wide in plan and with the introduction of lateral element; it becomes significantly stiffer than the structure above. This paper will focus on the most common example which is the effect of the ground floor or above diaphragm in contributing to backstay effects.

II. BACKSTAY EFFECT

The bottom part of a tall structure that is larger in the floor plan and contains a significantly increased seismic force resistance when compared to the portion of the tower above can be considered as a podium structure. Many tall structures have an arrangement in which the below few storeys have a larger floor plan than the towers above, this type of construction is common in multi-storey buildings where the lower part of storeys often used for various purposes like retail stores, parking lot, meeting rooms etc.

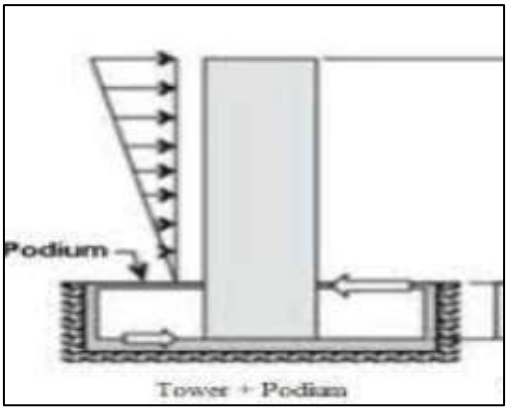

Fig. 1: Backstay action in a podium-tower assembly

The study enhances the effects of a setback on the dynamic response of the structure and design criteria to improve the response of setback building for lateral forces. The backstay effect which is most traceable in buildings with a distinct lateral system (ex: shear wall, core wall) which are connected with the base structure. It has been found that more than enough amount of study has been carried out on the displacement parameter for single tower connected by a podium structure in which the number of storeys in the podium structure is varied. In this present study, the behaviour of the single tower with different height of podium is carried out. To determine the optimum height of the podium will be determined which helps designer to consider this in a severe condition. Podium in a tall structure works as a separation between different building occupancy categories. It also 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.

III. Need of the Study

The need of present study is to compare the diaphragm effect for tall structures at junction level between tower and podium. Also to understand the phenomena of the Backstay effect observed in the tower-podium type structures by considering the provisions given in the Indian standards (IS 16700: 2017). This also helps to investigate the effect of increasing the number of storeys which can induce the backstay effect.

IV. Literature Review

This section provides a detailed review of the literature related to back stay effects. The literature review focuses on recent contributions related to seismic behaviour of buildings with backstay effects and past efforts closely related to the present work.

Hardik B. Rangani1 and Dr. Vinubhai R. Patel2, "Benefits of Backstay Effect in Design of Podium Structure for Tall Building as Per IS 16700:2017", IJARSCT ISSN (Online) 2581-9429 International Journal of Advanced Research in Science, Communication and Technology (IJARSCT) Volume 2, Issue 6, June 2022 PP 113 – 117, - this study determines the realistic behaviour of such structures under lateral loads considering the backstay effect as per IS: 16700(2017). The author focuses on the effect of podium structure of single tower structure connected by a common podium at the interface level under seismic load. For this purpose, the simulation model with varying tower height and podium height is created in the ETABs and is analysed for the equivalent static and response spectrum method. The positioning of the tower on the podium structure is found to be the reason for the differential displacement between the structural walls.

Nirav Bhatu1, Vishal B. Patel2, Pratiti M. Bhatt3, "Effect of Backstay on Tall Structures with Podium", SSRG International Journal of Civil Engineering Volume 9 Issue 6, 47-61, June 2022 ISSN: 2348-8352 - 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 and is also one of the scopes of this research. 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.

Kishan B. Champaneriya et al. (2021), "Effect of backstay on tall structure with podium structure", Volume 7, Issue 2, (IJARSCT 2021) PP 106 -112, The authors' goal in this research was to comprehend the realistic behaviour 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 modelled 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) "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 - In this paper, the authors' scope was to study the integrated modelling technique for a real-time 3B+G+20 storey building having a tower and below-grade podium to be able to forecast its behaviour 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, behaviour, 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 modelled together, a set of Backstay Sensitivity analyses was performed on the structure to understand the behaviour 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 behaviour and performance was compared and analyzed against the behaviour 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.

Ankan Kumar Nandi et al. (2020) "Backstay effect of diaphragm in tall building", Volume:9, Issue:3 (IJITEE, 2020) PP 645 -651 - 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 when the weight of structure increases, resulting in a corresponding increase in base shear. The authors concluded that when a tower was located at the centre of the plot area, it produces better outcomes than when it was placed in the corner.

Md Taqiuddin et al. (2019) - "Numerical study on behaviour of non-tower building attached with tower", Volume: 6, Issue:9 (IRJET,2019) PP 16 -22 - 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 modelled 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),"Seismic performance of a tall multi storey tower connected by a large podium", Volume:8, Issue:2 (IJRTE, 2019) PP 112 – 121, - 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 behaviour of the structure was more critical when the tower was offset from the centre, as opposed to when the tower was in the centre.

Mehair Yacoubian et al. (2017) "Effects of podium interference on shear force distribution in tower walls supporting tall buildings", (Elsevier 78 -92, 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 modelled 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 non conservative tower wall design.

Babak Rajaee et al. (2009) - "Seismic design of high-rise concrete walls: reverse shear due to diaphragms below flexural hinge." ASCE / August 2009, DOI:-10.1061/(ASCE)0733-9445(2009)135:8(916) - 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.

V. CONCLUSION

Following Conclusions have been made from the study undertaken –

- The forces in the members of the podium structure varies significantly when we analyze the tower with podium structure and compare it with tower structure only
- By increasing the height of podium, the backstay forces also increases.
- By increasing the area of podium, it can significantly increase the amount of backstay forces too.
- Displacement of structure reduces with an introduction of podium structure to a tall building.
- From this study, it is also seen that the behaviour of the structure was more critical when there was an offset in the placement of tower, as compared to when the tower was in the centre of the podium for the tall RC building.
- At the podium tower junction, the shear force reversal detected and the moment also varies significantly which will tends to change the behaviour of a tall structure.

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