A Review on To Research for The Effect of Pedestal Structure Modification in High-Rise Buildings

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Abstract - The growing population and limited land in urban areas are driving up demand for towering buildings on a daily basis. India and other emerging countries are seeing an increase in the use of tall buildings. Land becomes unavailable for further expansion in any city, particularly in major cities, beyond a certain point of horizontal development. Consequently, multi-story skyscrapers gained popularity as a means of optimising land use. The design principles used for low- and medium-rise structures are not applicable to high-rise skyscrapers. Tall structures demand the most advanced design techniques since they are intricate engineering tasks. Architects and engineers proposed/put forward the new idea of Podium sort constructions in order to meet the demands of both the growing population and the present bye-laws requiring a minimum parking space for such types of buildings. These days, tower-podium style structures are quite common since they provide for the best possible use of available space on the property and the financial leverage to meet the need for more commercial space. A portion of a structure known as a podium has lateral load resistance greater than that of a tower.

Key Word: *Backstay, Diaphragm, ETABS, Podium Height, lateral forces.*

I. INTRODUCTION

There is a shortage of adequate land for development as a result of population growth, urbanisation, and the need for diverse infrastructure. This has caused the cost of land to rise sharply. In order to maximise land utilisation, multi-story towers gained popularity. However, in order to apply financial leverage in addition to meeting the need for greater commercial space close to road level and ensuring that the building complies with the minimum number of parking spaces required for such mixed-use developments under current bylaws Developers and architects have developed a novel concept for Podium-style buildings. They might be above or below ground, or both. In terms of structural engineering, a podium is that portion of the structure whose lateral load resistance is comparatively much more than that of the tower above. In general, a podium is that portion of a building whose floor area is relatively much larger than the tower above. Thus, Podium-style buildings serve many purposes, such as parking and residential, parking and commercial, and commercial and residential, among others.

1.1 Back-Stay Effect

Historically, basic cantilever beams fixed at the base have been the standard understanding of lateral systems. Although this parallel makes sense for an above-grade structure, a more appropriate and practical comparison for a podium + tower type building would be a cantilever with a back span, which would account for the impacts of the podium's comparatively greater lateral stiffness. As per structural geometry, the above-ground, at-ground, and below-ground diaphragms as well as the peripheral shear (basement walls) supply this intermediate support, which is analogous to a cantilever beam overhanging from one intermediate support in the lateral load resisting system.

II. STATE OF DEVELOPMENT

Solanki Chirag Lalit et. al. (2023) These days, Tall structures are becoming a must in urban areas because of the growing population and scarcity of available land. Because of this, vertical development is frequently a more sensible and economical choice than horizontal extension, especially when taking into account accessibility and closeness to the city. By joining a floor's joints, diaphragms serve as lateral load-resisting structures, distributing inertial forces between structural elements. Together, the diaphragm and subterranean perimeter walls of the podium form a rigid box structure. This increases the resistance to lateral loads. In order to counteract the acting lateral pressures caused by seismic and wind activity, the podium creates an internal resisting couple that results in the backstay effect. This action is balanced in nature. In compliance with IS: 16700:2017, "Criteria for Structural Safety of Tall Concrete Buildings," India, Bureau of Indian Standards, 2017, this article looks at multi-story models that include spring action at the podium level and explores the impact of various podium shapes and grading in a vertical direction. Compared to typical rigid action, the study reveals that semi-rigid action at the podium level increases the backstay impact. Additionally, the study demonstrates that the grade and form of the podium enhance the shear-reversal effect, resulting in decreased base shear and base moment.

Hradik b. Rangani, et. al. (2022) The authors' goal in writing these articles was to investigate the backstay effect using IS 16700 (2017). The author of these studies examines the backstay effect by taking into account the various tower, podium, and diaphragm conditions. He created several models according to ETABS parameters and used IS 16700 (2017) to analyse them. He came to the conclusion that the backstay force at the Tower podium interface level increased together with the podium height after reading the data. Displacement eventually decreases further when the backstay takes effect. When comparing the three-story podium to the tower alone, there was a decrease in displacement when the backstay effect and backstay diaphragm effect were taken into account.

Nirav Bhatu et al (2022) The writers of these articles wanted to compare towers with podiums and many towers with shared podiums and shear walls. They also wanted to analyse the backstay effect by varying the tower's story count. He chose a 15-story tower with a plan size of 25 by 25 and a podium with a plan size of 85 by 85 as the framework for these works. CSI ETABS software was used to create 16 distinct models based on all points of comparison. The analysis was conducted using IS 16700 (2017). The author concludes that as the height of the podium in the Tower-Podium configuration increases, the top storey displacement of the structure increases in both directions based on comparisons of 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. The top-story displacement of the building diminishes when the number of towers increases from one with a podium to several towers with shared podium-type structures. The author also came to the conclusion that the Reversal of Shear at the main backstay diaphragm level increases with a rise in the number of towers.

Mohammed Danish Jamal et. al. (2022) The author of these articles intends to examine the residential construction system for seismic loading. He used a fifteen-story structure that measured 76 by 76 metres and 25 by 25 metres with and without a podium. Additionally, he examines models by moving the tower to the centre and off centre, and he creates models based on CSI ETABS points of comparison. He conducted an analysis using the IS 16700 (2017) criterion for tall building structural safety. Following research and a comparison of all the data, he came to the conclusion that the building with the podium exhibits greater base shear than the structure without the podium. The model with a podium has a maximum story drift that is more than the building without a podium. Therefore, while comparing the model with podium to the model without, it is observed that the time period is decreasing and the base shear and narrative displacement are rising.

Hardik B. Rangani et. al. (2022) A multi-functional tall structure often has a larger plan area at the lower story levels compared to the upper story levels, as well as more lateral resistance. The goal of this study is to comprehend how these constructions will actually behave under lateral loads while taking the backstay effect into account, in accordance with IS: 16700 (2017). The current study focuses on how a single tower building's podium structure behaves under seismic load at the interface level when connected by a shared podium. In order to do this, a simulation model with adjustable podium and tower heights is built in the ETABs and examined using the reaction spectrum and analogous static methods. This study examines how the equivalent static and response spectrum methods of analysis affect the tower's top displacement in relation to the podium construction. When lateral horizontal forces are transmitted from the tower to the podium, backstay forces are created to oppose lateral overturning motions at the interface. These forces are examined. We observe that the podium has an adverse influence on the shear force distribution at and above the structural wall's interface level. The explanation behind the difference in displacement between the structural walls is determined to be the tower's placement on the podium structure.

Kishan B. Champaneriya et al. (2021) The purpose of this study, according to IS: 16700 (2017), was to examine the realistic behaviour of tall buildings under lateral loads while taking the backstay effect into account. A sensitivity analysis was conducted in accordance with IS: 16700 (2017) considerations to comprehend the variations in the backstay force distribution among structural elements when the tower and Podium are modelled together. The stiffness parameters provided in the code were taken into account, and the variations in results were compared to structures that did not have a backstay effect. The findings indicated that raising the podium height might raise the backstay forces. It was also determined that the backstay forces may be raised by thickening the podium diaphragms and expanding the Podium area.

A. Dilsiz et. al. (2021) Reinforced concrete floor slabs are often represented as rigid diaphragms in dynamic analysis of structures subjected to seismic stresses, with the assumption of infinite in-plane stiffness in order to minimise computation time. Shear walls and columns receive the story shear and torsional moments in accordance to their respective stiffnesses, thanks to the rigid diaphragm assumption, which guarantees that the floors act as rigid bodies. Comprehensive analysis is necessary since the rigid diaphragm assumption can often result in unrealistic internal force and displacement distribution in structural elements. As to the Turkish Building Seismic Code for 2018 (TBSC 2018), the utilisation of rigid diaphragm is permissible in some instances but not permitted in structures with A2 or A3 type anomalies, which are associated with floor discontinuities and excessive projections, respectively. This study examines, using numerical analysis, the effects of a rigid diaphragm assumption on structural element internal forces, story shears, inter-story drift ratios (ISDR), and torsional irregularity coefficients (TIC) in a prototype building with and without the diaphragm. We find that, while other structural behaviours are relatively less sensitive to the rigid diaphragm constraint, the rigid diaphragm assumption has a significant impact on the in-plane floor stiffness and, as a result, the internal force distribution of structural elements, especially when story stiffness changes. While the rigid diaphragm assumption greatly reduces calculation time for nonlinear structural analysis, it is nevertheless advisable to verify its implications, particularly for buildings with irregularities caused by stiffness changes owing to elevation.

Ankan Kumar Nandi et al. (2020) The backstay impact was examined in this work in accordance with the most recent tall building code, IS:16700-2017, which applies to both low- and high-rise structures. For this investigation, models with stiff and semi-rigid diaphragms and low to high rise stories were developed. Investigating the impact of diaphragm flexibility on backstay forces at the tower and podium interface level included treating the podium floor diaphragm as a semi-rigid and rigid diaphragm. Also examined was the impact of the placement towers at the corner and centre on backstay forces. Two structural cases—20- and 40-story framed buildings—were chosen so that the circumstances involving stiff and flexible diaphragms could be compared. We used the structural analysis software ETABS to analyse both structural instances. Story drift, top story displacement, base shear, and story shear were among the parameters used to compare the results. The backstay's motion caused the diaphragm to wander inside the permitted range. Base shear rises in proportion to the influence of backstay as the weight of the structure increases. The writers came to the conclusion that placing a tower in the middle of the plot area yields better results than placing it at a corner.

Kush Shah et al. (2020) In order to realistically predict the behaviour of a real-time 3B+G+20 storey structure with a tower and a podium below grade, the authors of this work set out to investigate the integrated modelling approach. The study examined the effects 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, of a larger area and more lateral stiffness below-grade podium compared to above-grade tower. The structure was subjected to a series of Backstay evaluations when the tower and podium were modelled together. to comprehend changes in the force distribution between structural components. In order to comprehend the influence of the backstay effect's overturning resistance on the tower's behaviour and performance, the tower's behaviour and performance with and without the effect were cross-referenced and examined. The analysis and design of below-grade Podium type towers, taking into account both the Tower and Podium individually and in combination, revealed considerable changes in the magnitude and direction of forces generated in the diaphragm, beams, shear walls, and columns.

MD Taqiuddin, et. al. (2019) The primary foci of this study were the in-plane floor deformation at the tower-podium contact and the in-plane strutting forces. This paper addressed the reactive forces generated at the tower podium interface level and their effects on podium tower-type structures. The two types of podium buildings that were the subject of this research were 1) 3B+G+50 and 2) 3B+G+9. The podium width was varied in CSI ETABS analysis sets, but the tower measurements remained same. Flat plates, sometimes known as slabs, were modelled as semi-rigid diaphragms. A different method of conducting the study was to change the column spacing. The results on the effects of wind load on the structure were compared. A comparison analysis was carried out using the ETABS models' outputs for parameters such displacements, drifts, axial forces, and shell stresses. This study shows that the in-plane forces generated at the diaphragm levels are suppressed when a stiff diaphragm is assumed at the podium levels. The diaphragm's strutting forces rise as the distance between columns decreases. Positioning podiums can help minimise tower displacements, and enlarging the podium won't change the drift.

Geetha et al. (2019) This study examined structures with varying podium heights in order to track variations in the back-stay effects on a building type similar to a podium tower. There were two designs in consideration: a 36 x 36 m tower and a 108 × 108 m pedestal with different heights. The structures underwent reaction spectrum and equivalent static analysis. Also noted were the effects of displacements, shear pressures, and bending moments. The results of the research were compared to similar findings for different structural configurations with respect to characteristics such as shear force bending moments and top story displacement. When using the response spectrum strategy, the podium height has no effect on the top displacement until it reaches a particular degree of incrementation. The podium imposes the backstay effect at the podium–tower interface level, meaning that as the number of podium stories increases, the backstay forces at the tower and podium interface also increase. Additionally, they noticed that when the tower was positioned out from the centre as compared to in the centre, the behaviour of the building was more crucial.

Shilpa Thilakarathna et. al. (2019) This study examines how well a multi-tall structure that has two uneven towers and a huge podium performs seismically in relation to LTHA and RSA earthquake requirements. For the traditional analysis technique, two models were created: just one tower at a time with a full podium and only one tower at a time with a half podium. Another form has two towers occupying the entire podium. While single tower + half podium (RSA) appears to underestimate the replies, single tower + podium (RSA) seems to overestimate them. at comparison to the other methods, the LTHA and RSA findings for the multi tower model were more realistic and tended to overlap at the common podium levels.

Mehair Yacoubian et. al. (2017) The varied usefulness of high rise projects with a platform encircling the tower walls is a common preference. This research demonstrates that connected tower walls can be subject to a large degree of differential constraint from the podium. The primary cause of the in-plane strutting forces on levels above and below the podium-tower interface level was determined to be incompatible tower wall displacements under lateral loads. The immediate result of these activities was determined to be shear force localizations in the internal tower wall just above the interface. Through parametric investigations on representative models of the building and sub-assemblages, important parameters leading to this deleterious shear force localization in a tower wall were examined. Unconservative tower wall design can result from the widespread adoption of the in-plane rigid diaphragm assumption, which can greatly minimise compatibility forces generated inside the building floor. We've looked at a complex nonlinear model to illustrate the effects of underestimating the shear demands on these walls.

Mohammad T Bhuiyan et. al. (2013) Building floor plates are crucial in the distribution of horizontal forces among the vertical lateral-load bearing substructures. In engineering practice, it is common practice to model floors for lateral force evaluations of building structures under the assumption of a rigid diaphragm constraint. It is essential to understand that systems with stiff diaphragms act differently from building structures with flexible diaphragms. Assuming a strict diaphragm is not always a cautious practice. Research has been done in the past, mostly on low-rise buildings, to see how different the reaction would be if floors were represented as flexible diaphragms as opposed to stiff. This research aims to assess the influence of diaphragm flexibility on a tall building's structural response. They build a comprehensive floor model that incorporates all of the main structural components. An analogous shell element floor model is produced by computing the detailed floor model's in-plane diaphragm stiffness. Next, the global model for the 64-story diagrid tall skyscraper incorporates this corresponding shell element model. According to the study, structures with flexible diaphragms can undergo more displacements and accelerations than those with rigid diaphragms, and their basic vibration periods can also be substantially longer.

Wensheng LU and Xilin LU, (2000) This report presents the results of numerous scaled multi-tower high-rise building models on the shaking table testing. We propose a novel analytical model that takes the effect of a flexible transfer floor into account. We compare the test findings with the theoretical dynamic behaviour. On several models of varying tower and podium conditions, it conducted shaking table tests. He tested the model and came to the conclusion that, after a stronger earthquake, the coupling action between the transfer levels of a multi-tower structure with a big podium will be considerable and will result in damages close to the transfer floors. For multi-tower high-rise projects, the flexible connections between the towers can greatly minimise drift. The answers are quite complicated for multi-tower complexes with unusual shapes, like Shanghai Reception Center's U-shaped structure.

III. PROBLEM STATEMENT

For the current work, the construction is a building with 20 stories. The dimensions of the tower are 25m x 25m, and the Pedestal is 75m x 75m. The work is to be done on different structural formations of tower-Pedestal construction by varying the number of Pedestal stories and diaphragm conditions, 10 different models will be prepared and analysed in the structural analysis and design tool ETABS. After analysis the conclusion will be made on basis of results. Rough sketch of the building.

9 different models prepared in ETABS 2016 to analyze the effect. List of Models are as follow:

1. M1. Tower without Pedestal (T)
2. M2. Tower + 3 story Pedestal with rigid diaphragm (T+3-R)
3. M3. Tower + 3 story Pedestal with semi rigid diaphragm (T+3-S)
4. M4. Tower + 4 story Pedestal with rigid diaphragm (T+4-R)
5. M5. Tower + 4 story Pedestal with semi rigid diaphragm (T+4-S)
6. M6. Tower + 5 story Pedestal with rigid diaphragm (T+5-R)
7. M7. Tower + 5 story Pedestal with rigid diaphragm (T+5-S)
8. M8. Tower + 5 story Pedestal with rigid diaphragm (T+5-R)(One Sided Pedestal)
9. M9. Tower + 5 story Pedestal with rigid diaphragm (T+5-S)(One Sided Pedestal)

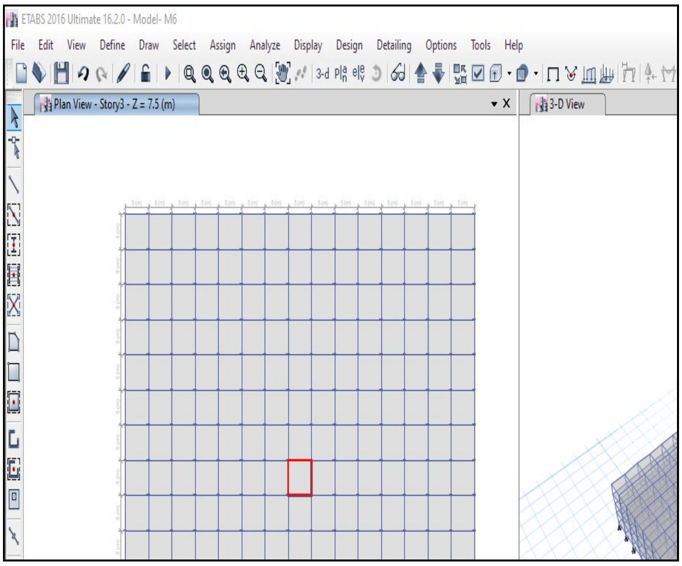

Fig 1 model with Pedestal

IV. CONCLUSION

The present review study highlights the growing importance of podium-tower structural systems in modern high-rise construction, particularly in densely populated urban regions where efficient land utilization and parking requirements have become essential considerations. From the literature reviewed, it is evident that podium structures significantly influence the seismic and lateral load behavior of tall buildings through the development of the backstay effect. This effect plays a major role in improving the overall structural response by creating additional resistance against overturning and lateral displacement at the tower–podium interface.

The reviewed studies collectively indicate that the height, geometry, stiffness, and diaphragm condition of the podium directly affect the magnitude of backstay forces and the global performance of the building. Increasing podium height generally enhances the backstay action, resulting in reduced lateral displacement and improved structural stability. However, excessive podium stiffness may also lead to localized shear concentration and force reversal near the interface region, which requires careful structural detailing and design consideration. The findings further suggest that semi-rigid diaphragms provide a more realistic representation of structural behavior compared to rigid diaphragms, especially in irregular and tall structures where floor flexibility influences force distribution and drift characteristics.

The literature also demonstrates that tower positioning on the podium significantly affects seismic performance. Centrally located towers tend to provide more balanced load transfer and reduced torsional effects, whereas eccentric or corner placements may increase irregularities and critical stress concentrations. Additionally, studies on multi-tower podium systems reveal that shared podium arrangements can improve displacement control and structural interaction, although they may produce complex dynamic behavior under strong seismic excitation.

Another important observation from previous research is that diaphragm modeling assumptions greatly influence analytical results. While rigid diaphragm assumptions simplify analysis and reduce computational effort, they may underestimate compatibility forces, in-plane strutting effects, and localized shear demands in tower walls. Therefore, semi-rigid diaphragm modeling in ETABS or similar structural software is recommended for more accurate prediction of real structural behavior in podium-supported tall buildings.

Based on the reviewed studies, it can be concluded that podium structures are not merely architectural or functional elements but are critical structural components that alter the load transfer mechanism of high-rise buildings. Proper consideration of podium height, diaphragm flexibility, tower placement, and stiffness variation is essential for achieving safe and economical design. The proposed future work involving multiple ETABS models with varying podium stories and diaphragm conditions will help in better understanding the variation of backstay forces, displacement behavior, story drift, base shear, and overturning moments in tall buildings.

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Finally, the review establishes that although considerable research has been carried out on podium-tower interaction, further analytical and experimental investigations are still required to develop optimized design guidelines for podium-supported high-rise structures under seismic and wind loading conditions. Such studies will contribute toward safer, more efficient, and economically viable tall building designs in rapidly urbanizing cities.

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