P-Delta Analysis of Multi-Storey Building using ETABS Software

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Abstract - *The study on P-Delta Analysis of Multi-Storey Building Using ETABS Software provides an essential understanding of second-order effects in tall structures subjected to axial and lateral loads. This review critically analyzes the original research, which evaluates the influence of P-Delta effects on parameters such as storey displacement, drift, base shear, and overturning moments, using ETABS modeling for a G+24 building with and without shear walls. The paper emphasizes that neglecting P-Delta effects in design can lead to unsafe approximations, particularly for high-rise structures where geometric nonlinearity significantly impacts performance. Findings demonstrate that while linear static analysis underestimates deformation, P-Delta analysis provides more realistic behavior by accounting for secondary moments and deflections. The inclusion of shear walls effectively mitigates lateral displacements and storey drift, confirming their role in enhancing structural stiffness. This review concludes that integrating P-Delta effects and shear wall optimization in design software like ETABS is crucial for accurate seismic and gravity load response analysis, ensuring both safety and serviceability of high-rise buildings.*

***Key Words*: P-Delta effect, Second-order analysis, Shear wall, ETABS, Structural stability, Storey drift, Non-linear behaviour.**

1.INTRODUCTION

In the structural design of high-rise buildings, accurate prediction of lateral and vertical responses under seismic and wind loads is vital to ensure both safety and serviceability. Conventional linear static analysis, commonly used in engineering practice, assumes a linear relationship between loads and deformations; however, this simplification neglects second-order effects such as the P-Delta effect, which can significantly influence the stability of tall and slender structures. The P-Delta phenomenon, caused by the interaction between vertical loads (P) and lateral displacements (Δ), results in additional moments and deformations that, if ignored, may lead to underestimated structural responses and potential instability during extreme loading conditions. The evolution of computational tools such as ETABS has made it possible to perform sophisticated non-linear geometric analyses that capture these second-order effects more realistically. Several studies have examined the influence of the P-Delta effect on reinforced concrete (RCC) and steel frame structures, emphasizing that the impact becomes increasingly significant as building height and slenderness ratio increase. Researchers such as Saheban Ali & Ajay Singh (2023), Yash Katare & Anubhav Rai (2023), and Bhavanishankar & Patil (2021) have reported that ignoring P-Delta effects can result in substantial discrepancies in storey displacement, drift, and base shear compared to linear analyses. Moreover, the introduction of shear walls as lateral load-resisting elements has been found to considerably enhance the stiffness of structures, thereby mitigating P-Delta-induced instability. This review paper focuses on the comparative evaluation of multi-storey buildings analyzed with and without considering P-Delta effects, and further investigates the effectiveness of incorporating shear walls to counteract these effects. The study synthesizes findings from previous works that employed analytical software such as ETABS, STAAD.Pro, and SAP2000, under various seismic conditions as per IS 1893:2016 and IS 875 (Part III):1987. Emphasis is given to parameters including storey displacement, drift ratio, base shear, and overturning moment, as these directly influence the overall stability and ductility of high-rise buildings. By consolidating and analyzing previous research, this review aims to highlight the critical necessity of incorporating second-order analysis into the design of high-rise structures and the advantages of using shear walls for improved performance. The discussion underscores the importance of adopting P-Delta analysis as a standard practice in modern structural design, particularly for tall buildings in seismic zones, to ensure greater safety margins, cost-effectiveness, and resilience.

2. LITERATURE REVIEW

The concept of the P-Delta effect has evolved as an essential consideration in the nonlinear analysis of high-rise structures. Earlier studies primarily focused on first-order linear analysis; however, as building heights and slenderness increased, researchers began to emphasize the need to include second-order geometric effects to accurately predict structural behavior under combined gravity and lateral loads.

2.1 Saheban Ali & Ajay Singh (2023)

This study investigates the *P-Delta effect on high-rise RCC buildings* using ETABS software under static and dynamic loading conditions. The authors emphasize that conventional first-order analysis is inadequate for tall structures as it neglects secondary effects arising from geometric nonlinearity. A 25-storey model was analyzed with and without P-Delta effects. Results indicated that the inclusion of P-Delta analysis led to an 11–16% increase in storey displacement and drift, particularly in the middle levels of the building. The study concluded that P-Delta analysis provides a more accurate representation of the real structural response and is essential for structures in high-seismic zones.

2.2 Yash Katare & Anubhav Rai (2023)

Their work focused on nonlinear seismic behavior of RCC buildings incorporating the P-Delta effect. ETABS was used to simulate G+20 storey buildings under Zone IV seismic conditions. The research demonstrated that P-Delta analysis captures additional deflection due to geometric nonlinearity and that the effect becomes significant with height. The authors observed that including shear walls at the building core reduced displacement by up to 35%. The study reinforced the idea that structural designers must not neglect P-Delta effects in tall, slender buildings.

2.3 Chandana P. & Dr. D.S. Sandeep Kumar (2023)

This paper analyzed G+10 RCC structures with different corner configurations—sharp, recessed, and cut—using Staad-Pro. Both linear static and P-Delta analyses were conducted with and without shear walls. The authors found that the P-Delta effect increased displacement by 8–15%, while the use of shear walls reduced it by 20–37%, depending on the geometry. The recessed shape at corners showed the best performance in minimizing base shear and overturning moment. The study concluded that architectural geometry and wall placement significantly influence structural stability under P-Delta effects.

2.4 Wagner Almeida Ferreira & Jeffer Cruz (2022)

This study introduced a modal P-Delta simplified geometric nonlinear method combining modal and buckling analysis. The method, validated through numerical modeling, efficiently accounted for geometric nonlinearity without iterative computation. It provided reliable accuracy for high-rise frame analysis, demonstrating that P-Delta effects substantially modify natural frequencies and mode shapes of tall structures.

2.5 R. Naik and A. Gawande (2020)

presents an in-depth analytical study on the nonlinear seismic response of reinforced concrete (RCC) frame structures, specifically emphasizing the P-Delta effect and its influence on the overall performance of tall buildings. The authors aimed to assess how geometric nonlinearity, arising from the combination of vertical loads (P) and lateral displacements (Δ), affects critical design parameters such as storey displacement, inter-storey drift, base shear, and bending moments. Their study reflects the growing recognition among structural engineers that neglecting second-order effects can result in non-conservative design outcomes, particularly for buildings located in high-seismic regions or those exceeding 15–20 storeys in height. he results of the study indicated a clear difference in the structural response between the two analysis types. Under P-Delta analysis, the storey displacement increased by approximately 12–18%, while inter-storey drift values increased by 15–20%, especially at the mid-height levels of the building. This behavior was attributed to the accumulation of secondary moments induced by the axial loads acting through laterally deflected frames. The authors noted that this phenomenon becomes more pronounced with the increase in building height, as the cumulative axial forces from upper storeys intensify the geometric nonlinearity in lower storeys. Moreover, the research revealed that the base shear and overturning moments remained relatively unchanged (<5% variation), suggesting that P-Delta effects primarily alter deformation rather than the overall load-resisting capacity. However, this deformation amplification was found to influence reinforcement detailing, column curvature demand, and drift control measures, which are critical to maintaining serviceability during seismic events.

2.6 Phani Kumar et al. (2019)

In this research, the behavior of P-Delta effects in high-rise structures with and without shear walls was evaluated. The ETABS-based study showed that P-Delta effects amplify displacements and bending moments considerably in tall frames. The addition of shear walls reduced overall deflection by 25–40%, enhancing rigidity and stability. The study suggested that designers must include second-order effects to avoid unsafe design simplifications in seismic analysis.

2.7 Deekshitha Y.L. & Kiran Kuldeep K.N. (2018)

The authors conducted linear and nonlinear dynamic analysis of multi-storey RC frame buildings with irregularities. Using ETABS, they evaluated the influence of plan and vertical irregularities on P-Delta effects. The findings showed that irregular geometries amplify nonlinear displacements and torsional irregularities, increasing the vulnerability of structures under seismic loads. The study highlighted that irregular high-rise buildings must undergo P-Delta analysis to ensure accurate estimation of drifts and base moments.

2.8 Vijayalakshmi R., Bindu N. Byadgi & Vahini (2017)

This study analyzed P-Delta effects on high-rise buildings located in seismic zones IV and V. The authors performed a comparative study between linear and nonlinear analyses. They found that P-Delta effects increased lateral displacements by 10–18% and that shear walls minimized these effects by about 30%. The study recommended adopting second-order analysis in seismic design as per IS 1893:2016 for all structures above 15 storeys.

2.9 Manik Rao & Rajendrakumar S. Harsoor (2016)

The authors explored *the effect of P-Delta in seismic analysis* of multi-storey buildings using STAAD.Pro. They concluded that P-Delta effects increase storey shear, overturning moment, and column moments substantially. The inclusion of shear walls and bracing reduced these secondary effects significantly. The study emphasized that high-rise buildings require second-order analysis for true assessment of seismic safety.

2.10 Pushparaj J. Dhawale (2016)

This research discussed *P-Delta effects in tall RCC buildings* through static and dynamic load analysis. The author found that neglecting geometric nonlinearity leads to an unsafe underestimation of displacements and stresses. For buildings above 20 storeys, the difference between first and second-order analyses exceeded 15%. The study concluded that P-Delta analysis is indispensable for tall structures subjected to wind and earthquake loads.

3. CONCLUSIONS

The collective review of ten significant studies from 2016–2024 clearly establishes that the P-Delta effect is a dominant factor affecting the seismic and structural performance of tall buildings. Across all studies, it is consistently reported that first-order linear static analysis underestimates displacement, drift, and internal moments. The inclusion of second-order analysis through ETABS or similar platforms captures the nonlinear geometric behavior more accurately.The literature reveals that buildings exceeding 15–20 storeys exhibit significant P-Delta sensitivity, where even small lateral displacements induce substantial secondary moments. Studies consistently emphasize that integrating shear walls greatly improves building stiffness and reduces both storey drift and lateral deformation by up to 40%. Furthermore, researchers found that architectural irregularities—such as corner recesses and asymmetric plans—can either amplify or mitigate P-Delta effects depending on wall placement and mass distribution.Overall, the literature converges on a unified conclusion: P-Delta analysis is essential for reliable design of high-rise structures. Modern computational tools like ETABS allow engineers to perform this complex analysis efficiently, aligning with code recommendations from IS 1893:2016 and ASCE 7-10. The reviewed studies collectively strengthen the argument that neglecting P-Delta effects may compromise safety, whereas incorporating them ensures both structural stability and design economy for tall and slender buildings.

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