Survey-Based Investigation of P-Delta Influence on RCC Building Design

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***Abstract* - The P-delta effect, which is important in structural analysis for tall structures, is investigated in this work utilizing linear static analysis in STAAD.Pro software. RCC-framed structures of varying heights are modeled using seismic loads from IS-1893(2016) for Zone III and load combinations from IS-456(2000).Bending moments and narrative displacements are calculated using and without the P-delta effect for various models. An iterative approach increases the rigidity of dangerous buildings to meet acceptable standards.**

The findings stress the importance of considering the P-delta impact in 5-story structures and encourage adequate planning for buildings taller than 20 meters. Furthermore, up to 25 storeys, primary analysis is sufficient, with measures such as cross-section adjustment efficiently bringing dangerous structures inside permissible limits.

Index Terms – ***P-delta effect, RCC building design, Structural analysis, STAAD.Pro software, Earthquake loads***

I. INTRODUCTION

The P-delta analysis approach is an important feature of structural engineering, especially for geometric nonlinearity in buildings subjected to lateral stresses such as wind or seismic forces. In contrast to linear analysis, real-world scenarios contain considerable lateral displacements that can change a structure's shape and the distribution of internal forces. P-delta analysis takes into consideration both axial loads (P) and lateral deformations (delta), which are especially significant in tall or flexible constructions. This cyclical procedure is frequently mechanized with powerful technologies, assuring compliance with building rules and accurate structural response assessments. Lateral loads, which include wind, seismic, and temperature-induced forces, are crucial in determining structure stability and design.Structural components such as shear walls, bracing systems, and damping systems help to withstand lateral loads, with different bracing types designed for specific structural requirements. STAAD.Pro software offers scalable structural analysis and design solutions, whereas RCDC improves concrete analysis by expediting the design process for elements such as beams, columns, and walls. The purpose of this study is to evaluate the P-delta effect on RCC columns using STAAD.Pro software, with objectives including stability analysis, comparing steel percentages for unsafe columns, and analyzing RCC structures with and without X-bracing to maximize performance.

II. RELATED WORK

Structural planning and design combine art and science, necessitating creativity, conceptual thinking, and a thorough understanding of structural engineering concepts. Akash Deep et al. (2016) stressed the need of following applicable design norms and standards to ensure structural safety while balancing cost and safety. Their research focused on constructing a G+5 building in Badarpur, New Delhi, with STAAD.PRO software, emphasizing the importance of rigorous planning and the use of powerful software tools for structural design.

In earthquake-prone areas such as India, understanding earthquake behavior and building earthquake-resistant structures is critical. Bhavesh Kumar Daharwal et al. (2018) emphasized the importance of designing structures that can withstand seismic forces in order to avoid potential hazards. Their research underscored the importance of shear walls in resisting lateral stresses during earthquakes, which contributes to greater structural stability.

Concrete cracking and the second-order geometric effect of P-Delta are important factors in the seismic response of high-rise reinforced concrete buildings, as established by Ruaa A. Abdulhameed et al. (2022). Their research, which used finite element analysis with ETABS software, shed light on the impact of concrete cracking and P-Delta effects on modal analysis, revealing the elongation of vibration time periods and other crucial parameters.

Prashant Dhadve et al. (2019) explored the P-delta impact in high-rise buildings, highlighting its importance as the number of storeys increased. Their study, which used ETAB software, emphasized the need of taking P-delta effects into account in structural design, especially for tall buildings that experience significant deformation.

Ahmed Sada Dheeb et al. (2019) investigated the second-order geometric nonlinearity effects of P-Delta analysis on the dynamic response of high-rise steel structures to deterministic wind loads. Their study, which used nonlinear time history analysis and ETABS software, revealed valuable insights into the dynamic behavior of tall steel buildings, resulting in better design methods.

Furthermore, Kanchan Gupta et al. (2020) demonstrated the importance of P-delta analysis in flat slab buildings, emphasizing the need to include second-order effects to ensure structural integrity.

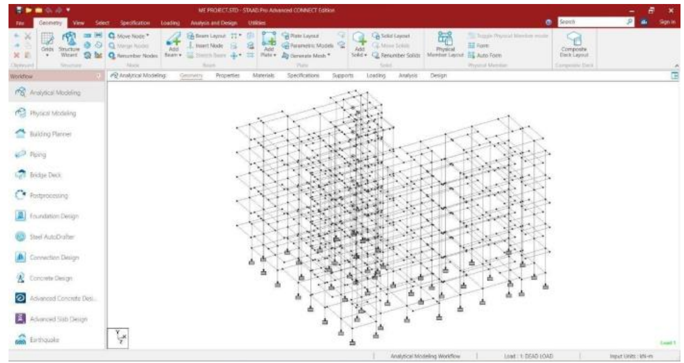
In addition, CM Meera et al. (2013) and Renjith Raju et al. (2019) investigated novel methodologies for structural design and retrofitting, respectively, making major contributions to advances in building practices.

On top of that, Kaif Khan et al. (2023) investigated the impact of the significance factor on reinforcing steel % during seismic analysis, with the goal of improving seismic design methods. Finally, Dr. Khadeeja Priyan and Dr. J. R. Pitroda (2021) investigated the strain capacities of engineered cementitious composites (ECC), emphasizing its ductility in comparison to traditional concrete and the potential to revolutionize structural engineering techniques.

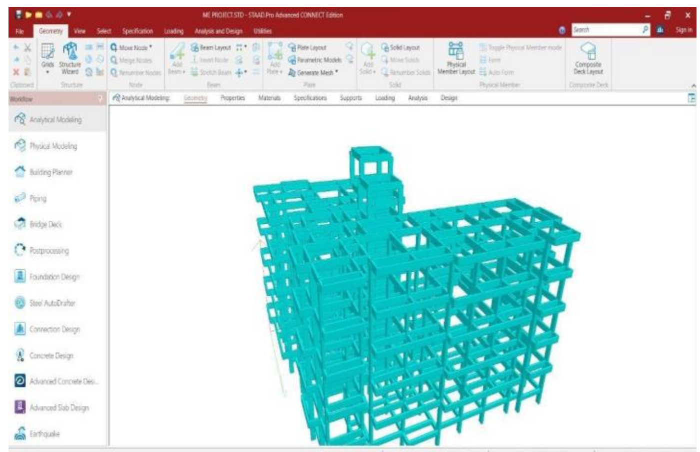
These studies collectively deepen our understanding of various aspects of structural engineering, including seismic design considerations, innovative material applications, retrofitting techniques, and the integration of advanced computational tools, all of which contribute to the field's ongoing advancement and the development of safer, more resilient structures.

III. METHODOLOGY

The methodology for P-delta analysis is a systematic approach specialized for structural analysis, particularly for tall or slender buildings where axial loads cause additional moments that affect overall stability. Initially, the structural geometry is determined, which includes dimensions, member sizes, and connections, as well as material parameters like modulus of elasticity and Poisson's ratio.

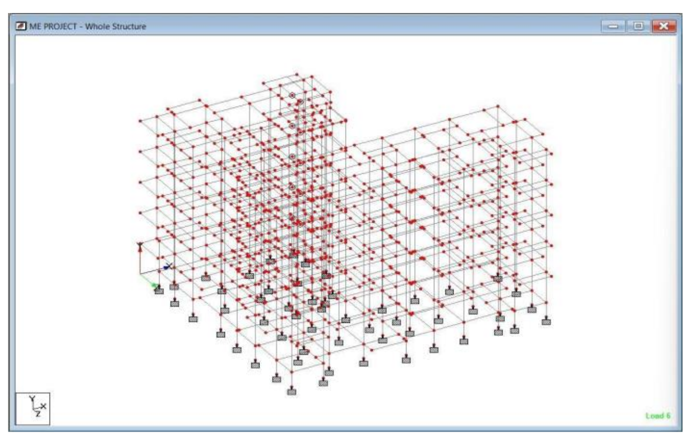


Staad model creation

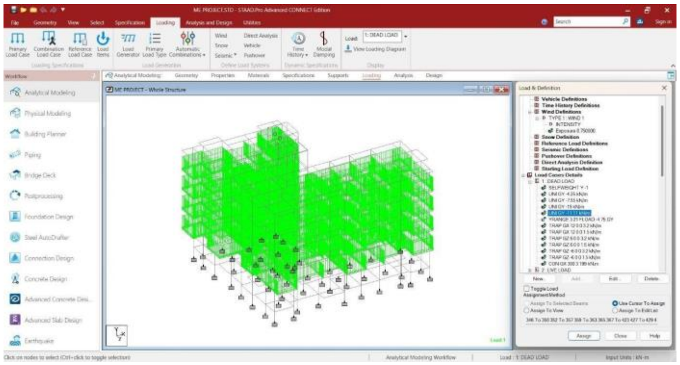


STAAD 3D Model

Then, using structural analysis software, a finite element model is created that includes all structural elements such as beams, columns, slabs, and braces, with boundary conditions applied to simulate structural supports.



Seismic load



Dead Load

All relevant loads, such as dead loads, live loads, wind loads, and seismic loads, are considered and applied in compliance with construction norms and standards.

COLUMN	LOADING	DISTANCE	X	Y	Z	RESULTANT
814	1 DEAD LOAD	0	0	0	0	0
		0.8	0	-0.001	0.001	0.001
		1.6	0	0	0.001	0.001
		2.4	0	0.002	0.001	0.002
		3.2	0	0	0	0
	2 LIVE LOAD	0	0	0	0	0
		0.8	0	0	0	0
		1.6	0	0	0	0
		2.4	0	0.001	0	0.001
		3.2	0	0	0	0
	3 WL X	0	0	0	0	0
		0.8	0	0	0	0
		1.6	0	0	0	0
		2.4	0	0	0	0
		3.2	0	0	0	0
	4 WL -X	0	0	0	0	0
		0.8	0	0	0	0
		1.6	0	0	0	0
		2.4	0	0	0	0
		3.2	0	0	0	0
	5 WL Z	0	0	0	0	0
		0.8	0	0	0	0
		1.6	0	0	0	0
		2.4	0	0	0	0
		3.2	0	0	0	0
	6 WL -Z	0	0	0	0	0
		0.8	0	0	0	0
		1.6	0	0	0	0
		2.4	0	0	0	0
		3.2	0	0	0	0
	7 ULC, 1.5 DEAD + 1.5 LIVE	0	0	0	0	0
		0.8	0	-0.002	0.001	0.002
		1.6	0	0.001	0.002	0.002
		2.4	0	0.004	0.002	0.004
		3.2	0	0	0	0
	8 ULC, 1.2 DEAD + 1.2 LIVE + 1.2 WIND (1)	0	0	0	0	0
		0.8	0	-0.002	0.001	0.002
		1.6	0	0.001	0.001	0.002
		2.4	0	0.003	0.002	0.003
		3.2	0	0	0	0

Analysis Result Without P-Delta Effect

Scenario	Maximum Displacement (mm)	Maximum Moment (kN-m)	Maximum Shear Force(kN)
Without P-Delta Effect	**0.0037**	**0.008**	**0.006**
With P-Delta Effect	**0.0034**	**0.007**	**0.005**
With P-Delta Effect & Bracing	**0.017**	**0.015**	**0.009**

Comparison of Analysis Results With And Without P-Delta Effect

Following that, a linear static analysis is performed to determine the structure's initial response to applied loads, resulting in initial displacements and member forces indicative of the structure's preliminary deformation. Distinct load cases are then developed for each applied load, taking into account P-delta effects and accommodating lateral displacements generated from the linear analysis. To accommodate for P-delta effects, the structural stiffness matrix is modified in response to initial deformations. To reach convergence, an iterative analysis is performed, with the stiffness matrix being updated iteratively until the findings stabilize, frequently using conventional iterative methods such as the Newton-Raphson method. To assess compliance with code requirements for stability and safety, the final results are thoroughly reviewed, including member displacements, rotations, and internal forces. Sensitivity analyses are then performed to determine the effect of parameter changes on P-delta values. Finally, a definitive P-delta analysis is done to confirm compliance with safety and performance standards.

IV. Results and Analysis

Our investigation on P-delta analysis in tall building design provides valuable insights into the behavior of structures under different loading scenarios. Using advanced technologies such as STAAD.Pro, our survey generated some significant findings. Initially, we found a considerable association between a building's height and the severity of the P-delta effect, emphasizing the importance of accounting for geometric nonlinearity in tall structures to avoid underestimating displacements and internal forces. When comparing P-delta analysis to standard stability analysis, we regularly saw higher displacements predicted by P-delta, demonstrating that it has a significant impact on structural deformations. Furthermore, our analysis found that P-delta impacts go beyond gravity loads to encompass lateral forces like wind and seismic loads, emphasizing the significance of a holistic design approach.

Furthermore, through parametric tests, we discovered X-bracing as an effective technique for minimizing P-delta effects, with the potential to minimize them by up to 95% and so improve structural stability. In conclusion, our survey findings highlight the importance of P-delta analysis in assuring the robustness of tall buildings under dynamic loading situations, hence contributing to advances in structural engineering methods in this field.

V. Conclusion

Our work into P-delta analysis in tall building design demonstrates the need of adding geometric nonlinearity in structural assessment. The found association between building height and the P-delta effect stresses the need of using P-delta analysis in high-rise structures over traditional stability analysis approaches. Furthermore, our findings show that displacements anticipated by P-delta analysis are approximately 10% higher than those predicted by normal analysis, demonstrating that geometric nonlinearity has a considerable impact on structural deformation. Furthermore, our investigation demonstrates that P-delta impacts go beyond gravity loads to encompass lateral forces like wind and seismic loads, demanding a comprehensive design approach. Furthermore, our research shows X-bracing as a viable technique for mitigating P-delta effects, with the potential to diminish them by up to 95%. In summary, our survey emphasizes the importance of P-delta analysis in tall building design, providing insights into improving structural stability and resilience in the field of structural engineering.

VI. References

1) Dr Ruaa Abdulateef Abdulhameed (Author) P-Delta Effect on The Dynamic Seismic Response of High Rise Buildings Paperback – Import, 22 April 2019

2) Amrul Kaish .A.B.M, Jamil.M,. Raman.S.N, Zain. M.F.M (2015) Axial behavior of ferrocement confined cylindrical concrete specimens with different sizes, Journal of Construction and Building Materials

3) Mallikarjuna B.N1 , Ranjith A STABILITY ANALYSIS OF STEEL FRAME STRUCTURES: P-DELTA ANALYSIS (2014)

4) Kanchan Gupta, Md. Tasleem Performance of P-Delta Analysis of Flat Slab and R C Framed Buildings (2020)

5) Prashant Dhadve “Assessment of P-Delta Effect on High Rise Buildings” (2015)

6) Atul Rupanvar, Deokate K “Assessment of P-Delta Effect on High Rise Buildings” (2016)

7) S.Sudheer, Analysis & design of g+5 residential building using STAAD Pro.

8) Mr. A. P. Patil, Mr. A. A. Choudhari, Mr. P. A. Mudhole, Mr. V. V. Patole, Ms. A. D. Dange, Ms.

9) S. K. Chendake, Design & Analysis of Multi Storeyed Building (G+10) By Using Stadd Pro V8i.

10) S.Karthiga, Hanna Elza Titus, Reetwiz Raj Hazarika, Mohamed Harris, Design and comparison of a residential building for seismic forces using the IS1893.