ANALYSIS AND DESIGN OF TALL BUILDINGS USING ETABS WITH P-DELTA ANALYSIS

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ABSTRACT: *As urbanization increases worldwide, the construction of tall buildings in seismic regions is becoming increasingly common. In heavily populated cities, the available land for buildings is becoming scarcer and scarcer, and the cost of land is becoming higher and higher. So, the high rise structures are proposed for residential and commercial purposes. They may be easily affected by seismic as well as wind loads, so the buildings get deformed and collapsed easily. To avoid these problems we consider p-delta effect in designing. As the number of stories increases p-delta effect becomes very important. The P-Δ effect is relevant in structural engineering problems, especially in civil engineering, where we're dealing with large structures with proportionally decreasing small moments of inertia as they continue to be extended in absolute height. In this study p-delta (P-Δ) effect on high-rise building is studied for the analysis of G+10 building and models were done by ETABS. Seismic and wind loads are applied to model and the displacements, storey drifts, Bending Moments and Shear Forces are compared for the structure by considering with and without P-delta effect and by providing shear walls at different locations.*

Keywords: p-delta effect (P-Δ), displacement, shear wall, ETABS.

I. INTRODUCTION

National Building Code (NBC) defines all buildings which are 15 m or above in height are considered as high-rise buildings. But many development authorities define a high-rise building or a multi-Storied building as a building of a height of 24 meters or above.

When a slender structure is exposed to lateral loads i.e. wind or seismic loads it experiences sway or lateral displacement. Whenever this lateral displacement is increased to peak then gravity loads start to act with an eccentricity. This is equal to the magnitude of elastic deflection causing an additional overturning moment. Due to which, a second order deflection is developed in the structure. This second order effect caused in the structure is known as P-Delta effect. Where "P" is the gravity load and "Δ" is the displacement experienced through first order or elastic analysis for lateral forces. The P-Delta effect is shown in the Figure 1. Where the Δ2 is second order deflection caused due to P-delta effect.

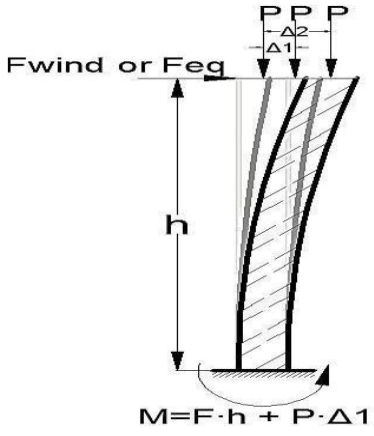


Figure 1: P-Delta Effects on a Simple Cantilever Column

The P-Δeffect is experienced in all structures when they were subjected to an axial load in combination with lateral displacement. The major effect is observed due to deflection of the structure as a whole and also termed as P-delta (P-Δ). However, this research is done on the P-delta effect observed through structural instability (P-Δ). Tall structures and buildings with more

number of stories will undergo large P-delta effect. They are to be designed with Proper recommended considerations. The importance of P-Delta non-linear analysis is continually increasing in high rise buildings are getting very popular and playing a key role.

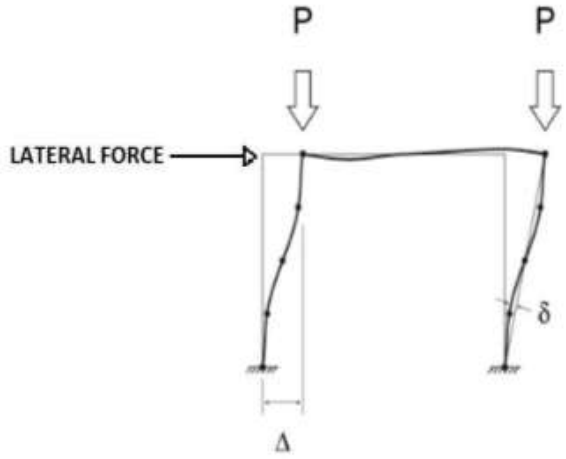


Figure 2: Schematic representation of P-delta effect on a frame

II. OBJECTIVES OF WORK

- To perform linear static analysis of the tall structure by using E-TABS.
- To study the P-DELTA (non-linear) effect on tall structure by using ETABS and to study the effect of axial loading on the structure.
- To study the results of the structure, i.e. deflections and forces with and without P-DELTA effect.
- To compare the results in structure with shear walls and without shear walls in E-TABS.

III. LITERATURE REVIEW

- **Ragina Gaiotti et al[1989]** performed P-delta analysis of building structures and published **"P-Delta analysis of building structures", Journal of Structural Engineering ASCE, Vol.115, No4, April 1989.** The P-Delta analysis methods were reviewed and compared in terms of their efficiency and accuracy. The methods reviewed include the amplification factor method, the direct method, the iterative method, the negative property member method and second order computer program method. The results were identical to those given by the iterative method while the analysis took less than one-third of the time. It was found that P-Delta analysis is more suitable for high rise structures. They concluded that due to non-linear relationship between deflection and the gravity loads, it is necessary that loads corresponding to the failure state under consideration be used in P-Delta analysis.

- **Pushparaj J Dhawale et al [2016]** had published a journal on **"Analysis of P-Delta effect on high rise buildings", International of journal of Engineering Research and General Science, Vol-4, Issue-4 August 2016** and conducted analysis of P-Delta effect on high rise buildings. Here linear static analysis (without P-Delta effect) and nonlinear static analysis (with P-Delta effect) were carried out on high rise RCC framed buildings with 20, 25 and 30 storeys. Buildings have been analysed using SAP2000-12 software in accordance with the provisions of IS-1893 (2002) for zone III and IS-456 (2000). Bending moments and storey displacements with and without P-Delta effect on all building models were compared. The results suggest that it is essential to consider the P-Delta effect for buildings 25 storeys and above. He found that P Delta effect should be considered in the design of buildings having height 75m or more.

- **Manasa C. K et al [2016]** published a journal on **"P-Delta effect in Tall RC Buildings", International Online Multidisciplinary Journal", 2016** and examined the behaviour of reinforced concrete buildings under lateral loading. The focus of the study was to assess the P-Delta effect in tall RC buildings. Five building models with 10, 20, 30, 40 and 50 storey are analysed using non-linear static analysis method in ETABS 2015. The drift ratio is found out by considering P-Delta effect for all building models. The results demonstrated the effectiveness of P-Delta analysis in tall RC buildings.

- **M.A.A Mollik et al [1997]** published a journal on **"Experimental study on P-Delta effect in RC high-rise building"**, Journal of Civil Engineering The institution of Engineering Bangladesh, Vol CE 25, No.2 1997 and conducted an experimental study on P-Delta effect in RC high rise buildings. P-Delta effect was examined through the tests on three one-forth scale reinforced concrete frame structure model which represents the lower parts of high rise buildings subject to seismic force. From the results it is concluded that P-Delta effect is to be essentially included in analysis for the design of high rise buildings subjected to seismic force. His study revealed that P-Delta effect becomes an important factor to be taken into account if the storey drift of high rise building exceeds 1/85 rad during an expected earthquake excitation in seismic region. The test results also revealed need for a rigorous analysis in the design of high rise building rather than using the conventional equation for the member strength.

- **Akshay Gupta et al [2000]** published a journal on **"Dynamic P-Delta effect for Flexible Inelastic Steel Structures", Journal of Structural Engineering, ASCE, Vol 126 January 2000** and investigated the influence of P-Delta effect on flexible inelastic steel structures. Seismic performance of three building models of 3, 9, and 20 stories are designed for different seismic conditions. The computer program DRAIN-2D is used for modal analysis. The study revealed that the seismic response becomes very sensitive to building models if P-Delta effect is considered.

- A. **Aziminejad et al [2004]** presented **"Interaction of Torsion and P-Delta effect in Tall buildings", 13th world conference on Earthquake Engineering, Vancouver B.C, Canada, Paper No 799 2004** and examined the interaction of torsion and P-Delta effects in tall buildings. The influence of asymmetry of building on the P-Delta effect in elastic ranges of behaviour is evaluated. Elastic static, elastic dynamic, inelastic static and inelastic dynamic behaviour of four different buildings with 7, 14, 20 and 30 storeys with and without P-Delta effect were investigated. Each building with 0%, 10%, 20% and 30% eccentricity levels were considered. It was found that the P-Delta-effect increases with increase in number of storeys and eccentricities of the buildings. The result indicated that the effect of P-Delta is quite sensitive to characteristics of ground motion such as the frequency content of earthquake. Conclusion is that the characteristics of lateral load resisting system have far more importance compared with the number of storeys in the building.

- **Ashraf Uddin et al [2013]** published a journal on **"P-Delta effect in Reinforced Concrete Structures of Rigid Joint",**

IOSR Journal of Mechanical and Civil Engineering", Volume 10, Issue 4, Nov 2013 and studied P-Delta effect in reinforced concrete structures of rigid joint. 12 cases and 2 different analyses were performed to throw light into P-Delta effect in RC framed structures of rigid joints. He observed that, under P-Delta effect, displacement varies exponentially with increase in height or increment in stories. Axial force also varies with the height of the structure. It was concluded that both linear static and P-Delta analyses are necessary for tall RC structures.

- **Yousuf Dinar et al [2013]** in the journal **"Variation of Deflection of Steel High rise Structures due to P-Delta effect Considering Global Slenderness Ratio". International Journal of Emerging Technology and Advanced Engineering, Volume 3, Issue 12, December 2013** evaluated the deflection of high rise steel structures under the P-Delta effect. Linear static analysis was done to observe the severity of P-Delta phenomenon. The analysis was done by using STAAD Pro v8i software. They found that because of wide variation in displacement with increase in slenderness, P-Delta analysis is required for structures taller than 7 storeys.

- **Spoorthy S K et al [2014]** published a journal on **"Effect of Soft Story on Tall Buildings at Various Stories by Pushover Analysis", International Journal of Engineering Research, Vol-2, Issue-3, 2014** and investigated the effect of soft story on tall buildings at various stories by using Pushover analysis. 5, 10, and 15 story reinforced concrete building models with both regular and irregular building plan were analysed. The study summarizes the performance based seismic analysis of tall buildings having soft story at various levels in building using Equivalent static and Pushover analysis method in ETABS 9.7.4 software. The story displacement, story drift, and story shear obtained from pushover analysis are about twice the story displacement, story drifts, and story shears of Equivalent static analysis. The parameter increases with increase in the number stories, mass and height of the building.

- **Deepak Soni et al [2014]** published a journal **"Dynamic Behaviour of Reinforced Concrete Framed Buildings under Nonlinear Analysis", International Journal of Engineering Development and Research, Vol-2, Issue-4, 2014** and experimented with the Dynamic behaviour of reinforced concrete framed buildings under non linear analysis. In this study, P-Delta analysis of 30 storied RC framed symmetric and asymmetric buildings in zone III and zone IV was performed using STAAD Pro V8i software. The building response quantities (storey drift, storey displacement and nodal displacement) under the P Delta analysis on both symmetric and asymmetric buildings were evaluated. It was observed that response quantities were higher when P-Delta analysis was performed and also that the response quantities in respect of asymmetric structures were higher than that of the symmetric structures.

- **Mallikarjuna B.N et al [2014]** published a journal **"Stability analysis of Steel frame structures: P-Delta analysis", International of research in Engineering and Technology, Vol.3, Issue 8 2014**. In this study describes seismic analysis for an 18 storey steel framed structure using in STAAD Pro V8i

software. A comparison of P-Delta analysis with linear static analysis has been attempted. The influence of different bracing patterns like X, V, single diagonal, double X, K bracing etc. on the P-Delta effect has been investigated. It was found that the building response values on P-Delta analysis were twice as that on static analysis. The X bracing in continuous bracing pattern is proven to be more effective under both static and P-Delta analyses.

- **Sagar B Patil et al [2015]** published a journal **on "Study of Behaviour of Plan and Vertical irregularity by Seismic Analysis", International Journal for Scientific Research and Development", Vol 3, Issue 04, 2015** and presented the behaviour of plan and vertical irregularity by seismic analysis. Reinforced concrete building of 10, 15 and 20 storey having 3m storey height is selected for the study. The maximum storey displacement was found in irregular structure. The study reveals that the shape structure with irregularities in plan or vertical irregularities directly affects the whole structure in seismic action.

- **P V Dhanshetti et al [2015]** published a journal on **"Effect of P-Delta action on multi-story buildings", International Journal of Engineering Research and Technology, Vol-4, Issue-1, 2015** and investigated the action of P Delta effect on multi-storey buildings. In this work, multistoreyed reinforced concrete building models with different number of storeys were analyzed by using STAAD Pro V8i structural analysis software. The maximum response values in buildings in terms of storey drifts, column moments, beam moments, column shear and beam shear were investigated. It was observed that the P-Delta effect will be substantial when lateral forces exist on the structure and this increases with increase in number of storey. The P-Delta effect is not predominant on buildings up to seven storeys and it is very negligible when only gravity loading exists on the structure.

- **Jose Antonio Flores Ruiz8 (2015),** published a journal on **"Study of P-Delta Effect on Tall Steel Structure", International Journal of Allied Practice, Research and Review, Page No. 26-36.** and studied the effect of P Delta on four, six and twelve storey RC frame building. A series of non-linear time history analyses using Takeda hysteric rule considering the P-delta effect was studied. It was shown that P-delta effects have a significant influence to the response even for the four and six storey structures and concluded that P-delta effect should always be included in the design and analysis of structures.

- **Christoph ADAM1 , Luis F. IBARRA1 (2004)**, published a journal on **"Evaluation of p-delta effects in non deteriorating MDOF structures from equivalent SDOF systems", 13th World Conference on Earthquake Engineering Vancouver, B.C., Canada, Page no. 3407** and addressed the assessment of destabilizing effects of gravity, usually referred to as P-Delta effects, in highly inelastic structures when subjected to seismic excitations. The proposed approach is based on an equivalent single-degree-of freedom (ESDOF) system of the actual building. Appropriate properties of the ESDOF system are defined, based on results of a corresponding global pushover analyses. P-Delta effects are incorporated via an auxiliary backbone curve, which is rotated by a uniform stability coefficient.

The procedure is evaluated for several multistorey generic frame structures. The collapse capacity of these structures is derived from a set of Incremental Dynamic Analysis (IDA) studies involving 40 ground motions whose intensity is increased until P-Delta instability occurs. The results are translated from the ESDOF domain into the domain of the multi-degree-of-freedom (MDOF) system, and utilized for the estimation of P-Delta effects in MDOF structures. "Exact" results are contrasted with outcomes of the analyses utilizing ESDOF systems. Assumptions and limitations of the ESDOF system approach are discussed. The emphasis is on the level of response at which the structure approaches dynamic instability (sidesway collapse).

- **T.J. Sullivan6 , T.H. Pham6 (2008)**, published a journal on **"P delta effects on tall RC frame-wall buildings", The 14th World Conference on Earthquake Engineering Beijing, China October 12-17**, analysed the design of a 45- storey reinforced concrete frame-wall case study structure is used to highlight the significance of the p-delta limit within the modal response spectrum analysis procedure of the Euro code 8. It is found that the strength of the structure is dictated by the P-delta limit for seismic actions, despite anticipated storey drifts and ductility demands being relatively low. A series of non-linear time-history analyses using a suite of spectrum-compatible real and artificial accelerograms, indicate that P-delta effects do not have a significant influence on displacements or storey drifts of the tall building The likely causes of this behavior are identified, making reference to earlier investigations into P delta behavior and with consideration of substitute structure concepts. To investigate the significance of the P-delta ratio further, a series of SDOF studies are undertaken for systems designed with P-delta ratios of up to 0.85. The results demonstrate that the p-delta ratio has little influence on the behavior of long-period systems subject to real earthquake records and therefore it does not appear appropriate to impose strict limits on the P-delta ratio. Instead, it is recommended that the P-delta effects be evaluated for tall building systems as part of an overall assessment of their response, using advanced non-linear time-history analyses with real records and within a large-displacement analysis regime.

- **Rafael Shehu, 2014** published a journal on **"The P-Δ-Ductility Effect: Overview the Effect of the Second Order in the Ductile Structures", European Scientific Journal, 2014; 3; 1857 – 7881**. Building behaviour is an element of various elements and their interaction versus outside activity was picked by them. This exchange transcends the geometry of the structure, its hardness and their connections capacities. The primary parameters of the connection capacities are loads at the current stage. With loads they mean static and dynamic, while the calculation stage they refer to the stage conduct of the material and structure, the flexible stage or post versatile stage, without distorted or twisted components. Every stage is acknowledged or let's say, inexact in estimations techniques and altering some standard methods. In this discussion they addressed in a compact manner, two key factors in the configuration of structures, which are second order effects (P-Delta) and the ductility of structures . Both components

have risen as a need of approximating genuine complex conduct in a design system. It is realized that a nonlinear examination is more precise than a direct analyses, however then again is an inefficient analysis in term as time consuming with calculations and PC memory.

- **Prashant Dhadve, et al., (2015),** published a journal on **"Assessment of P-Delta Effect on High-rise Buildings", International Journal on Recent and Innovation Trends in Computing and Communication, Vol-3, Issue-5, May 2015** and concluded that P-Delta effect becomes more essential as the number of stories increases. In case of 20 storey and 25 storey buildings and mostly in 25 storey building only in exterior columns and in adjacent beams in some load cases P-Delta effect is observed. If these load cases are leading load cases for design of members, then only P-Delta effect can be considerable. So it is required to check the analysis results by considering P-Delta effects and without considering P-Delta effects for the buildings. Upto 20 storey buildings there is no change in the results, so P-Delta analysis is considered for designing a minimum of 25 storey building considering seismic loads and buildings upto 20 stories can be designed by linear analysis or conventional primary analysis

- **Nikun Mangukiya, et al., (2016),** published a journal on **"Study of "P-Delta" Analysis for R.C. Structure", Global Research and Development Journal for Engineering, March 2016** and concluded that G+24 storey building is analysed with linear static analysis and with P-Delta analysis, from the comparison displacement is varying from 12% to 20% in the result. Similarly, for a load combination (EQ Y-) bending moment shows 5% to20% variation, value of modal period, in the different mode shapes are also variable. It is advisable to account such effect in high rise structures.

- **Rajath R, et al., (2016),** published a journal on **" P-Delta Analysis of Multi Story RC Building", international Journal of Research in Engineering and Technology Volume 5, Issue 12, Dec.-2016** and concluded that displacements with respect to earthquake load with P-Delta effects are maximum when compared with only earthquake load. From this it concludes that P-Delta effects have more effect than linear static effect in designing of a structure. Pounding action of two high rise structures with roof displacement can be minimized

IV.SUMMARY OF LITERATURE REVIEW

- The literature review conducted as part of the study shows that there are numerous studies found on P-Delta effect.

- The following conclusions are drawn from the previous studies :

- P-Delta effect is a major issue on high rise structures.

- P-Delta effect is very negligible when only gravity loading exists on structure.

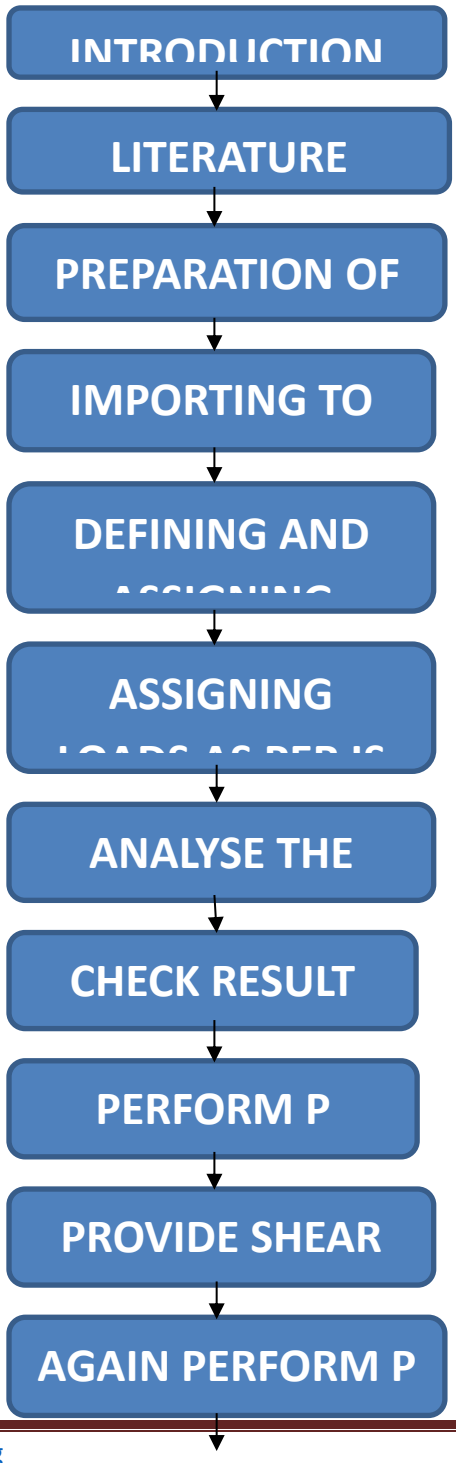
- As the number of storey increases P-Delta effect becomes more important.

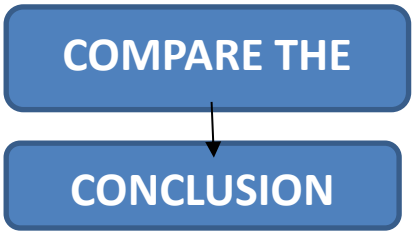
- Generally P-Delta effect is negligible up to 7 storey buildings.

- Effect of P-Delta is quite sensitive to characteristics of ground motion such as the frequency content of earthquake.

- Linear static and P-Delta both are necessary for RC structures.
- The results of storey shear obtained from 20 storey and 15 storey model, when analysed for P-delta effect shows respectively 66.21% and 43.12% more than that obtained from linear static analysis.
- The effect of P-Delta can be reduced upto certain extent by providing the shear walls. Thus Structure with dual configuration (columns with shear wall) performs better than conventional beam-column system
- P-Delta effects have more effect than linear static effect in designing of a structure. Pounding action of two high rise structures with roof displacement can be minimized
- From the results it is revealed that P-Delta effect becomes an important factor to be taken into account if the storey drift of high rise building exceeds 1/85 rad during an expected earthquake excitation in seismic region
- The result indicated that the parameters story displacement, story drifts, and story shears increases with increase in the number stories, mass and height of the building
- It was observed that response quantities were higher when P-Delta analysis was performed and also that the response quantities in respect of asymmetric structures were higher than that of the symmetric structures
- It was found that the building response values on P-Delta analysis were twice as that on static analysis. The X bracing in continuous bracing pattern is proven to be more effective under both static and P-Delta analyses.
- The maximum storey displacement was found in irregular structure. The study reveals that the shape structure with irregularities in plan or vertical irregularities directly affects the whole structure in seismic action.

V.METHODOLOGY





- ✓ **INTRODUCTION:** The objective and scope of the project are determined and knowledge about ETABS and p delta effect has been gained.
- ✓ **LITERATURE REVIEW:** Literature reviews of various authors are collected and their results were studied.
- ✓ **PREPARATION OF PLAN IN AUTOCAD:** A G+10 IT building plan is drawn in AUTOCAD.
- ✓ **IMPORTING TO ETABS:** The plan drawn in AUTOCAD is imported in ETABS with proper grid spacings.
- ✓ **DEFINING AND ASSIGNING MATERIALS:** The material specifications are assigned and beams and columns are placed.
- ✓ **ASSIGNING LOADS AS PER IS CODES:** After the building is designed various loads are assigned as per IS CODE specifications.
- ✓ **ANALYSE THE BUILDING MODEL:** Run the analyses after applying loads.
- ✓ **CHECK RESULT:** The results are checked for any errors.
- ✓ **PERFORM P DELTA ANALYSIS:** The P delta analysis is performed and the results are noted down.
- ✓ **PROVIDE SHEAR WALLS:** Few walls are replaced with shear walls.
- ✓ **AGAIN PERFORM P DELTA ANALYSIS:** Again the P DELTA analysis is performed with the provided shear walls.
- ✓ **COMPARE THE RESULTS:** The results of P delta analysis before and after providing the shear walls are compared.
- ✓ **CONCLUSION**

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