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Study of "P-Delta" Analysis for R.C. Structure

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Abstract

In this modern era of 21st century the urbanization increases worldwide, in heavily populated cities the availability of land is becoming less and cost of land is becoming higher. In view of popularity & less availability of land, tall structures are only solutions for overcoming the problems. A tall structure should be designed to resist the lateral load like Earthquake force within the permissible limits set by Standards. Loads are mainly of two types that are Gravity Loads & Lateral Loads likes Earthquake load. Earthquake forces are further two types, Static Forces & Dynamic Forces. It would be linear and Non-linear also. Linear static analysis can be performed for Low Rise Structure & law earthquake zones only. For tall structure it is necessary to consider nonlinearity, which is generally observed in geometry & materials. Our study is based on "P-Delta" analysis which incorporates geometric nonlinearity in the analysis. The study will be performed on structural software ETABS.
Keyword- Geometric Nonlinearity, Lateral Loads, Linear Static Analysis, Non-Linear Analysis, P-Delta, Structural Software, Tall Structure

I. INTRODUCTION

A. General

Generally, the analysis of buildings is done by using linear elastic methods, which is first order structural analysis. In a first order analysis displacements and internal force are evaluated in relation to the geometric undeformed structure. It does not consider buckling and material yielding. In the case of first order elastic analysis, the deformations and internal forces are proportional to the applied loads. However, in some cases, the deflection of the structure can have a geometric second order effect on the behaviour of the structure, which is not evaluated by the linear first order analysis. This type of geometric non-linearity can be analysed by performing through iterative processes which is only practicable by using computer programs. It is generally known as second order analysis. In this type of analysis, the deformations and internal forces are not proportional to the applied loads.

B. Nonlinearity

Nonlinearity caused by large deformations is referred to as Geometric Nonlinearity. Linear stress-strain equations are assumed to hold in this category. Problems involving geometric nonlinearity arise from finite changes in geometry. This category encompasses large strains and large displacements. There are four sources of nonlinear behaviour in case of structural analysis. The corresponding nonlinear effects are identified by the term geometric, material, force boundary conditions and displacement boundary conditions. Non linearity can also arise when the stress-strain relationship of the material is non-linear in the elastic or in the plastic range, this is called Material Nonlinearity.

C. Second Order Effect

Second-order effects are generally explained by considering the additional displacements, forces, and moments which generated from the use of actions on a deflecting structure. These are known as second-order effects. In certain situations, a first-order analysis may be used to estimate the effects of a second-order analysis by procedure, which is suitable for elastic frame analysis by computer. Second order effects introduce additional deflections, moments and forces beyond those calculated by first-order analysis. So it should be considered in the design. Main second-order effects are listed below:

- Geometric non-linearity, P-δ and P-Δ Effects
- Column Axial Shortening (Bowing Effect)
- Panel-zone Effect
- Differential Settlement of Foundation
- Non-uniform Temperature Effects
- Out-of-straightness and Out-of-plumpness Effects
- Residual Stresses & Other Imperfections
- Column or Beam Yielding
- Redistribution Effect
- Semi-rigid behavior of connections rather than a fully rigid / ideally hinged condition

The issue occurs mainly in the element that is subjected to both bending and axial compression known as "Beam-Column". Also, Geometric non-linearity of P-δ and P-Δ effects can be significant for the members having initial imperfections. That is why the design of a member by considering only the axial compression is prohibited by the design specifications.

II. P-DELTA EFFECTS

The movement of the structural mass to a deformed position in the analysis of building systems subjected to lateral displacements generates second-order overturning moments that are normally not accounted for in static and dynamic analysis. This second-order behavior has been termed the P-Delta effect since the additional overturning moments on the building are equal to the sum of story weight "P" times the lateral displacements "Delta". The effect of P-Delta is mainly dependent on the applied load and building characteristics. In addition to this it also depends upon the height, stiffness and asymmetry of the building. The building asymmetry may be unbalanced mass, stiffness, in plane. There are two distinct types of P-delta effects: P- Δ (sometimes referred to as "large P delta" or "P-Big delta"), and P- δ (sometimes referred to as "small P-delta" or "P-Small delta"); which are explained as under;

A. P- Δ EFFECT (P-BIG DELTA)

P-Δ has reference to the effects of the vertical loads acting on the laterally displaced structure. For example, wind or seismic forces (V) cause a horizontal displacement (Δ) of the structure, while the gravity loads (P) simultaneously act vertically on this displaced structure. Secondary moments are induced into the structure equal to the total vertical load P times the structural displacement Δ. Shown in Figure 1.

B. P- δ EFFECT (P-SMALL DELTA)

P-δ has reference to the effects of the axial load in an individual member subject to a deflection (curvature) between its endpoints. For example, column loads (P) due to gravity, wind, and/or seismic forces act on a column that has a curvature induced by the connection conditions of supported beams. Moments are induced in the member proportional to the axial load P times the member deflection δ. Note that axially loaded beams also experience these effects. It is shown in figure 2.

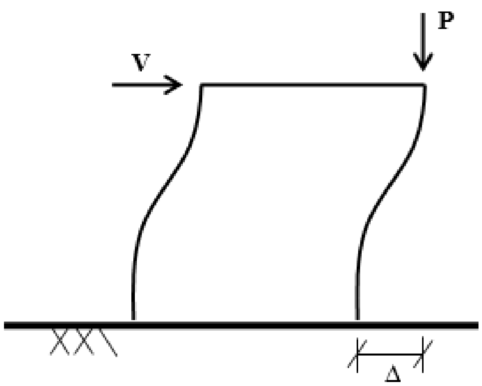

Fig. 1: P-Δ EFFECT

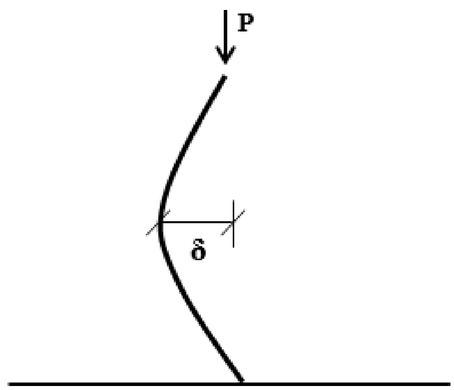

Fig. 2: P- δ EFFECT

C. COMBINE EFFECT OF P - Δ - δ

Since both of these contribute to the deformation of the frame as shown in figure 3, it is important to consider their combined effect. These secondary effects cause the member to deform more and induce additional stresses in the member and there are also reductions of their strength and stiffness. This reduction in strength and stiffness results weakening or destabilizing effect on the structure.

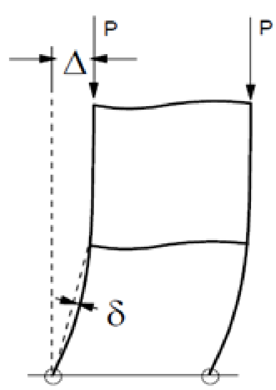

Fig. 3: P - Δ - δ Effect

In a well-proportioned structure conforming to code-specified drift limits, these effects will generally result in an increase over the first-order effects by 10 – 25%, often less for braced frame or shear wall buildings. P-delta effects can be reduced and controlled by using heavier members and/or stiffer frames.

III. ANALYSIS OF R.C. FRAME BUILDING IN ETABS

A 25 storey building has plan dimensions 15 m x 28 m with bay width 4 m in X-direction and 5 m in Y-direction is considered for the study. The building is located in Zone III as per IS 1893 (Part-I) – 2002. Modeling and analysis of the structure is done on ETABS software. Preliminary data of the building are as follows:

Storey Height	*Ground Floor: 4 m* *Typical Floor: 3.5 m*
Dead Load	*Typical Floor: 1.2 kN/m* *Roof: 2 kN/m*
Live Load	*Typical Floor: 3 kN/m* *Roof: 1.5 kN/m*
Beam	*0.30 m X 0.60 m*
Column	*0.55 m X 1.15 m*
Slab Thickness	*0.125 m*
Seismic Data	*Zone III Moderate (Zone factor: 0.16)* *T=2.15 & R=5*
Soil Type	*II*
Importance Factor	*1*
Damping Percentage	*5% (Damping factor: 1)*
Grade of Concrete & Steel	*M25 & Fe415*

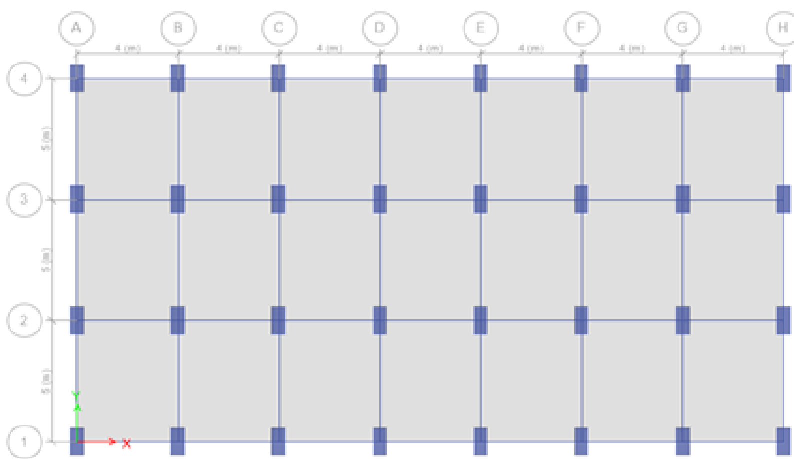

Fig. 4: Plan of The Building

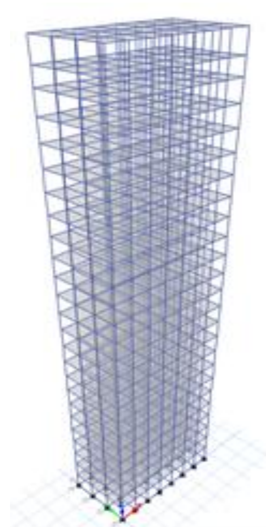

Fig. 5: 3D-VIEW

The significance of the building responses like displacement, column moment, story stiffness & Mode shape are studied in detail.

IV. RESULTS

A. Displacement

Displacement of the joint at top storey in mm with and without P-delta effect:

Sr. No.	Load Case/ Load Combination	Displacement without P-Delta Effect (mm)	Displacement with P-Delta Effect (mm)	% Difference
1	EQ X+	123.2	141.2	14.61%
2	EQ X-	113.1	129.9	14.85%
3	EQ Y+	129.2	152.6	18.11%
4	EQ Y-	164.5	192.2	16.84%
5	1.2 (D.L.+L.L+EQ Y-)	197.4	230.7	16.87%
6	0.9 D.L.+1.5 EQ Y-	246.7	288.3	16.86%

B. Moment

Moment of the column under load case (EQ Y-) at different levels is shown in the table:

Sr. No.	Moment without P-Delta Effect (kN-m)	Moment with P-Delta Effect (kN-m)	% Difference
Storey 25	-48.8395	-52.2334	6.95%
Storey 20	-131.2358	-145.9392	11.20%
Storey 15	176.0734	196.5329	11.62%
Storey 10	226.6859	265.9263	17.31%
Storey 05	260.0094	320.3062	23.19%
At Base	525.1856	593.201	12.95%

C. Modal Period & Frequencies for Different Mode Shape

Modal period & frequencies for different mode shape with and without P-delta is shown in table:

MODE	MODAL PERIOD (Second)		FREQUENCIES (cyc/sec)	
	Without P-Delta	With P-Delta	Without P-Delta	With P-Delta
1	5.322	5.806	0.188	0.172
2	4.925	5.32	0.203	0.188
3	4.36	4.657	0.229	0.215
4	1.665	1.76	0.601	0.568
5	1.61	1.701	0.621	0.588
6	1.419	1.485	0.705	0.673

V. CONCLUDING REMARK

In this study of G + 24 story structure, is analyzed with static linear and static non-liner analysis, here Geometric non linearity is considered by accounting, p-delta effect it is shown from displacement comparison that there is about 12% to 20% variation in the result. Similarly, the bending moment for the load combination (EQ Y-) shows 5% to 20% variation, value of modal period, in the different mode shapes are also variable. It is advisable to account such effect in tall structures.

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