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Effect of Wind Load on Tall R C Buildings by P-Delta Analysis

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***Abstract*—The P - delta effect becomes more important when columns are slender. A method of designing for p-delta effects in high rise buildings is presented. In this paper the effect of lateral load on the structural system is considered for the p delta effect. The drift ratio is found out for wind loading, considering with and without p-delta effect for different number of stories such as 10, 20, 30, 40, 50 stories.**
The load–deflection curves and drift ratios have been obtained for different cases and the results so obtained have been compared to identify the drift ratios for different stories of the structure. The results of the analysis show that the p-delta effect is more in the upper stories for wind loading.
In this present study, the non-linear static analysis has been carried out using ETABS with identification of p-delta effects in multi- storey buildings based on its behavior. The load deflection curves and the results so obtained have been compared.

I. INTRODUCTION

General

High rise design comes into play when a structure's slender nature makes it sensitive to lateral loads. In the design of multi-storey structures, allowance should be made for "p-delta" effects.
The p-delta effects are dependent on the applied load and material characteristics, in addition to parameters such as height and stiffness of a building. The degree of its asymmetry may also be of importance. P-delta effects become more significant when the columns are slender.

Wind

Wind is composed of a number of eddies of varying sizes and rotational characteristics carried along in a general stream of air moving relative to the earth's surface. These eddies give wind its gusty or turbulent character. The strong winds in the lower levels of the atmosphere largely arise from interaction with surface features. The average wind speed over a time period of the order of ten minutes or more, tends to increase with height, while the abrupt rush of wind tends to decrease with height. A consequence of turbulence is that dynamic loading on a structure depends on the size of the eddies. Wind load is a lateral load which has a

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direct effect on the structure. Wind loading factor is important in considering the p delta effect for designing purposes of the high rise structures.
Eddies generated around a typical structure are shown in figure 1.

Figure 1.1 ElevationFigure 1.2 Plan

Figure 1.Generation of eddies

II. P-DELTA

In structural engineering, the P-Delta effect refers to the abrupt changes in ground shear, overturning moment, the axial force distribution at the base of a sufficiently tall structure or structural component when it is subject to a critical lateral displacement**.**
Generally Structural designers are prone to use linear static analysis, which is also known as first order analysis, to compute design forces, moments and displacements resulting from loads acting on a structure. The first order analysis performed by assuming small deflection behavior where the resulting forces, moments and displacements take no accountof the additional effect due to the deformation of the structure under vertical load prior to imposing lateral loads. P-Delta is a non-linear (2^{nd} order) effect that occurs in every structure where elements are subject to axial loads.

III. METHODOLOGY

In the present investigation a simple procedure of analysis has been done for tall buildings. The analysis is carried out using ETABS Commercially available finite element software.
The following ten types of models are considered for analysis under Wind loading

- 10 storey RC building with p-delta and without p-delta
- 20 storey RC building with p-delta and without p-delta
- 30 storey RC building with p-delta and without p-delta
- 40 storey RC building with p-delta and without p-delta
- 50 storey RC building with p-delta and without p-delta

Building Models

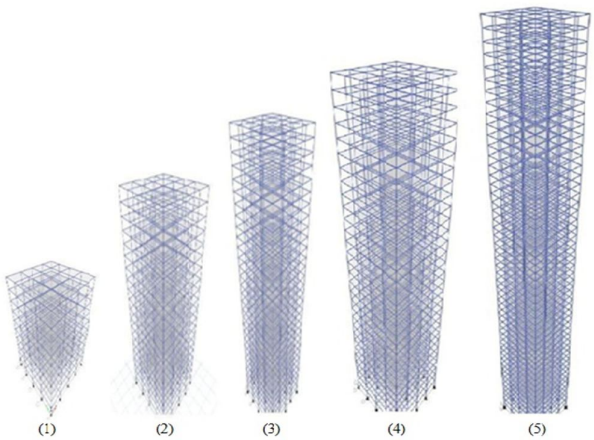

Figure 3.Building models

Plan

The buildings are square in plan of dimensions 24mx24m as shown in a figure.
The columns of square size have been used.

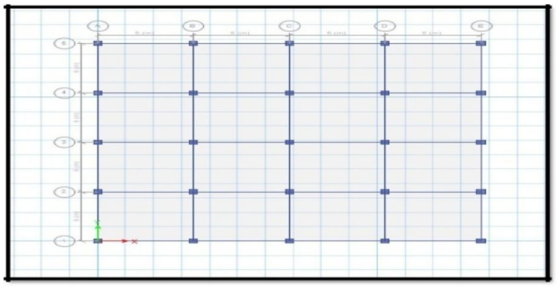

Figure 4

Material Properties

The materials used for the construction is reinforced concrete with M-30 and M-40 grade concrete Fe-500 grade reinforcing steel. The Stress-Strain relationship used is as per I.S.456:2000.

Model Geometry

The structure analysed is for 10, 20, 30, 40 & 50 storey building with reinforced concrete properties as specified above. The concrete floors are modelled as rigid. The details of the models are given below:

- Number of bays along the X and Y– direction = 5
- Storey height = 3 meters and depth of the slab = 150 mm
- Bay width along the X and Y– direction = 6 meters
- Size of the beam in longitudinal and transverse direction = 300mm*600mm
- Size of the column = 500mm*500mm for 10 storey building
- Size of the column = 700mm*700mm for 20 storey building
- Size of the column = 800mm*800mm for ground 10 storey &700mm*700mm for the rest 20 storey.
- Size of the column = 1000mm*1000mm for ground 10 storey, 800mm*800mm for next 10 storey and 700*700mm for the rest 20 storey.
- Size of the column = 1100mm*1100mm for ground 10 storey, 1000*1000mm for next 10 storey, 800mm*800mm for next 10 storey and 700*700mm for the rest 20 storey.
- Zone = II, Response reduction factor = 5, Importance factor = 1, Soil condition = Medium

IV. Effect Of Wind Loading Withoutp-Delta Effect

Analysis Output

Model - 1

TABLE I. DISPLACEMENTS AT DIFFERENT HEIGHTS FOR10 STOREY BUILDING MODEL

Story level	Height (m)	Displacement (mm)
10	30	10.9
9	27	10.6
8	24	10.2
7	21	9.6
6	18	8.7
5	15	7.6
4	12	6.2
3	9	4.7
2	6	3.0
1	3	1.2

Model – 2

TABLE II. DISPLACEMENTS AT DIFFERENT HEIGHTS 20 STOREY BUILDING

Story level	Height (m)	Displacement (mm)
20	60	132.7
18	54	129.1
16	48	123.2
14	42	114.5
12	36	102.7
10	30	87.9
8	24	70.5

Model - 3

TABLE III. DISPLACEMENTS AT DIFFERENT HEIGHTS FOR 30 STOREY BUILDING MODEL

Story level	Height (m)	Displacement (mm)
30	90	90.1
27	81	87.3
24	72	82.8
21	63	76.5
18	54	68.6
15	45	59.1
12	36	48.1
9	27	35.9
6	18	23
3	9	9.5

Model - 4

TABLE IV. DISPLACEMENTS AT DIFFERENT HEIGHTS FOR 40 STOREY BUILDING MODEL

Story level	Height (m)	Displacement (mm)
40	120	169.7
36	108	163.5
32	96	154.1
28	84	141.3
24	72	125.5
20	60	106.8
16	48	86.4
12	36	63.9
8	24	39.9
4	12	16

Model - 5

TABLE V. DISPLACEMENTS AT DIFFERENT HEIGHTS FOR 50 STOREY BUILDING MODEL

Story level	Height (m)	Displacement (mm)
50	150	285.4
45	135	273.5
40	120	256.2
35	105	233.7
30	90	206.2
25	75	175.5
20	60	141.1
15	45	104.8
10	30	65.8
5	15	26.3

Lateral Displacement

Results For Wind Loading Without p- Effect

TABLE VI. LOAD, BASE SHEAR, DEFLECTION AT TOP & STORY DRIFT AT TOP

SL NO	No. Of Stories	Height (m)	Load (KN)	Base Shear (KN)	Deflection At Top (mm)	Story Drift at Top
1	10	30	91885.554	1985.86	10.9	0.000061
2	20	60	185931.26	3847.86	132.7	0.000453
3	30	90	308615.1	5786.61	90.1	0.000219
4	40	120	427162.7	8101.25	169.7	0.000366
5	50	150	552010.16	12151.875	285.4	0.000571

Relationship Between Load, Deflection Andno. Of Stories

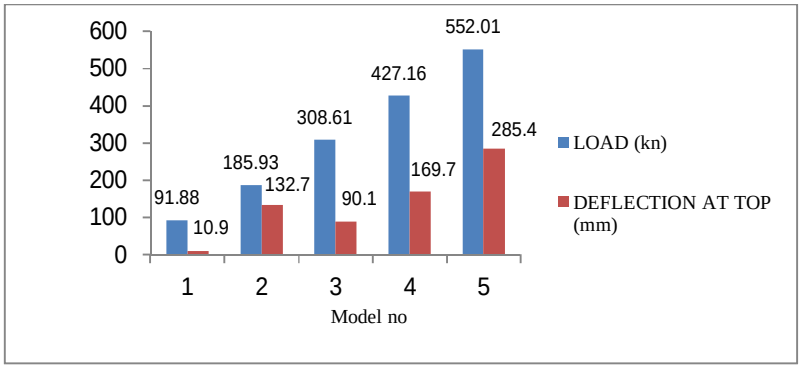

Figure 5.Load, Deflection & No. of stories

The relationship between load, deflection and no. of stories is shown under wind loading without considering p-delta effects from the analysis.

V. EFFECT OF WIND LOADING WITH P-DELTA EFFECT

In the seismic design of a multi-storey structures allowance should be made for "p-delta" effects. These are additional overturning moments applied to the structure resulting from the seismic weights (p), supported by the structure, acting through the lateral deflections (Δ), which directly results from the horizontal seismic inertia forces. They are second order effects which increase the displacements, the member actions and lengthen the effective fundamental period of the structure.

Analysis Output

Model – 1

TABLE VII. DISPLACEMENTS AT DIFFERENT HEIGHTS FOR 10 STOREY BUILDING MODEL

Story level	Height(m)	Displacement(mm)
10	30	11.2
9	27	11
8	24	10.5
7	21	9.9
6	18	9.0
5	15	7.8
4	12	6.5
3	9	4.9
2	6	3.1
1	3	1.3

Model – 2

TABLE VIII. DISPLACEMENTS AT DIFFERENT HEIGHTS FOR 20 STOREY BUILDING MODEL

Story level	Height (m)	Displacement (mm)
20	60	153.5
18	54	149.6
16	48	143.3
14	42	133.6
12	36	120.5
10	30	103.7
8	24	83.3
6	18	59.9
4	12	34.8
2	6	11.7

Model – 3

TABLE IX. DISPLACEMENTS AT DIFFERENT HEIGHTS FOR 30 STOREY BUILDING MODEL

Story level	Height (m)	Displacement (mm)
30	90	95.9
27	81	93
24	72	88.3
21	63	81.8
18	54	73.5
15	45	63.4
12	36	51.7
9	27	38.7
6	18	24.8
3	9	10.2

Model – 4

TABLE X. DISPLACEMENTS AT DIFFERENT HEIGHTS FOR 40 STOREY BUILDING MODEL

Story level	Height (m)	Displacement (mm)
40	120	184.9
36	108	178.3
32	96	168.3
28	84	154.8
24	72	137.9
20	60	117.7
16	48	95.5
12	36	70.7
8	24	44.1
4	12	17.5

Model – 5

TABLE XI. DISPLACEMENTS AT DIFFERENT HEIGHTS FOR 50 STOREY BUILDING MODEL

Story level	Height (m)	Displacement (mm)
50	150	319.4
45	135	306.4
40	120	287.7
35	105	263.3
30	90	233.2
25	75	199.3
20	60	160.8
15	45	119.7
10	30	75.1
5	15	29.7

Lateral Displacement

Results For Earthquake Loading With P-Effect

TABLE XII. LOAD, BASE SHEAR, DEFLECTION AT TOP & STORY DRIFT AT TOP

Sl No	No. of Stories	Height (m)	Load (KN)	Base Shear (KN)	Deflection at top (mm)	Story Drift at Top
1	10	30	91885.554	1985.86	11.2	0.000062
2	20	60	185931.26	3847.86	153.5	0.000486
3	30	90	308615.1	5786.61	95.9	0.000230
4	40	120	427162.7	8101.25	184.9	0.000391
5	50	150	552010.16	12151.87	319.4	0.000626

Relationship Between Load, Deflection Andno. Of Stories

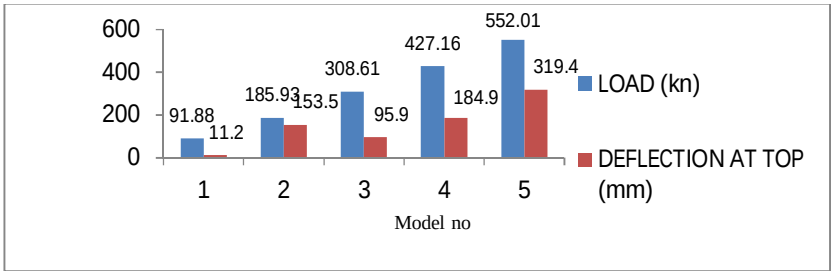

Figure 6.Load, Deflection & No. of stories

The relationship between load, deflection and no. of stories is shown under wind loading considering with p-delta effects from the analysis.

VI. CONCLUSIONS AND RECOMMENDATIONS

In the present study, the non-linear response of tall RC buildings using ETABS under the lateral loading has been carried out with the intention to study the relative importance of p-delta effects on tall RC buildings, story drift ratios and to identify the load deflection curves and the results so obtained have been compared.

Summary And Results Of Story Drift Under Wind Loading

TABLE XIII. COMPARISON OF DRIFT RATIOS

Sl no	No of stories	Height (m)	Story drift at top without p-Δ	Story drift at top with p-Δ
1	10	30	0.000061	0.000062
2	20	60	0.000453	0.000486
3	3	90	0.000219	0.00023
4	40	120	0.000366	0.000391
5	50	150	0.000571	0.000626

VII. CONCLUSIONS

The p-delta analysis is a simple way to investigate the nonlinear behaviour of the buildings. The drift ratio is found out for wind loading, considering with and without p-delta effect for different number of stories such as 10, 20, 30, 40 & 50 in ETABS software. The selection of building configuration is basically done as per IS: 456 and the loading details are taken as per IS: 875 provisions.

- Wind loading has significant effect on the building.
- Drift ratio is very small in lower stories and reaches a maximum at the top stories.

- The effect of p-delta increases as the height of the building increases.
- Behaviour of p- effect can be easily known for the slender members.

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