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P-Delta Effect on High Rise Building Subjected to Earth Quake and Wind Load

Rizwan Akhter[1], Shree Prakash[2], Mirza Aamir Baig[3]
M.Tech (Structural & Foundation Engineering) [1], Assistant Professor[2, 3]
Department of Civil Engineering
Al-Falah University, Faridabad, India

Abstract:
In first order analysis of a structure both kinematic as well as equilibrium relationships are taken with respect to un-deformed shape of the structure. But this does not consider the load which caused due to deflection of the structure. For stability design of a structure second order analysis is required which counteracts equilibrium and kinematic relationship of a structure. In a deformed structure in addition to the applied loads many additional loads due to deformation which develops second order or P-delta effects in the structure. In the present study seismic analysis and wind load analysis of a multi -storey RC building with and without P-Delta effects is analyzed by using ETABS structural analysis software. The seismic zone factor of 0.24 is considered which falls under Zone-IV. From the analysis, both the displacement and drifts with respect to earthquake loads are Minimum when compared with earthquake load with P-delta effects.

Keywords: I P-DELTA EFFECT DISPLACEMENT, DRIFTS, LINEAR AND NON LINEAR ANALYSIS

I. INTRODUCTION

The reinforced concrete building can be damage during earthquake and due to these damages our structures needs to be retrofitted of existing buildings in sub-continents in India, these practices are usually used because of lack of awareness of regarding structural behavior during earthquake. Most of the structures are designed statically due to the regular shape of the building but we have to know the difference between static and dynamic behavior and we know that the earthquake response is a dynamic behavior and building response with respect to time in dynamic analysis. There are two types of analysis can be done.
1) Linear Static and Dynamic analysis
2) Non-linear Static and Dynamic analysis
Due to shortage of land and increasing of population we required to build the multi-storied buildings. In developing countries, multi-storied buildings are generally provided with prismatic sections. Structural engineer should be design a building in such a manner that buildings must follow the codal provision and it should be designed economical. Following of codal provision help us to decide the suitable sections for the structure. Beams are major member of carrying and transferring loads and transverse moment and it can supports the slab also and if the axial force is0.1% of transverse of load the we should also check it for axial forces only. Taking of careful approach in its design may lead to good serviceability and optimization of the cost of structure. Prismatic beams are commonly used for medium span and bending moments. Bending moment and Shear forces are usually increases when the span increases in this case prismatic property beams are uneconomical and if we are increasing the depth of beam there is decreases in headroom. Therefore in such cases non-prismatic beams are an appealing solution when the structural elements are subjected to axial load, P-Delta effects occur in the structure. It is one of the second order effects which corresponds to the load imposed on the structure with respect to deformation. It is a second order effect which is related with the displacement and the axial load amount applied. As we know P-Delta effect is a non-linear analysis and it can be applied for multistoried high rise structure to calculate the deflections.

II. OBJECTIVE

1. To perform Linear Analysis without P-delta effect.
2. To perform Linear Analysis with P-delta effect.
3. To perform Non-Linear Analysis with P-delta effect.
4. To study the performance of R.C.C building different parameters such as story drift, story displacement, base shear, shear force etc.
5. To determine the effect of earthquake on various parameters like fundamental, time period, storey drifts, lateral joint displacements, bending moments and shear force in beam and columns.

III. METHODOLOGY

Linear Static Analysis

Linear static analysis is kind of analysis in which we cannot give response to the building with respect to time. In this analysis we can check the small deflections, bending moments and shear forces of the applied load over the structure. P-Delta effect is non-linear analysis. The results of different load cases can be combined with each other and with other linear load cases, such as response spectrum analyses. Geometric and material nonlinearity, except for the P-Delta effect, are not considered in a linear static analysis

Equivalent Static Method

In equivalent static method Seismic analysis of most structures is still carried out on the assumption that the lateral (horizontal) force is equivalent to the actual (dynamic) loading. In this method requires less effort because, we don't need to calculate the fundamental period, and shapes of higher natural modes of vibration are not required. The base shear is a total horizontal mass which can be calculated by the multiplication of acceleration coefficient and lump mass of the structure. Fundamental time periods should also be calculated and shapes of the building. The base shear can be distributed along the member and the total distribution can be done with respect to height and lump weight. The sum of the distributed forces cannot increases the base shear and we can calculate the overturning moment, displacement, torsion, bending moment and shear forces. Now a days we are using computational programs to calculate the fundamental time period and base shear to avoid the time consumption.

Response Spectrum Method

This method is also known as Modal Method or Mode Super-Position Method. In this method we are getting the maximum response of any structure due to earthquake. Basically it is a application of structure in which building response with respect to time and give the accurate result. As per IS1893-2002 the value response spectrum can be calculated according to the zone factors and importance factor, there are values of Z,I and R have been given in Indian codes and the computational program can calculate the time period according to the soil condition. Generally, this method is applicable to analysis of the dynamic response of structures, which are asymmetrical or have geometrical areas of discontinuity or irregularity, in their linear range of behaviour. Response spectrum method is used to calculate the earthquake forces. Response spectrum plots a graph of peak-steady acceleration. Sinusoidal graph have been taken for response spectrum to calculate earthquake forces. The reversal of load should be taken for response spectrum dynamic analysis because this load is dangerous and will be responsible of building collapse. Response spectra are curves which plots maximum response of SDOF subjected to specified earthquake ground motion. The damping ratio of building are constant for RCC framed structure which is 5% and the value of static base shear should be equal to dynamic base shear for initial analysis to calculate the time period of the building.

Non-Liner Static Analysis

Nonlinear static analysis are of two types:

1) Geometrical non-linearity

2) Material non-linearity

P-Delta is geometrical non-linearity because when the deflection increases we have to test the against the additional forces which are generated by P-Delta effects. The word p is the force and Delta gives the deflection of the particular member on which force p applied. It generates additional shear and bending moment in column and we must design against that. There is one more case for this analysis is Push-over analysis to calculate ultimate load and deflection capability.

Material nonlinearity is defined as when the material goes beyond its yield strength and it no longer behaves in linear fashion due to this the material gets cracked, dissipates energy, permanent deformation and beam rotations.

P-delta EFFECT

P-Delta is a geometrical non-linearity and it give the additional shear forces and bending moment to the structure due the applied force P, whereas P is the load and delta is a lateral deformation. This case is most dominant in case of earthquake instead of wind. This can be checked n P-M interaction diagram of column cross-section. P-Delta is actually only one of many second-order effects. It is a effect that is genuine and associated with the magnitude of the applied axial load (P) and a displacement (delta).

There are two ways to specify the initial p-delta analysis in ETAB as follows:

Non-iterative Based on Mass: The load is computed automatically from the mass at each level as a story-by-story load upon the structure. This approach is approximate, but does not require an iterative solution. This method is identical to p-delta analysis in ETABS. This method essentially treats the building as a simplified stick model to consider the P-Delta effect. It is much faster than the iterative method. It does not capture local buckling as well as the iterative method. This method works best if you have a single rigid diaphragm at each floor level though it also works for other cases as well. The reason we provide this method is to allow you to consider P-Delta in cases where you have not specified gravity loads in your model. If you have specified gravity loads in your model, then in general, we recommend that you use the Iterative Based on Load Cases option. Iterative Based on Load Cases: The load is computed from a specified combination of static load cases. This is called the P-Delta load combination. ¾ P-Delta Load Combination: This area is active if you select the Iterative Based on Load Cases option in the Method area of the dialog box. Here you specify the single load combination to be used for the initial P-Delta analysis of the structure. As an example, suppose that the building code requires the following load combinations to be considered for design:

(1) 1.4 dead load

(2) 1.2 dead load + 1.6 live load

(3) 1.2 dead load + 0.5 live load + 1.3 wind load

(4) 1.2 dead load + 0.5 live load - 1.3 wind load

(5) 0.9 dead load + 1.3 wind load

(6) 0.9 dead load - 1.3 wind load

For this case, the P-Delta effect due to the overall sway of the structure can usually be accounted for, conservatively, by specifying the P-Delta load combination to be 1.2 times dead load plus 0.5 times live load. This will accurately account for this effect in load combinations 3 and 4 above, and will conservatively account for this effect in load combinations 5 and 6. This P-Delta effect is not generally important in load combinations 1 and 2 since there is no lateral load.

Second-order analysis when accounting for P-Delta combines two effects to reach a solution

1. Theory of large displacement: - In this theory both forces and moments due to deformed shape of structure and also members are considered.

2. Stress stiffening: - In this the effect of axial load on structure stiffness is seen. Normally tensile loads straighten the geometry of an element this increases the stiffness whereas compressive loads accentuate deformation which in turn reduces the stiffness of the structure.

There are two P-Delta effects: P-“BIG” delta (P-Δ) - a structure effect • P-“little” delta (P-δ) - a member effect The magnitude of the P-Delta effect is related to the:

• Magnitude of axial load P

• Stiffness or slenderness of the structure as a whole

• Slenderness of individual elements.

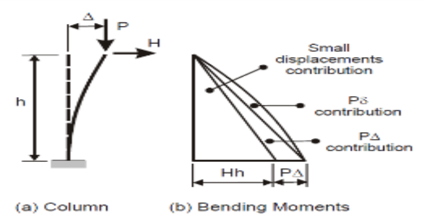
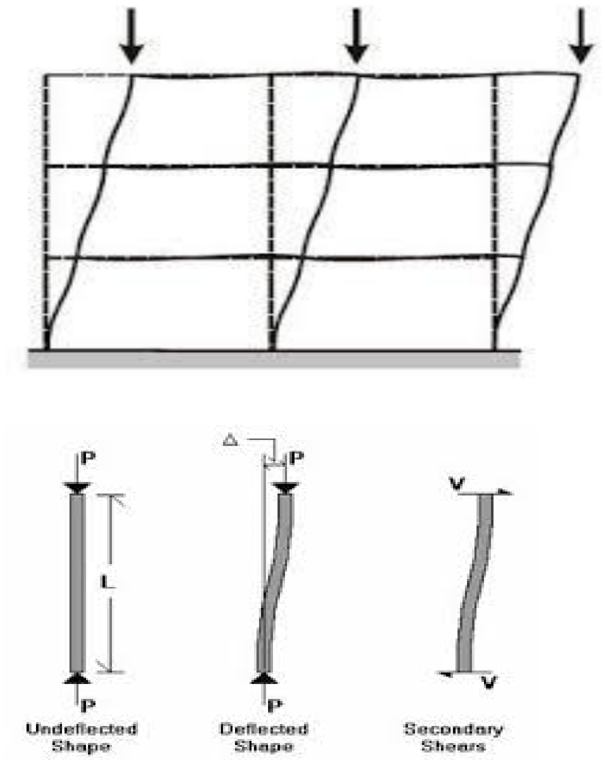


Figure 1 - P-Delta about column



$P * \Delta = V * L$

P-delta effect by axial load

STATIC ANALYSIS OF BUILDINGS USING IS 1893

Design Seismic Base Shear-
The design base shear is depends on the lump mass of structure and acceleration coefficient. Base shear is total lateral force at a base of the structure and distributed along the member to calculate the serviceability and behaviour.

VB= Ah x W

Ah = Design horizontal seismic coefficient.
W = Seismic weight of the building

Seismic Weight of Building-
The seismic weight of each floor is its full dead load plus appropriate amount of imposed load as specified. The mass source from which e can compute the seismic weight is (DL+0.25LL) up to 3 KN/m^2 and (DL+0.5LL) for above 3KN/m^2 While computing the seismic weight of each floor, the weight of columns and walls in any story shall be equally distributed to the floors above and below the story. The seismic weight of the whole building is the sum of the seismic weights of all the floors. Any weight supported in between the story shall be distributed to the floors above and below in inverse proportion to its distance from the floors.

Fundamental Natural Time Period- The fundamental natural time period (Ta) calculates from the expression
Ta = 0.075h^0.75 for RC frame building
Ta = 0.085h^0.75 for steel frame building
If there is brick filling, then the fundamental natural period of vibration, may be taken as

$$T_a = \frac{0.09\mathbf{h}}{\sqrt{\mathbf{d}}}$$

Distribution of Design Force- The design Base Shear, VB computed above shall be distributed along the height of the building as per the following expression

$$Q_i = \frac{Vb*Wi*hi^2}{\sum Wj*hj^2}$$

Seismic Loads As per IS-1893-2002, seismic analysis of the structure is performed. The design horizontal seismic coefficient, Ah for the structure has been computed using the following:
1. Zone factor, Z =0.24 (Zone IV)
2. Importance factor I =1.0
3. Response Reduction factor, R =5
4. Soil type = Medium Soil
5. Damping Coefficient = 0.05
6 Time period = .075 H^.75= 0.75 *48.5^0.75= 1.298 sec

WIND LOAD CALCULATION
Basic wind speed= Vb =47m/s
Terrain category 2
Risk coefficient = 1
Topography = 1
Design wind speed Vz = Vb*k1*k2*k3
Terrain Category I
Plan length = 32 m
Plan width = 20 m
Height of building = 48.5 m
Face width = 20 m
Face depth = 35.5 m
Interval = 4 m
k1 = 1
k2 (at 33.5 m) = 1.00
k3 = 1.00
Vb = 47 m/s
Vz = Vb x k1 x k2 x k3 =47 m/s
Wind pressure = P=0.6*(Vz)^2=0.6*(47)^2=1.325KN/m^2

4. MODEL CONFIGURATION

Table.no.1

	R.C.C BUILDING
HEIGHT	48.5 m
AREA	1300 sqm.
Each Story height	3m
COLUMN	0.250Mm*0.750Mm (1st to 20th floor)
BEAM	250mm*750mm
SLAB	150mm
GRADE OF CONCRETE	25M (SLAB)
GRADE OF CONCRETE	25M (BEAM)
GRADE OF CONCRETE	30M(COLUMN)
GRADE OF STEEL	FE415 (Rebar)
ZONE	IV
REGION	DELHI
LIVE LOAD	3KN/sqm

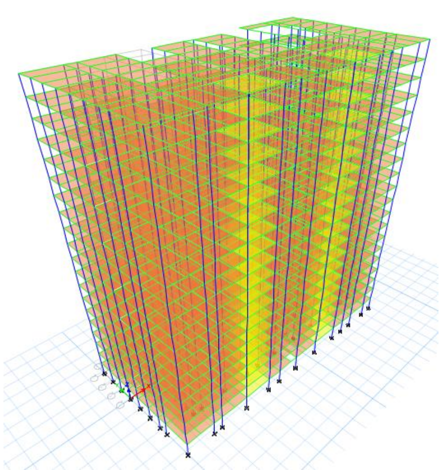


Figure.1. 3d view

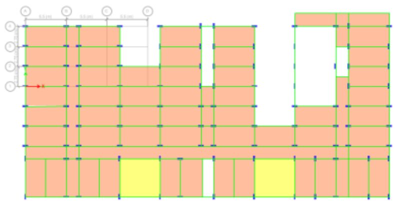


Figure.2. Plan view of Building

4.1. DISPLACEMENT

Table.2.

DISPLACEMENT DUE TO EARTH QUAKE				
	WITHOUTP-DELTA		WITH P-DELTA	
	X-DIR	Y-DIR	X-DIR	Y-DIR
Story20	58.7	62.5	59.9	64.2
Story19	57.3	61.2	58.6	62.9
Story18	55.7	59.5	57	61.2
Story17	53.8	57.5	55.1	59.2
Story16	51.5	55.1	52.8	56.8
Story15	49	52.4	50.2	54.1
Story14	46.1	49.4	47.4	51.1
Story13	43.1	46.2	44.3	47.9
Story12	39.9	42.9	41.1	44.4
Story11	36.5	39.3	37.6	40.9
Story10	33	35.7	34.1	37.1
Story9	29.4	32	30.4	33.3
Story8	25.7	28.2	26.7	29.4
Story7	22.1	24.3	22.9	25.4
Story6	18.4	20.5	19.1	21.4
Story5	14.7	16.7	15.2	17.5
Story4	11.1	12.9	11.5	13.5
Story3	7.6	9.2	7.9	9.6
Story2	4.4	5.6	4.5	5.8
Story1	1.6	2.2	1.6	2.3
Base	0	0	0	0

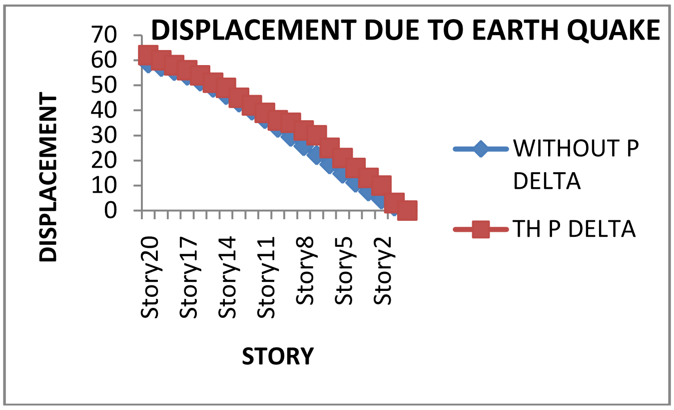


CHART.NO.1 X-DIR

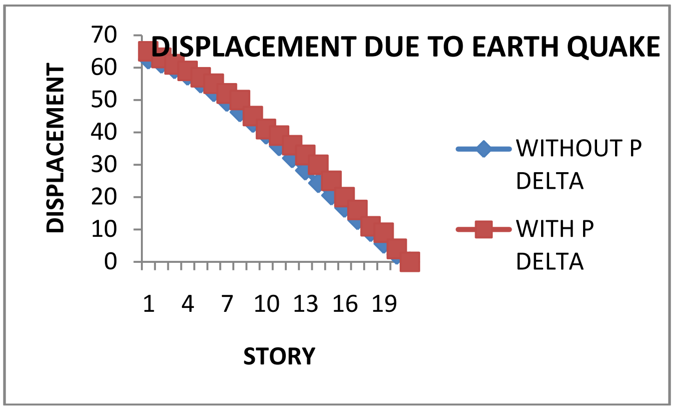


CHART.NO.2 X-DIR

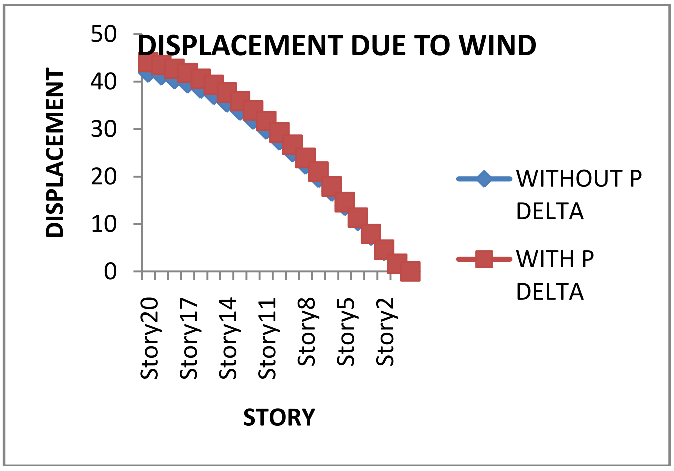


CHART NO.3 X-DIR

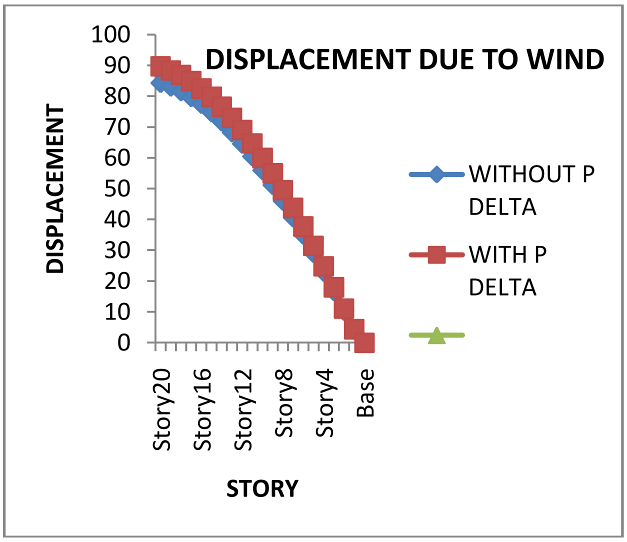


CHART NO.4 Y-DIR

Table.3.

DISPLACEMENT DUE TO WIND FORCE				
	WITHOUTP-DELTA		WITH P-DELTA	
	X-DIR	Y-DIR	X-DIR	Y-DIR
Story20	41.9	84.2	44.1	89.6
Story19	41.3	83	43.5	88.3
Story18	40.5	81.5	42.7	86.8
Story17	39.6	79.6	41.8	84.8
Story16	38.5	77.4	40.6	82.4
Story15	37.2	74.7	39.3	79.7
Story14	35.6	71.7	37.7	76.5
Story13	33.9	68.2	35.9	72.9
Story12	32	64.5	33.9	69
Story11	29.9	60.4	31.7	64.6
Story10	27.6	55.9	29.3	59.9
Story9	25.1	51.1	26.7	54.9
Story8	22.5	46	23.9	49.5
Story7	19.7	40.6	21	43.7
Story6	16.8	35	17.9	37.7
Story5	13.8	29.1	14.6	31.4
Story4	10.6	23	11.3	24.8
Story3	7.5	16.7	7.9	18
Story2	4.3	10.3	4.6	11.1
Story1	1.5	4.2	1.6	4.4
Base	0	0	0	0

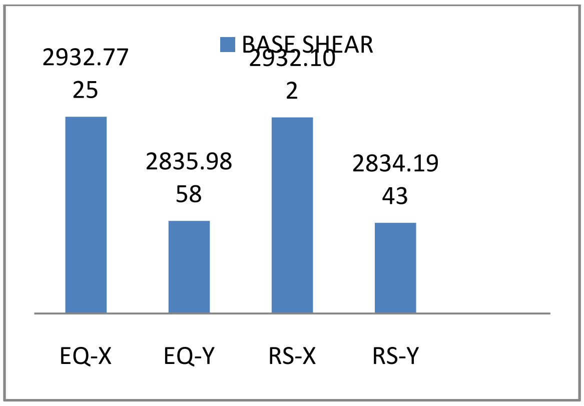


CHART.5.

Table.4.

	BASE SHEAR
Dead Load	142361.2
EQ-X	2932.773
EQ-Y	2835.986
RS-X	2932.102
RS-Y	2834.194

5. CONCLUSIONS

P-delta investigations and linear static analysis are carried out for 18 storey RC framed structure using ETABS. On the basis of results obtained, following conclusions are drawn.

1. Displacements with respect to earthquake load with P-delta effects are maximum when compared with earthquake load.

2. This concludes P-delta effects have more effect in designing of a structure rather than first order effect.

3. We can minimize pounding action of two tall buildings with roof displacements.

4. Storey displacement values for all the load cases are within the permissible limit.

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8. BIOGRAPHY

RIZWAN AKHTER, M.Tech (Structural & Foundation Engineering) Department of Civil Engineering **AL-FALAH University,** Faridabad **INDIA**

SHREE PRAKASH, Assistant Professor, Department of Civil Engineering **AL-FALAH University,** Faridabad **INDIA**

MIRZA AAMIR BAIG, Assistant Professor, Department of Civil Engineering **AL-FALAH University,** Faridabad **INDIA**