Parametric Study on P-Delta Effect for Various Structural Systems

Deep Dobaria[1], Prof. P. G. Patel[2]

[1]*Post Graduate Student, Applied Mechanics Department, L.D. College of Engineering, Ahmedabad, Gujarat, India*
[2]*Associate Professor, Applied Mechanics Department, L.D. College of Engineering, Ahmedabad, Gujarat, India*

---***---

Abstract - *Nowadays cities are getting overpopulated and to overcome this situation, there is a need to build a multi storey buildings and it leads to irregular type of building because of architectural aesthetic and functional requirement. Therefore, there is a need to study the second order effect when both horizontal and lateral load acting simultaneously. The second order effect is the additional effect in the structure due to the structural deformation by virtue of the applied loads which is also known as P-delta effect. The P-Delta is a non-linear effect that occurs in every structure where elements are subjected to axial load and lateral load and in this type of analysis, the deformations and internal forces are not proportional to the applied loads. So, in high rise buildings it is very important to account such second order effect like P-Delta while analyzing the structure.*

***Key Words*: P-Delta effect, Second order effect, Time history analysis, Nonlinear dynamic, Response spectrum analysis, ETABS**

1. INTRODUCTION

As urbanization increase worldwide, the requirement to tall building increase drastically and caused many developments in shape and size of tall building specifically in developing country. Height of building become more significant when the structure subjected to more than one loading case. Generally, in nature there are too many load cases that impact on the structure regularly or simultaneously. In both cases structure require sensitive loading analysis and design. The most severe load case will be ground motion excitation which has a damage effect in term of value, shape and vector. As a result, the respond of the structure against this huge amount of forces could be so weak and cause total damage of the structure. When the structure exposed to such a force the lowest column of the structure would be subjected to lateral and horizontal force in addition to fluctuated force.

Gaiotti and Smith (1989) suggested a P-delta analysis and proposed to include this second order in low stiffness and high-rise structure. Yen (1993) introduced a method for direct analysis of nonlinear behaviour of slender beam-columns based on the strain control techniques. Williamson (2003) found out that the effect of load acting through the inelastic displacements caused by an earthquake can lead to response that is five times grater that the case in which P-Delta is not included.

Sardar and Hama (2018) found out that steel structural shows more effect of P-delta than Reinforced concrete structure and suggested to consider this effect in more than 15-storey buildings. Dinar, Karim, Barua, Uddin (2013) also found that displacement of top storey is varying exponentially if P-delta effect is considered.

The main objectives of research are

1. To analyse the RCC structure with and without P-Delta effect for different structural system subjected to dynamic loading.
2. To find out optimum structural system to overcome P-Delta effect for high rise building.

2. MODELING IN SOFTWARE

The following was applied to reach the above objectives:

1. A case study was carried out for 30, 40 & 50 storey building of bare frame structure and 3 different structural system with varying shear wall density and position.
2. These structural systems were analyzed using ETABS software. Time History analysis(Bhuj, El-Centro and Uttarkashi) and response spectrum analysis are performed.

2.1. Geometric Parameters

The common geometric parameter for all structural system is building plan with dimensions 30 m x 40 m and a typical story height of 3 m. The mean compressive strength of concrete is 45 MPa for beam, column, slab and shear wall. The mean compressive strength of reinforcement is Fe500.

The size of structural elements is shown in Table 1 and the percentage of shear wall of plan area is shown in Table 2.

2.2. Loading Conditions

A dead load as floor finish of 1 KN/m^2 and live load of 2 KN/m^2 ^{is} applied at all floors. Importance factor is 1 and response reduction factor is 5. Seismic zone is V and Silt type is II for static analysis.

Table -1: Geometric parameters of structural elements

Column dimension (m)	0.9*0.9	**Slab thickness (m)**	0.2
Beam dimension (m)	0.6*0.3	**Shear wall thickness (m)**	0.3

Table -2: Density of Shear wall in structural systems

Structural Systems	Density of Shear wall
Bare Frame (BF)	0%
Shear wall 1 (SW1)	0.9%
Shear wall 2 (SW2)	2.3%
Shear wall 3 (SW3)	3.2%

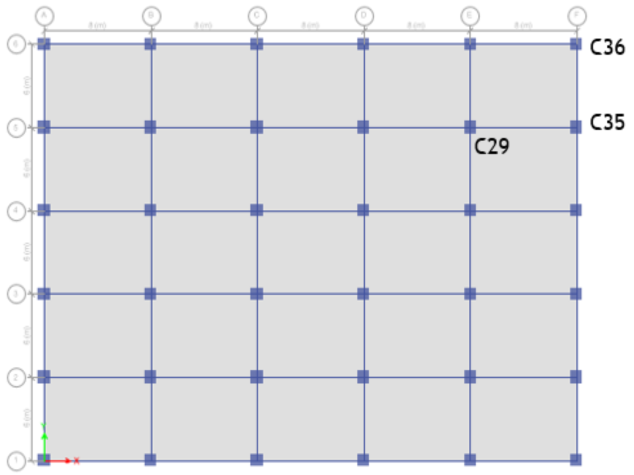

Fig -1: Plan of Bare frame structure

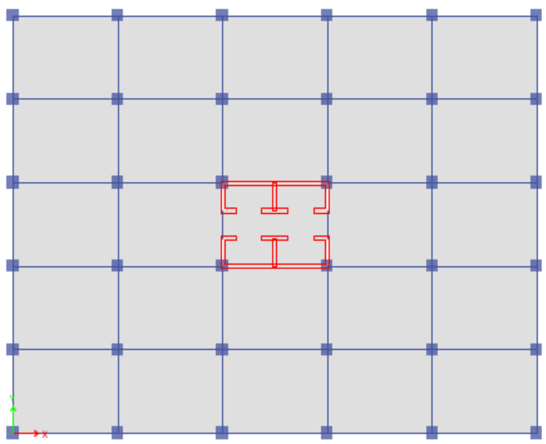

Fig -2: Plan of Shear wall-1 structure (SW-1)

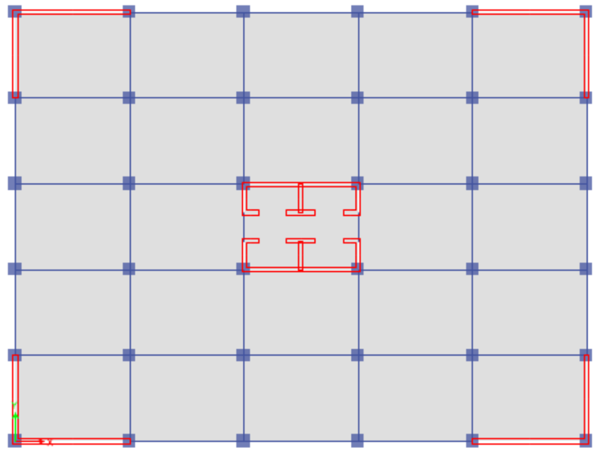

Fig -3: Plan of Shear wall-2 structure (SW-2)

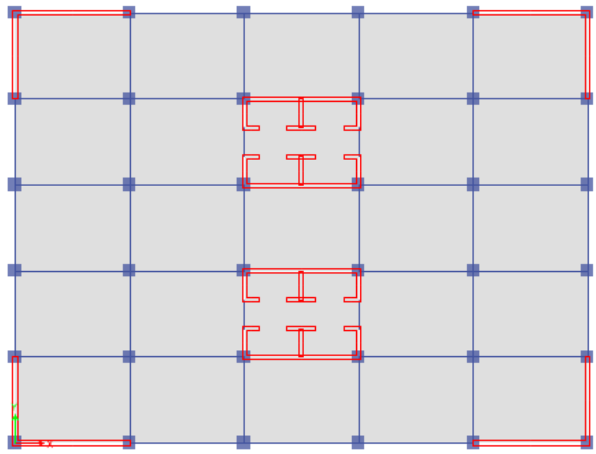

Fig -4: Plan of Shear wall-3 structure (SW-3)

3. ANALYSIS AND RESULTS

3.1. Analysis cases:

The following cases of analysis were considered to calculate P-Delta effect using ETABS.

I. Static Coefficient Method

II. Response Spectrum Analysis (IS 1893-2016)

III. Time History Analysis

- Bhuj, India (16 January, 2001)
- El-Centro (19 may, 1940)
- Uttarkashi (20 October, 1991)

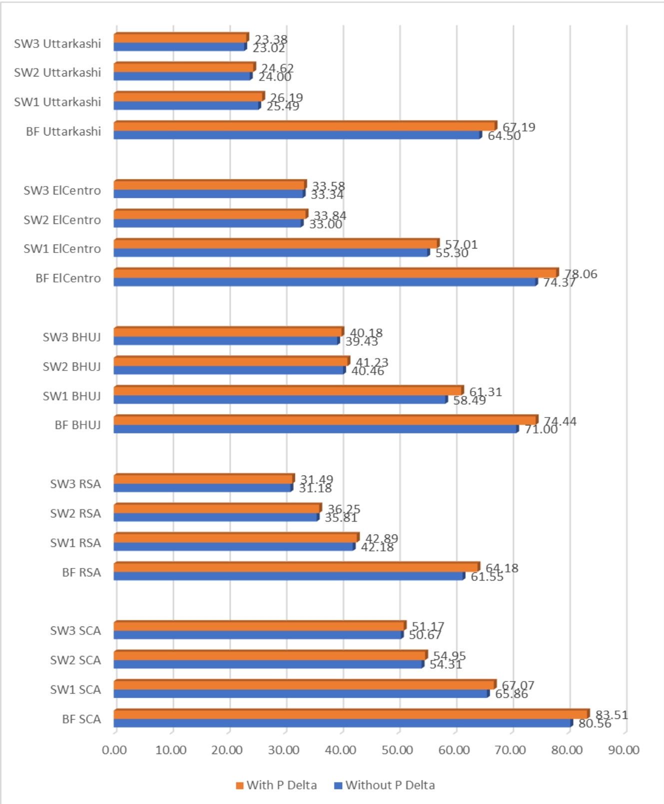

Chart -1: Top storey displacement of 30 storey (in mm)

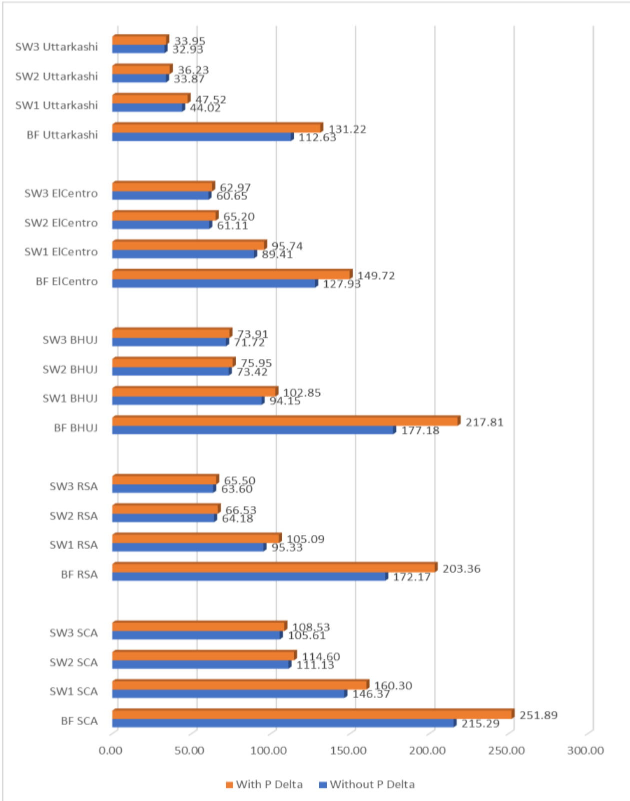

Chart -3: Top storey displacement of 50 storey (in mm)

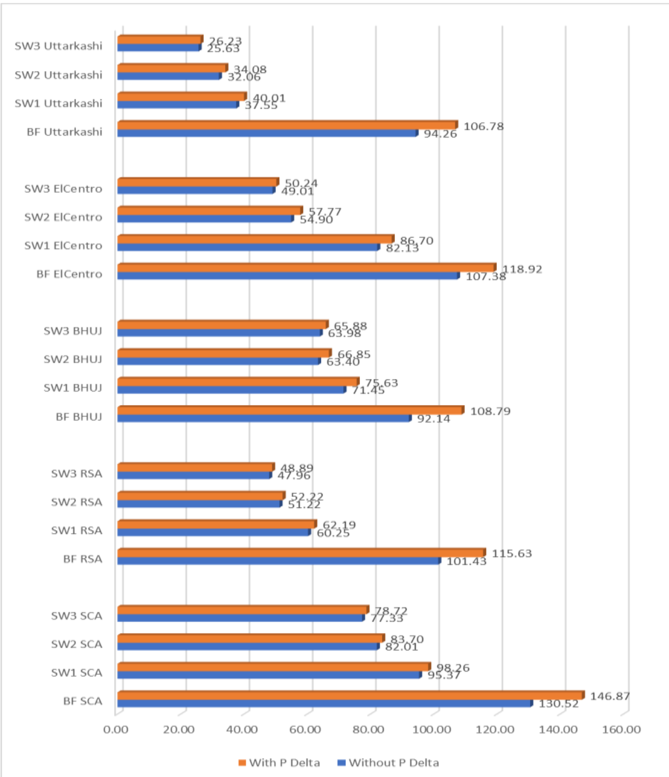

Chart -2: Top storey displacement of 40 storey (in mm)

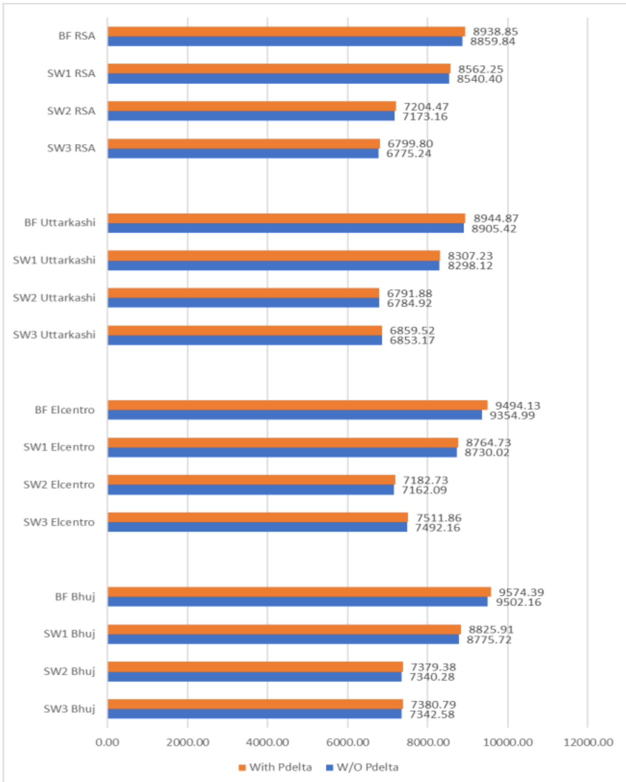

Chart -4: Axial force in C36 column of 30 storey structures (in KN)

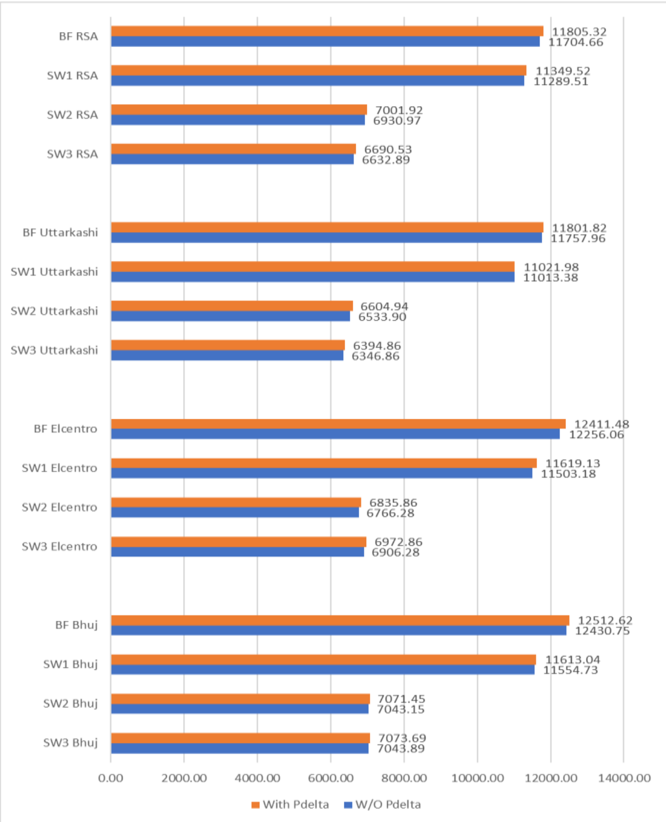

Chart -5: Axial force in C35 column of 30 storey structures (in KN)

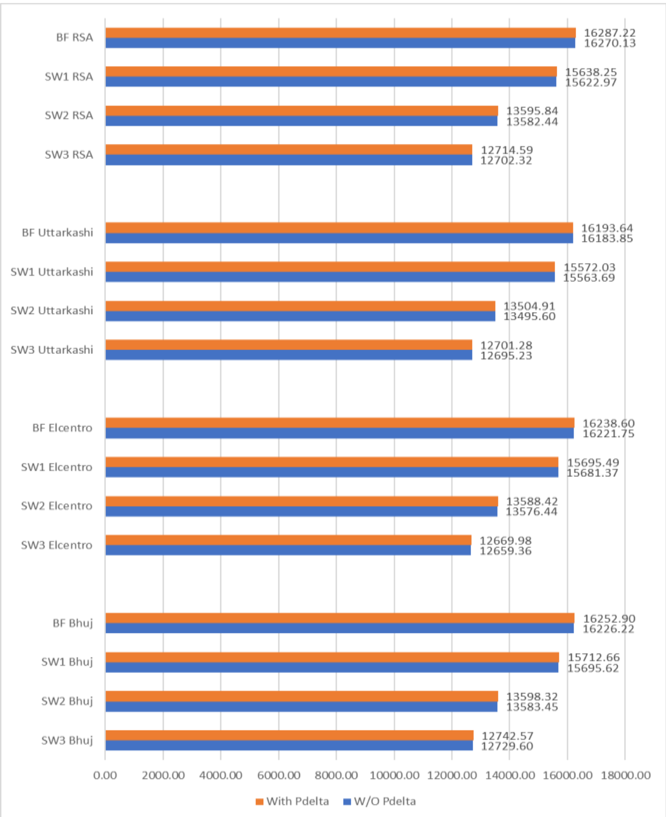

Chart -6: Axial force in C29 column of 30 storey structures (in KN)

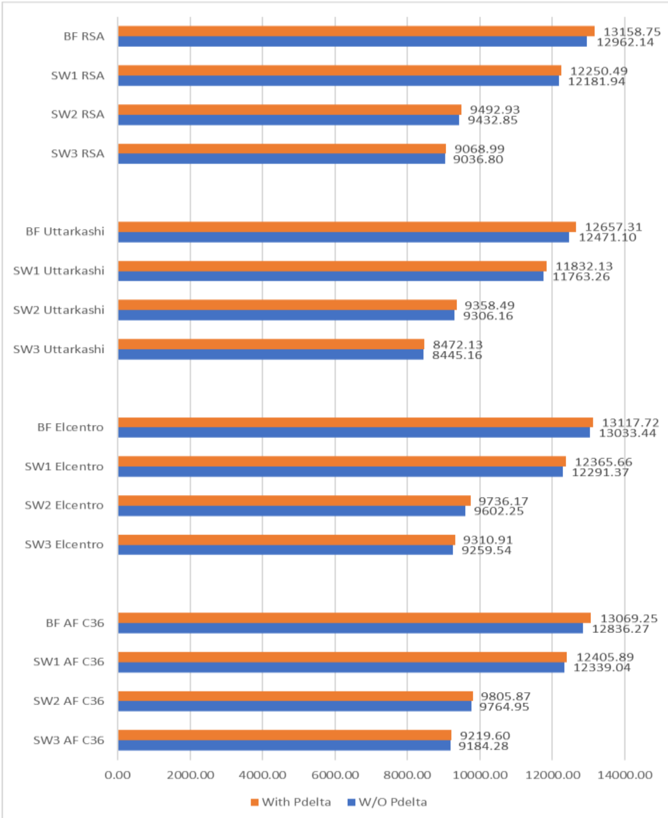

Chart -7: Axial force in C36 column of 40 storey structures (in KN)

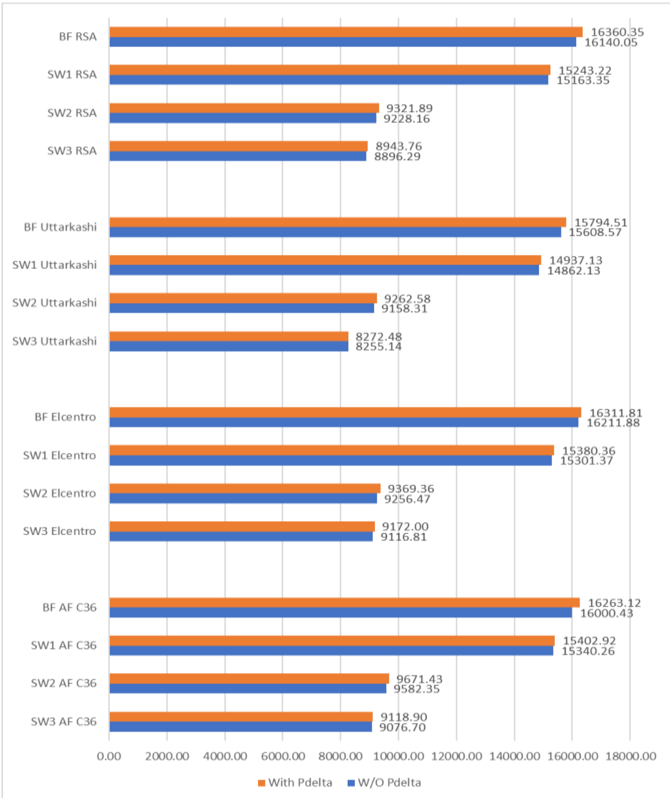

Chart -8: Axial force in C35 column of 40 storey structures (in KN)

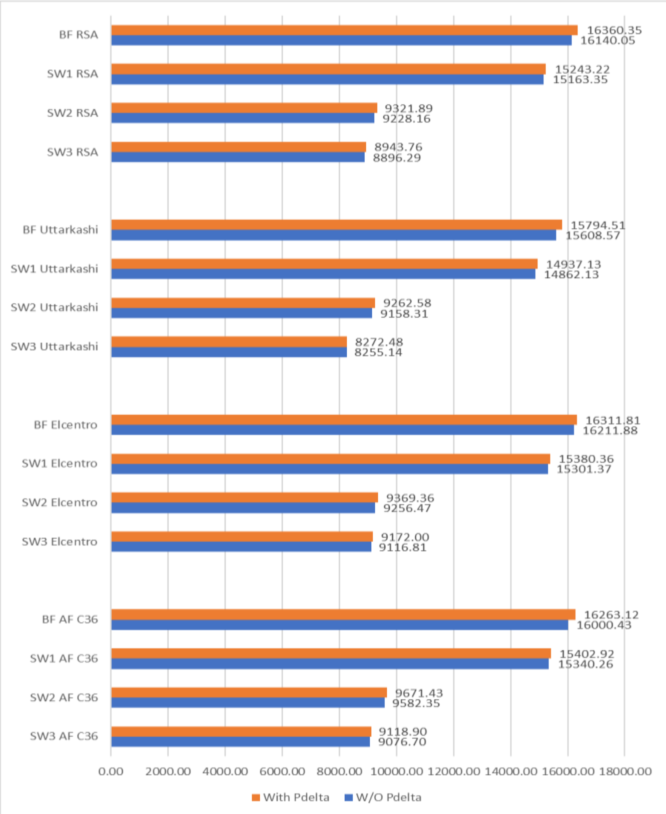

Chart -9: Axial force in C29 column of 40 storey structures (in KN)

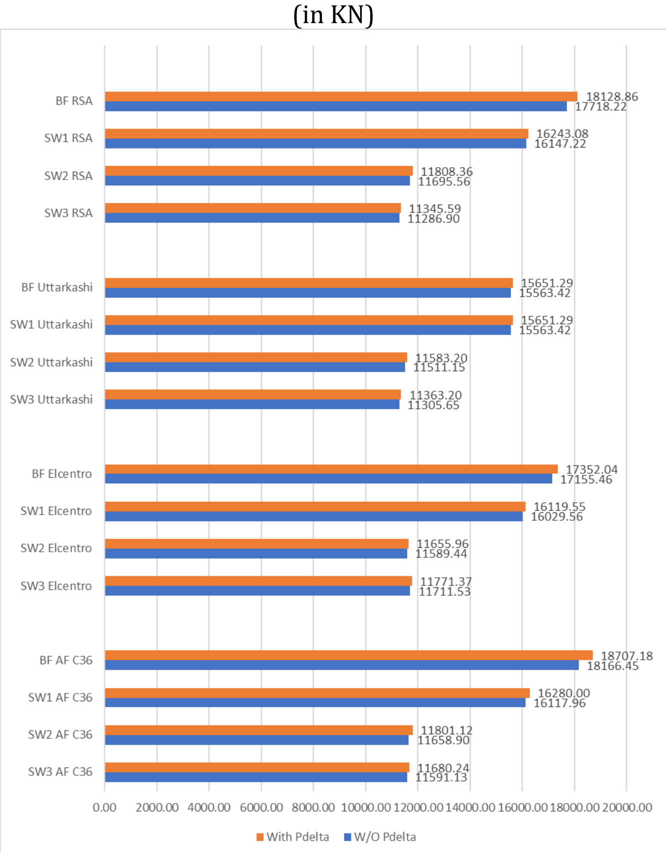

Chart -10 Axial force in C36 column of 50 storey structures (in KN)

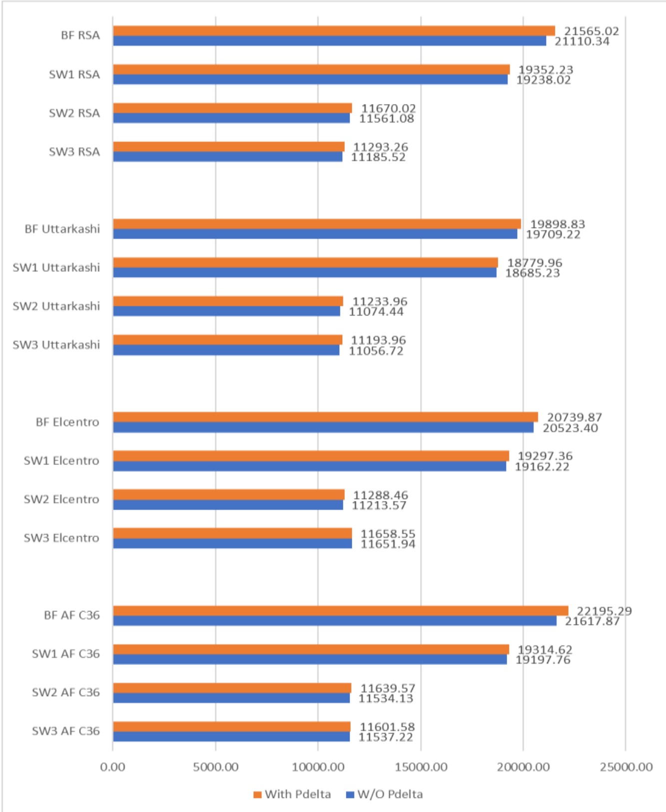

Chart -11: Axial force in C35 column of 50 storey structures (in KN)

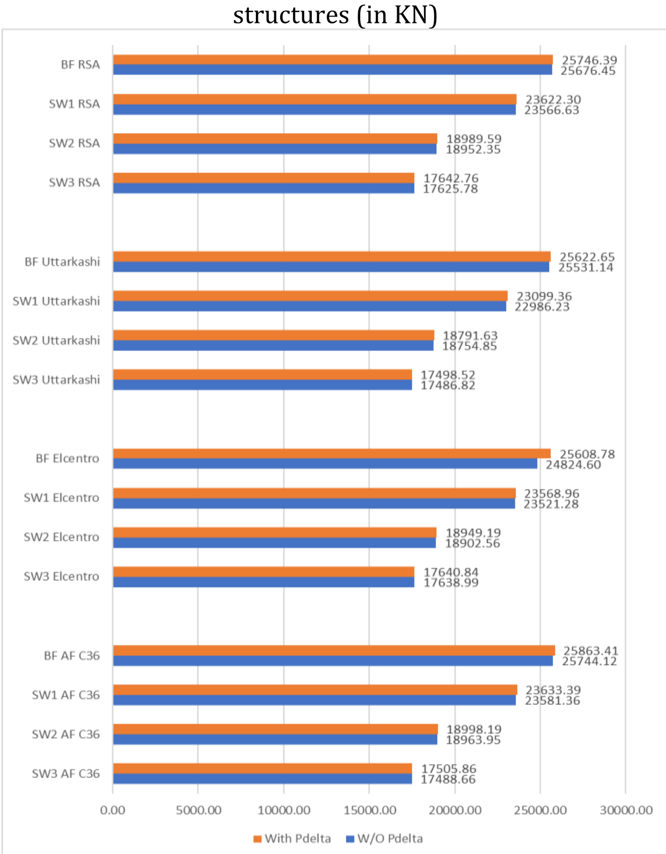

Chart -12: Axial force in C29 column of 50 storey structures (in KN)

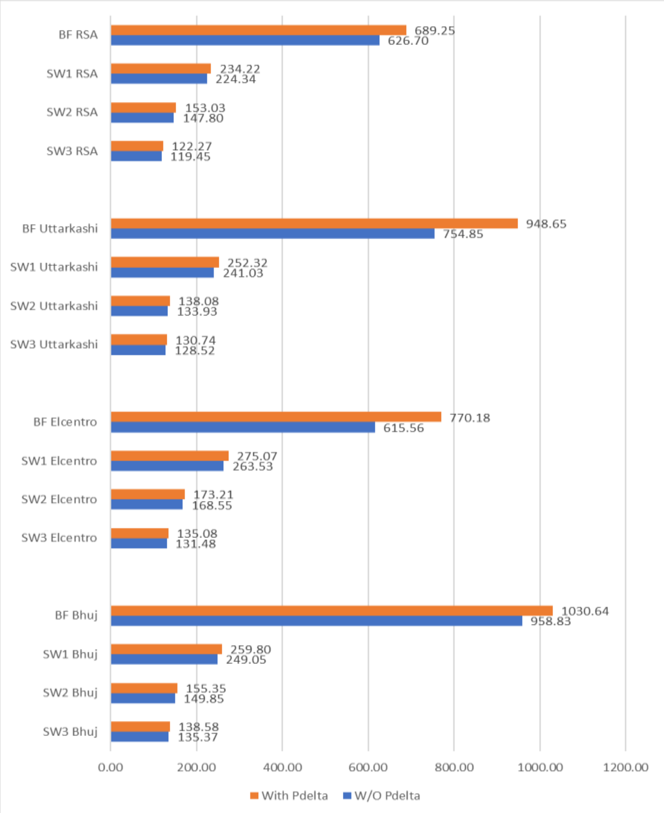

Chart -13: Bending Moment in C36 column of 30 storey structures (in KNm)

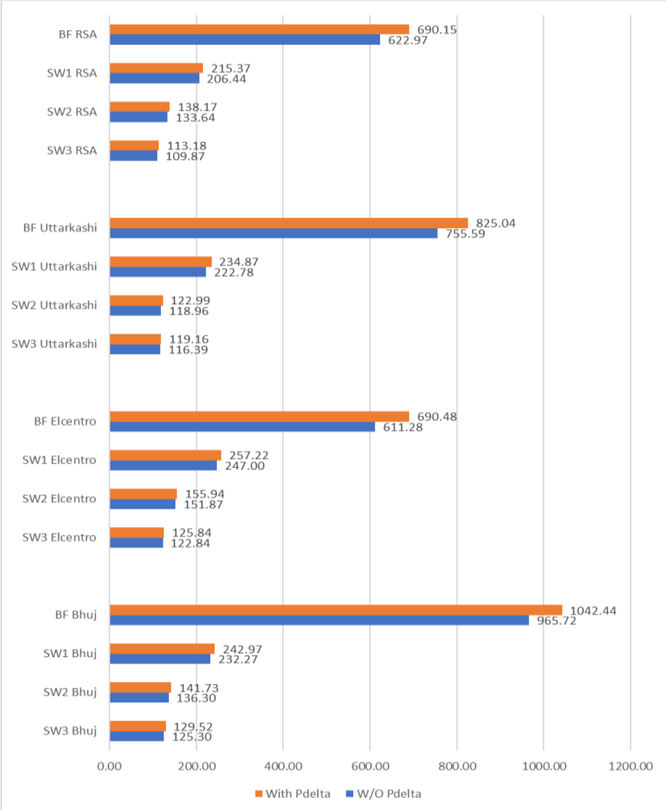

Chart -15: Bending Moment in C29 column of 30 storey structures (in KNm)

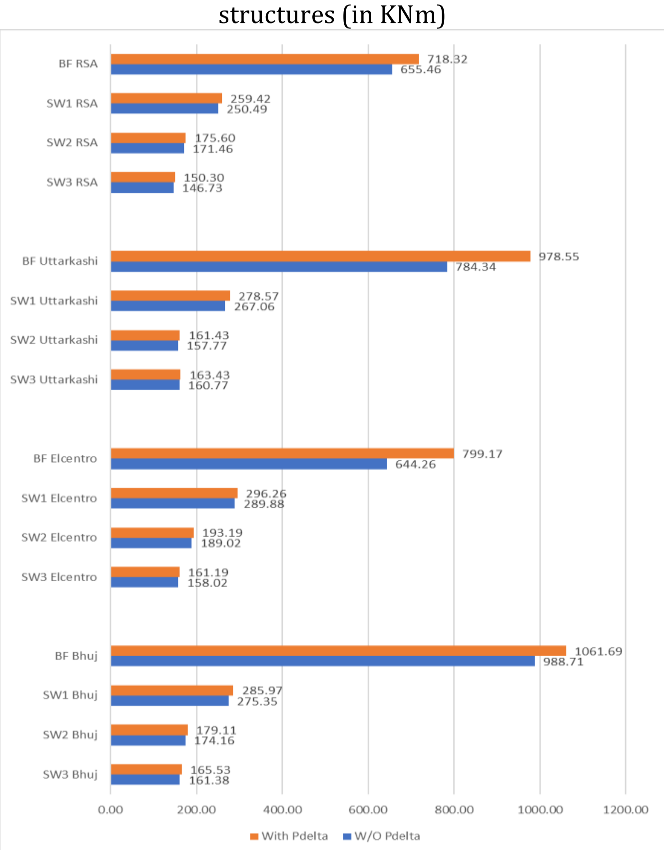

Chart -14: Bending Moment in C35 column of 30 storey structures (in KNm)

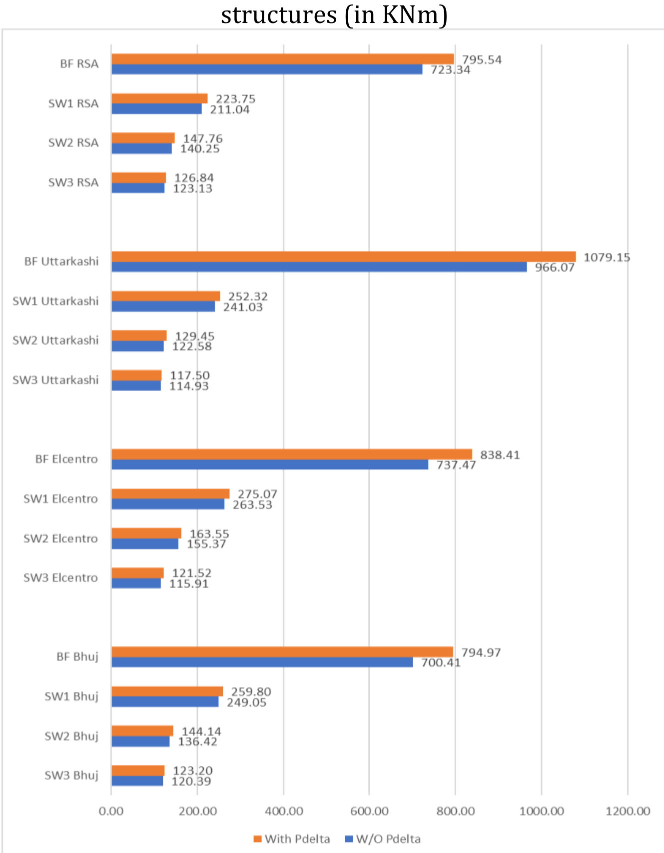

Chart -16: Bending Moment in C36 column of 40 storey structures (in KNm)

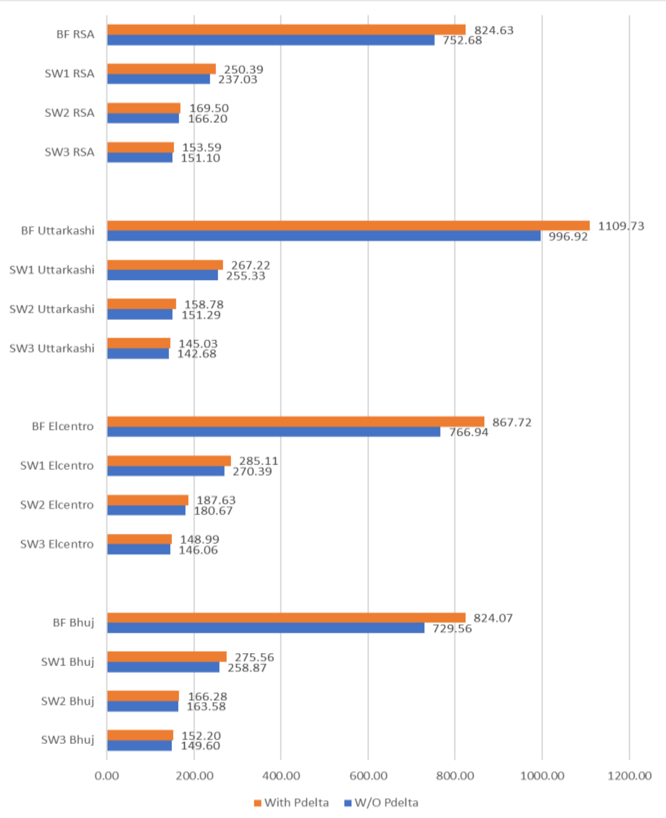

Chart -17: Bending Moment in C35 column of 40 storey structures (in KNm)

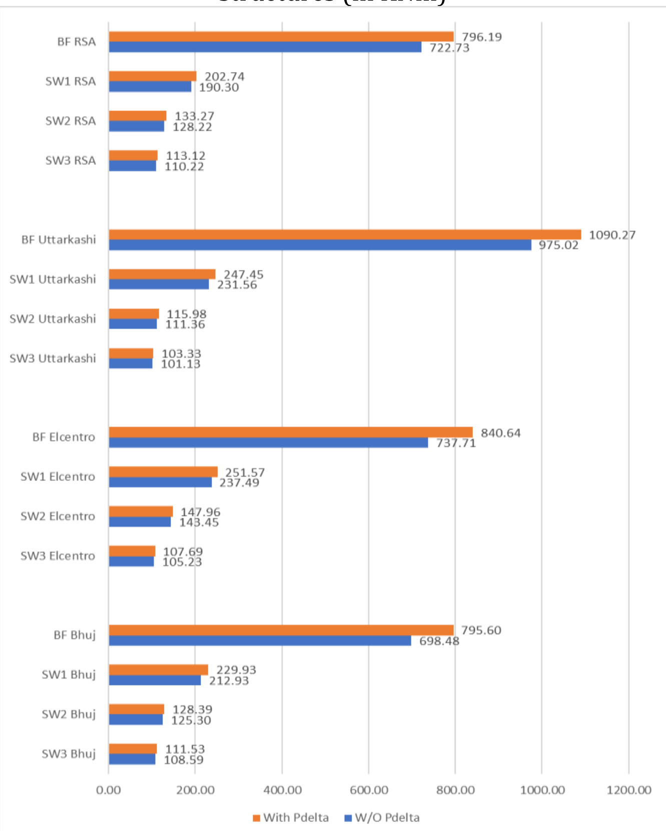

Chart -18: Bending Moment in C29 column of 40 storey structures (in KNm)

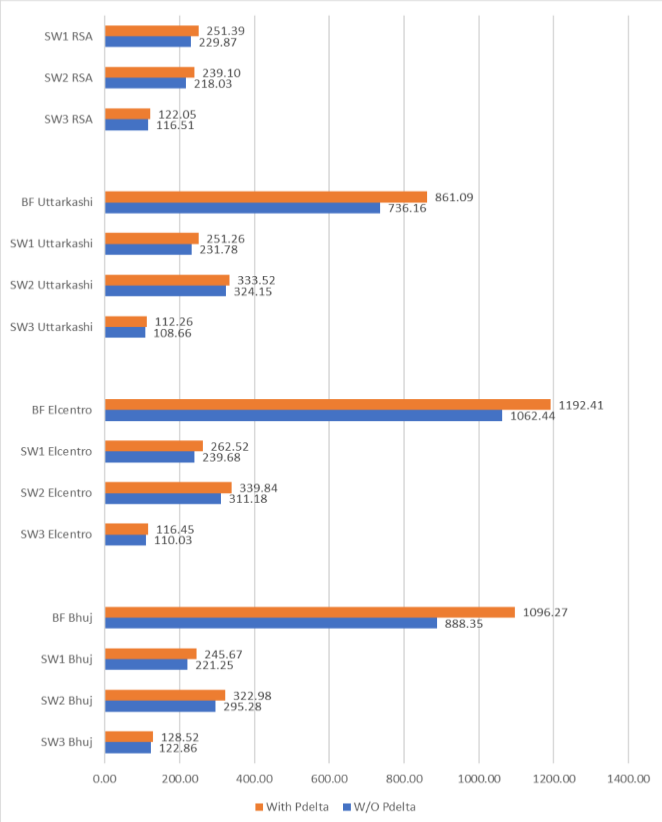

Chart -19: Bending Moment in C36 column of 50 storey structures (in KNm)

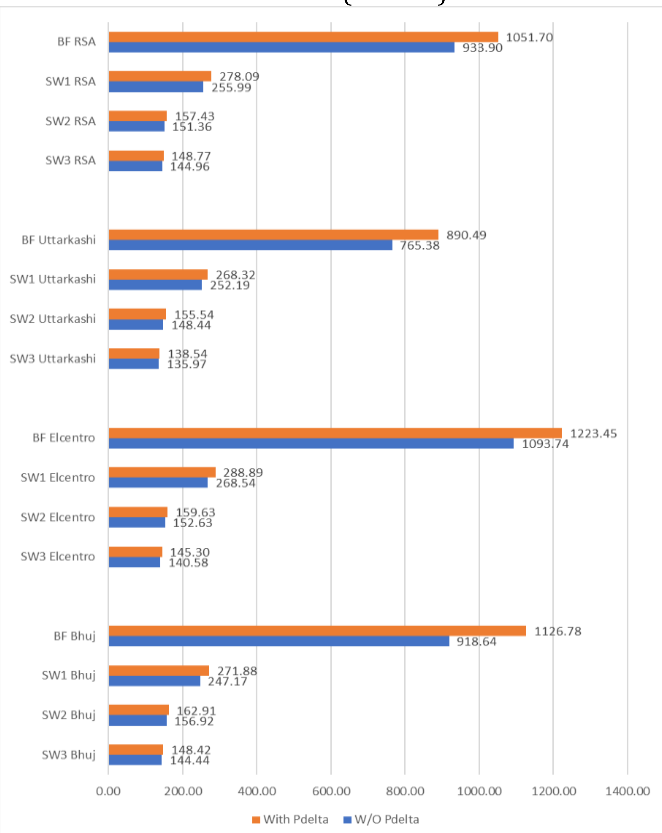

Chart -20: Bending Moment in C35 column of 50 storey structures (in KNm)

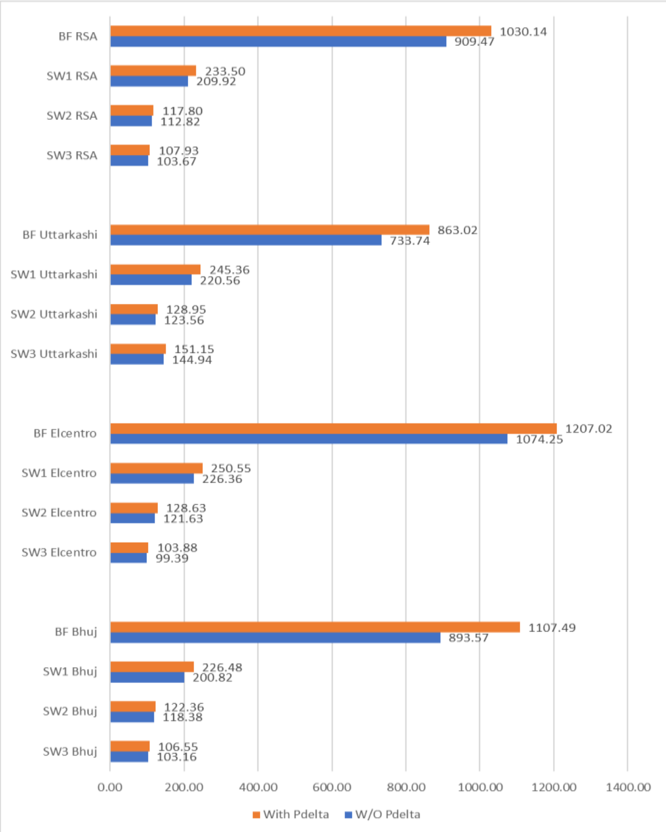

Chart -21: Bending Moment in C29 column of 50 storey structures (in KNm)

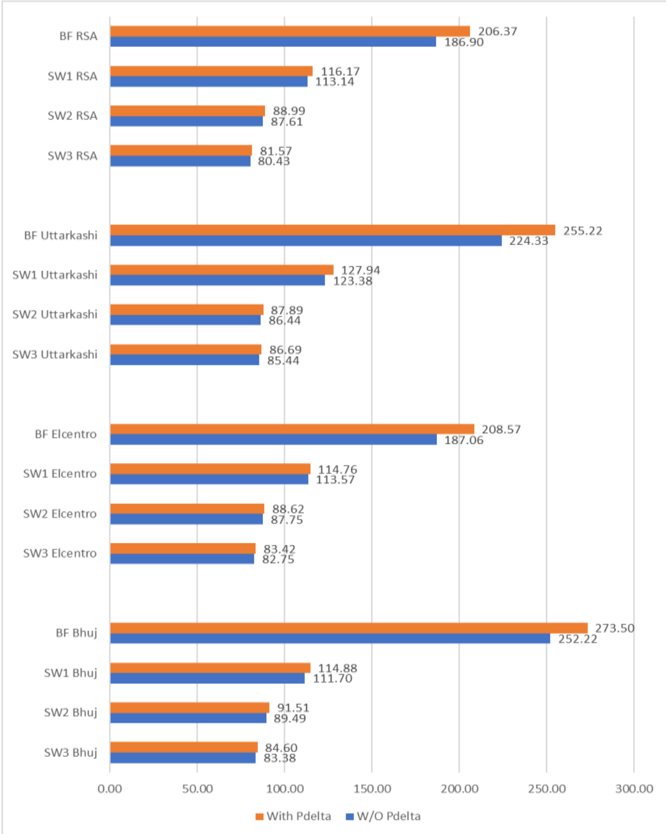

Chart -23: Shear force in C35 column of 30 storey structures (in KN)

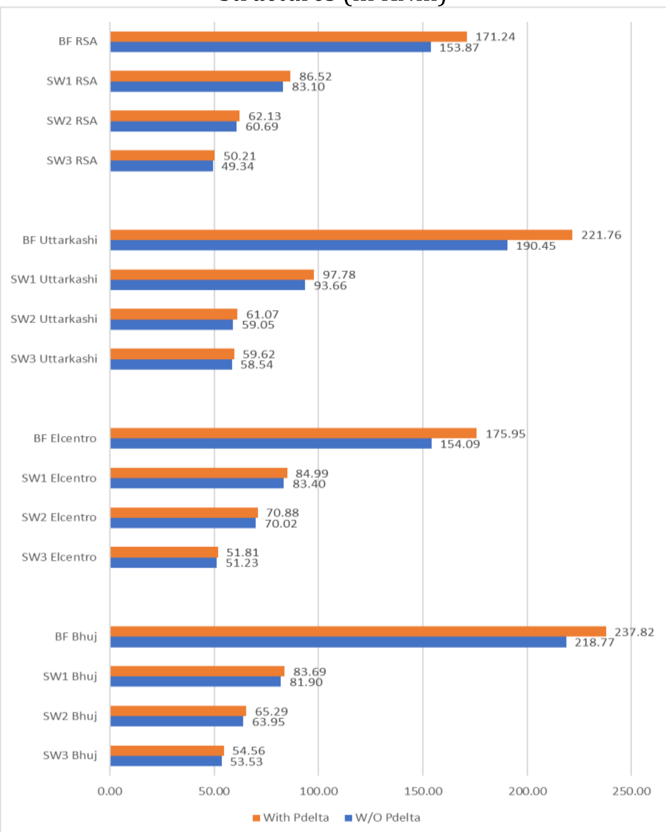

Chart -22: Shear force in C36column of 30 storey structures (in KN)

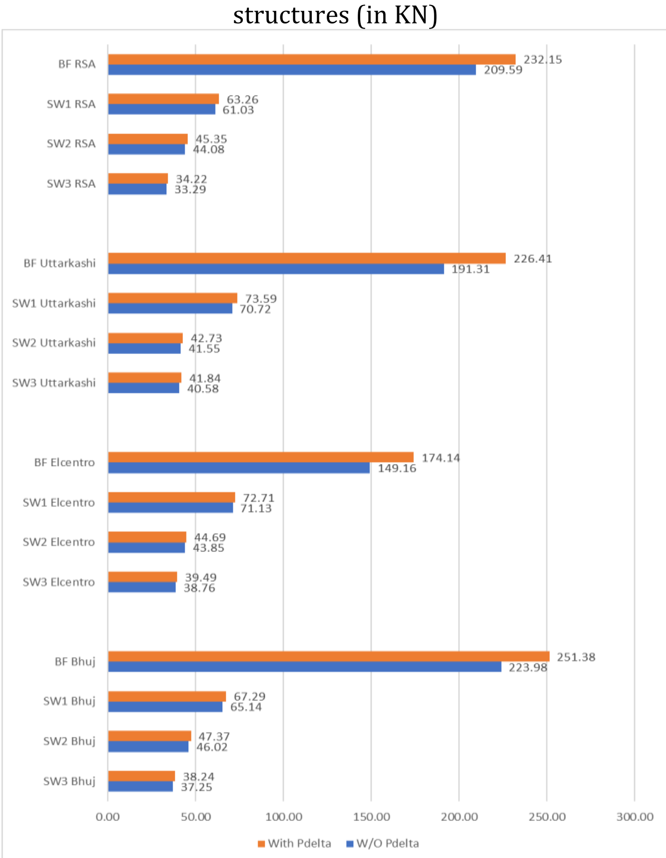

Chart -24: Shear force in C29 column of 30 storey structures (in KN)

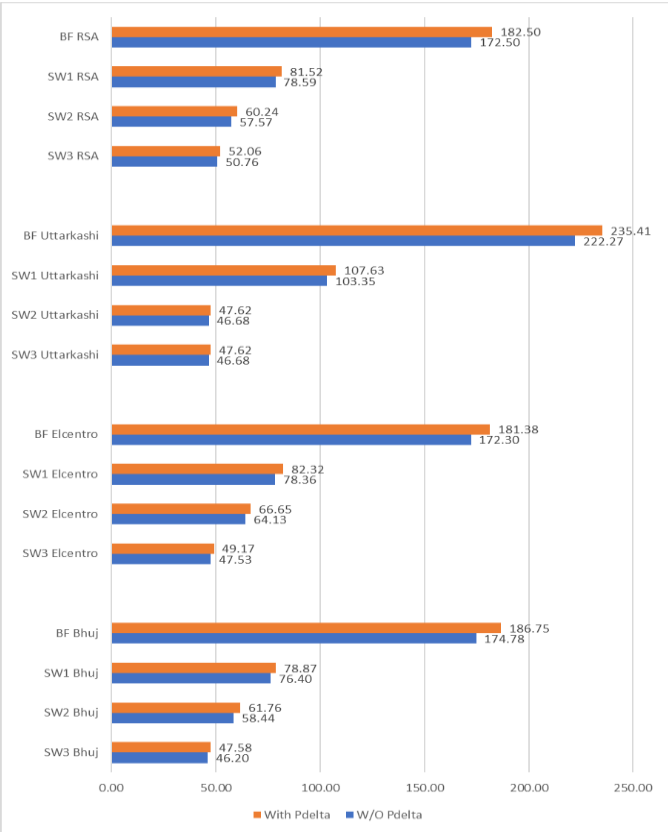

Chart -25: Shear force in C36 column of 40 storey structures (in KN)

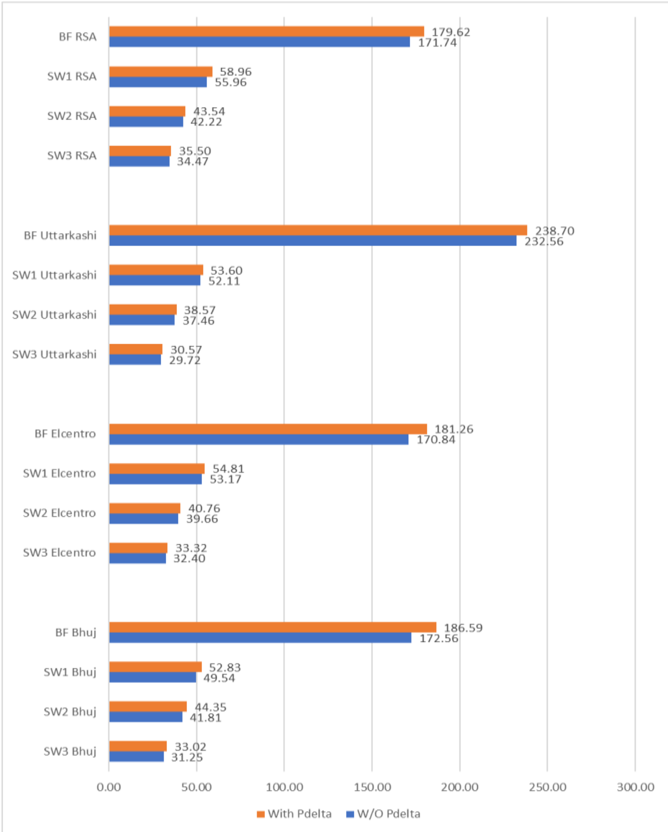

Chart -27: Shear force in C29 column of 40 storey structures (in KN)

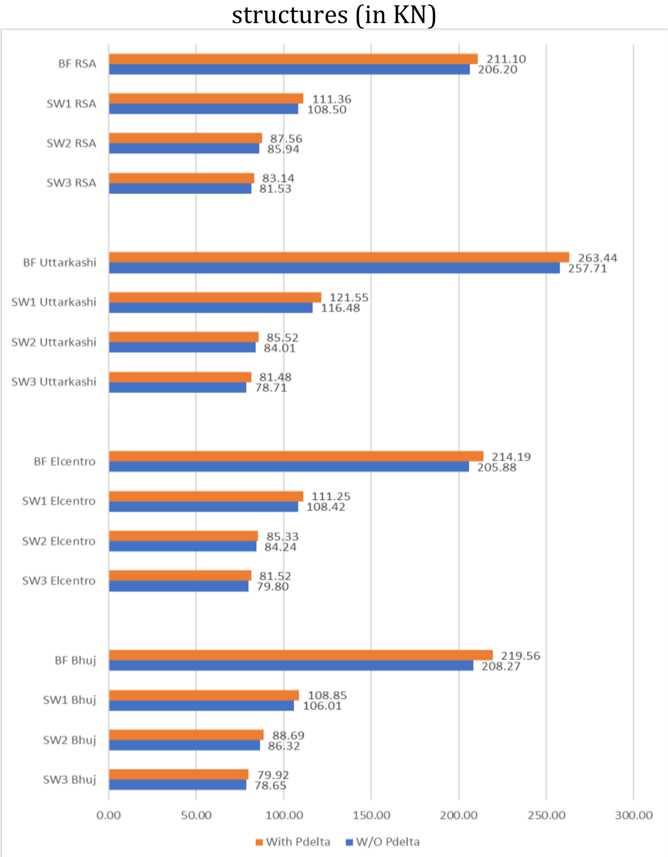

Chart -26: Shear force in C35 column of 40 storey structures (in KN)

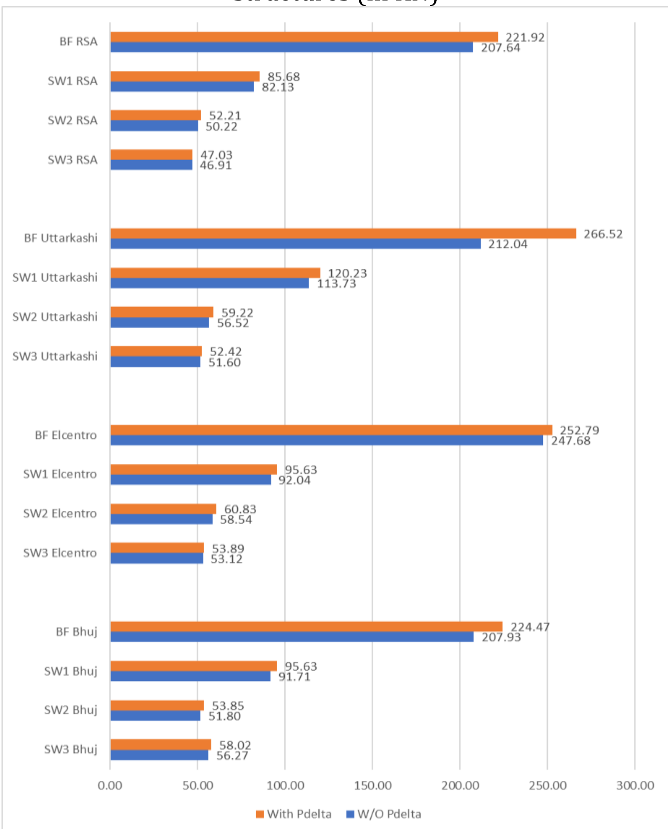

Chart -28: Shear force in C36 column of 50 storey structures (in KN)

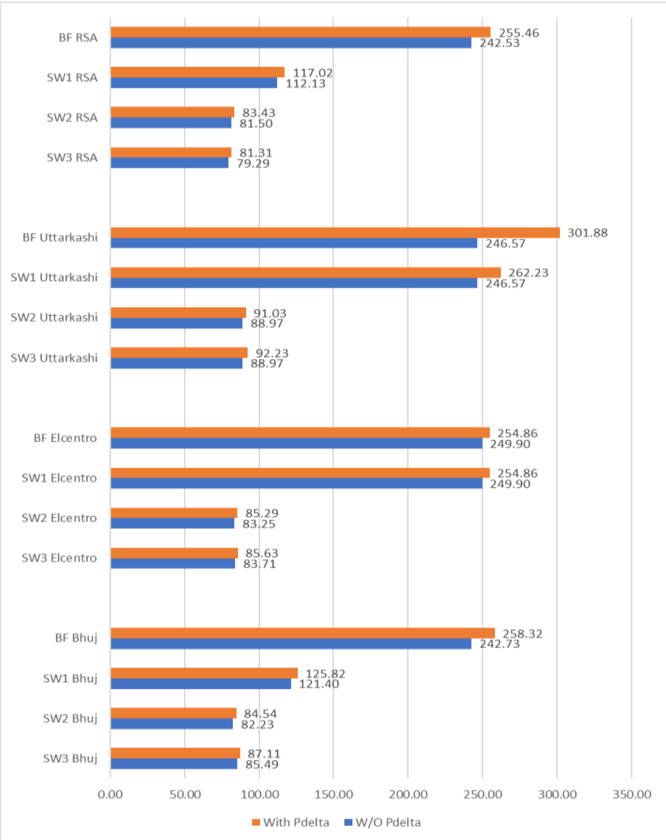

Chart -29: Shear force in C35 column of 50 storey structures (in KN)

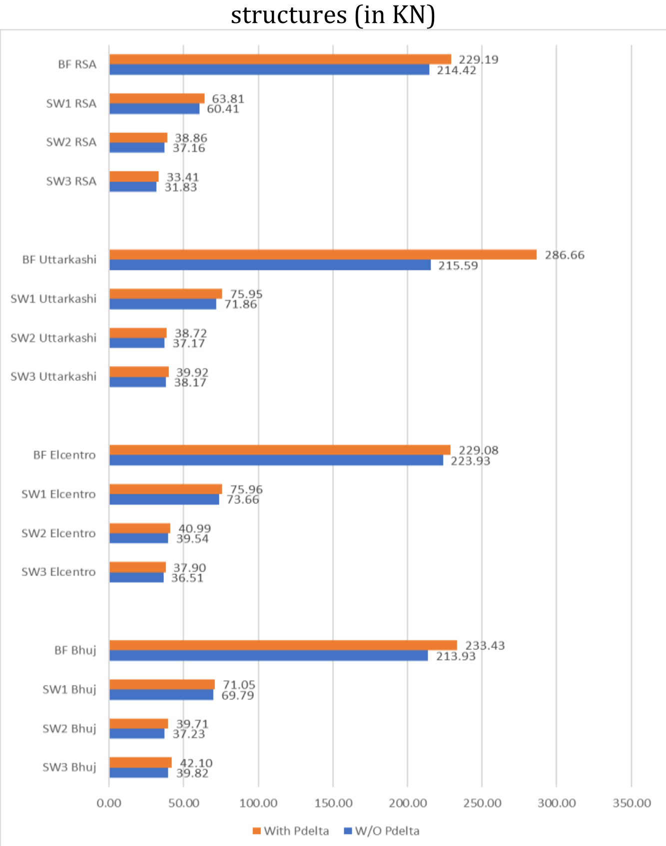

Chart -30: Shear force in C29 column of 50 storey structures (in KN)

4. CONCLUSIONS

The following conclusion can be drawn from the above results:

1. Top storey displacements of all the structures have shown increase in the P-Delta effect if height of building is increased.
2. For 30-storey building in El Centro time history analysis has shown maximum reduction in the effect of P-Delta effect from 4.96 % to 0.71 % (SW 3). Similarly, for 40-storey building in Uttarkashi time history analysis 13.27% to 2.31% (SW 3) and for 50-storey building in Bhuj time history analysis 22.93% to 3.05% (SW 3). In all time history analysis, in term of displacement 'SW 3' structural system has shown maximum reduction in P-Delta effect except one 30-storey Bhuj time history analysis.
3. In term of axial force in columns for 30-storey building maximum P-Delta effect is shown in the BF-C36 as 1.49% and minimum is SW3-C29 as 0.05%. For 40-storey building maximum is BF-C36 as 1.81% and minimum 0.01% in SW3-C29. Similarly, for 50-storey building maximum is BF-C36 as 2.96% and minimum is 0.07%. Hence, SW3 gives most favorable results to reduce the P-Delta effect.
4. In term of bending moments in columns for 30-storey building maximum P-delta effect is shown in the BF-C36 as 25.68% and minimum is 1.65%& in SW3-C35.for 40-storey building minimum is 1.64% in SW3-C35 and for 50-storey minimum is 1.89% in SW3-C29. Hence, SW3 gives most favorable results to reduce the P-Delta effect.
5. In term of Shear force in columns for 30-storey building maximum P-Delta effect is shown in BF-C29 as 18.35% and minimum in SW3-C35 is 0.81%. Similarly, for-40 storey building minimum P-delta effect is shown in SW2-C35 as 1.3% and for-50 storey building minimum is 1.46% in SW3-C36. Hence, SW3 gives most favorable results in 2 case out of 3 to reduce the effect of P-Delta.
6. By this study it can be summarized that increasing the density of shear wall in plan of building can reduce the P-Delta effect significantly so that SW3 has shown most favorable results to the objective of study.

REFERENCES

[1] R. Gaiotti and B. S. Smith, "P-Delta Analysis of Building Structure", Journal of Structural Engineering, ASCE, Vol. 115, No. 04, 1989

[2] J. Y. R. Yen, "Direct Analysis of Slender Columns with P-Delta Effect", Journal of Structural Engineering, ASCE, Vol. 119, No. 03, 1993

[3] E. B. Williamson, "Evaluation of Damage and P-Δ Effects for Systems Under Earthquake Excitation", Journal of Structural Engineering, ASCE, Vol. 129, No. 08, 2003

[4] S. Sardar and A. Hama, "Evaluation of P-Delta Effect in Structural Seismic Response", MATEC Web of Conferences, Vol. 162, 2018

[5] Y. Dinar, S. Karim, A. Barua and A. Uddin, "P-Delta Effect in Reinforced Concrete Structure of Rigid join", IOSR Journal of Mechanical and Civil Engineering, Vol. 10, Issue. 04, 2013

[6] E. N. Rakesh, I. A. Parvez, A. Kumar," Study on Dynamic P-Delta Effects of a Building with Soft Storey", International Journal of Engineering Research in Mechanical and Civil Engineering, Vol 2, 2017

[7] B. Shankar, K. Dheekshith, N. Kumar," Study on Effects of P-delta Analysis on RC Structures", International Research Journal of Engineering and Technology, Vol. 04, 2017