International Journal of Scientific Research & Engineering Trends
Volume 12, Issue 2, Mar-Apr-2026, ISSN (Online): 2395-566X

Analysis Of Irreguler Structure Using P- Δ Effect

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Abstract- — In metropolitan areas, high-rise structures are built with various irregularities in their design and loading conditions. These irregular structures can experience sudden and significant effects when subjected to different types of loads, which is why additional considerations are necessary to prevent undesirable outcomes. Past earthquakes have demonstrated the adverse consequences that can occur in such structures. To mitigate these adverse effects, nonlinear analysis techniques like the P-Δ effect have been investigated in this current study. The P-Δ effect refers to the additional actions exerted on a structure due to its deformation resulting from applied stresses. In the study, the axially loaded columns of G+18 story structures were analysed using ETABS software under nonlinear dynamic time history conditions, taking into account the influence of the P-Δ effect. The displacement and drift response analysis revealed that these values tend to be higher as the height of the structure height increases. This finding underscores the importance of considering the P-Δ effect in structural analysis. By comparing the results with and without the consideration of the P-Δ effect, it was observed that there was an approximately eight percent variation in the outcomes. This indicates that neglecting the P-Δ effect could lead to significant discrepancies in the analysis results, further highlighting its significance in accurately predicting structural behaviour.

Keywords: The axially loaded columns of G+18 story structures were analysed using ETABS software under nonlinear dynamic time history conditions, taking into account the influence of the P-Δ effect.

I. INTRODUCTION

The displacement of flexible structures due to lateral forces introduces horizontal displacements, which in turn generate additional overturning moments as the gravitational load undergoes displacement as well.

$$Mub = VuH + Pu\Delta$$

Hence, apart from the overturning moments caused by the lateral force Vu, there is an additional moment Pu-Δ that needs to be countered. This increase in moment Pu-Δ, in turn, generates more lateral displacement, leading to a further increment in Δ. In highly flexible structures, this escalating cycle of instability can ultimately lead to collapse.

Considering seismicity levels, the significance of Pu effects tends to be greater for structures situated in regions with low-to-moderate seismic activity compared to those in high seismicity regions, where design lateral forces are naturally higher. It is crucial to acknowledge this aspect when assessing seismic design forces. However, it should be noted that P-Δ phenomena usually do not dictate the design of frames, particularly in areas where robust seismic design forces must be considered.

Apart from the overturning moments generated by lateral force (Vu), it is crucial to consider the secondary moment P-Δ, which also needs to be resisted. This additional moment increment leads to an increase in lateral displacement (Δ). In highly flexible structures, this can potentially result in instability, leading to collapse.

When evaluating seismic design forces, it is important to acknowledge that the significance of P-Δ effects varies depending on the seismicity level. Generally, structures in regions with low-to-moderate seismicity are more affected by P-Δ phenomena compared to structures in high seismicity regions, where the design lateral forces are accordingly greater. Consequently, in most cases, especially in areas with substantial seismic design forces, the design of frames is not primarily governed by P-Δ effect.

Why P-Δ analysis is important?

P-Δ analysis becomes necessary when a structure is subjected to high vertical and lateral forces concurrently, resulting in both first and second-order lateral displacements. This analysis accounts for a nonlinear geometric effect caused by significant direct stress acting on transverse bending and shear behavior within the structure.

When vertical and lateral forces act simultaneously on a structure, the resulting deformations can introduce significant changes in its geometry. The P-Δ effect considers the nonlinear behavior arising from these deformations, taking into account the interaction between axial load and structural displacement.

The P-Δ effect primarily manifests as a geometric nonlinearity due to the large direct stresses induced by the applied loads. As these stresses increase, they influence the bending and shear behavior of the structure, leading to additional lateral displacements that can significantly impact its overall stability.

By including the P-Δ effect in the analysis, engineers can accurately capture the interaction between the structural deformations and the applied loads. This enables a more comprehensive understanding of the structural response, particularly when dealing with high vertical and lateral forces.

Considering the P-Δ effect becomes crucial for ensuring the safety and integrity of structures under such loading conditions. Neglecting this nonlinear geometric effect may lead to underestimation of displacements, overstressing of structural elements, and inaccurate predictions of the structural response.

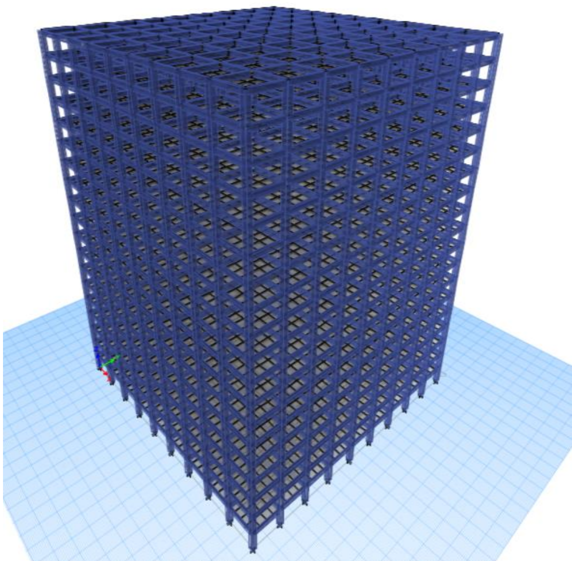
To account for the P-Δ effect, sophisticated analysis techniques and software, such as finite element analysis, are employed. These tools enable engineers to simulate the complex behavior of structures subjected to combined vertical and lateral forces accurately, providing valuable insights for design optimization and ensuring structural performance meets the required standards and safety criteria.

II.MODELING, ANALYSIS AND REASULTS OF VERTICAL IRREULARITY

This chapter deals with the details of the RCC structure of multi-story buildings using Time-History analysis and the P-Δ effect by using ETABS software. The type of building is a multi-story building.

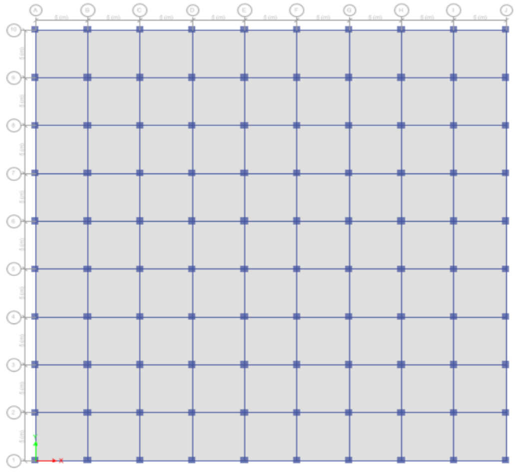
Properties of Main model

- Type of structure G+18 story: G+18 Story
- Seismic zone: V, as per IS 1893 Part I, Z=0.36
- Plan Dimensions: 45 m x 45 m
- Bay Spacing: 5 m
- Importance Factor: 1
- Damping Ratio: 0.05
- Imposed load for commercial floor: 4 kN/m2
- Story Height: 3.0 m
- Floor load: 3.75 kN/m2.
- Floor finish: 1.5 kN/m2.
- Specific Weight of RCC: 25 kN/m3
- Specific Weight of Brick infill: 21 kN/m3
- Basic Wind Speed: 39 m/s
- Brick wall on external beams: 230 mm thick
- Brick wall on internal beams: 150 mm thick
- Column size: 500 x 500 mm
- Column size: 700 x 700 mm
- Beam size: 300 x 600 mm
- P-Δ scale factor for dead load: 1.2
- P-Δ scale factor for live load: 0.6



Main Model

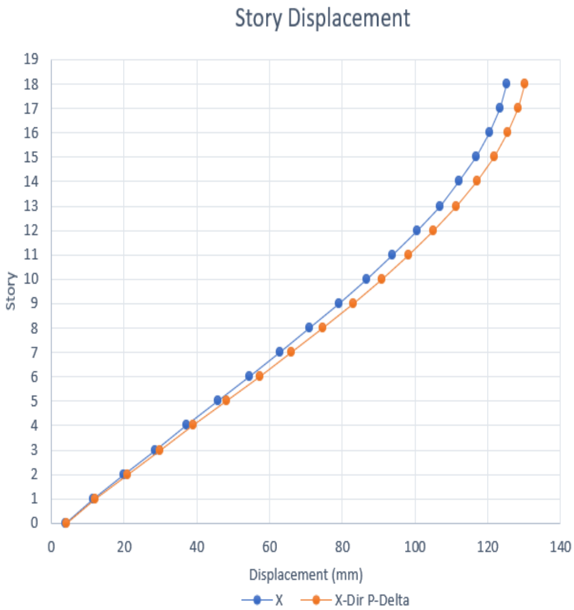
International Journal of Scientific Research & Engineering Trends
Volume 12, Issue 2, Mar-Apr-2026, ISSN (Online): 2395-566X



Plan view

Results

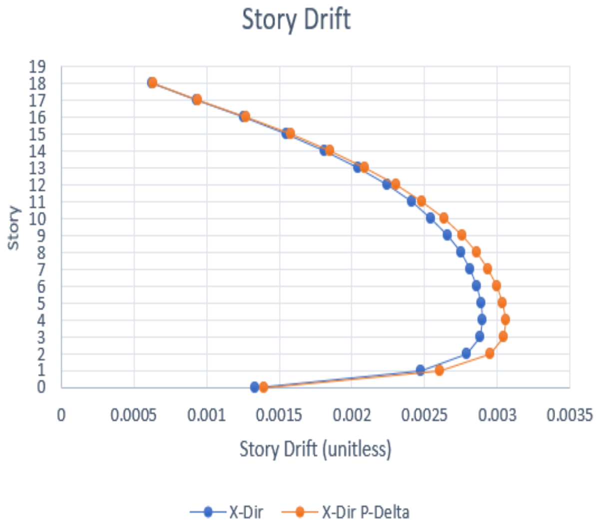
Maximum Story Displacement



Maximum Story Displacement of Regular structure

It can be seen in figure story displacement. Moreover, the compression of P-Δ & without P-Δ results mentioned. also, with P-Δ result slightly more than without P-Δ model as the number of story increase.

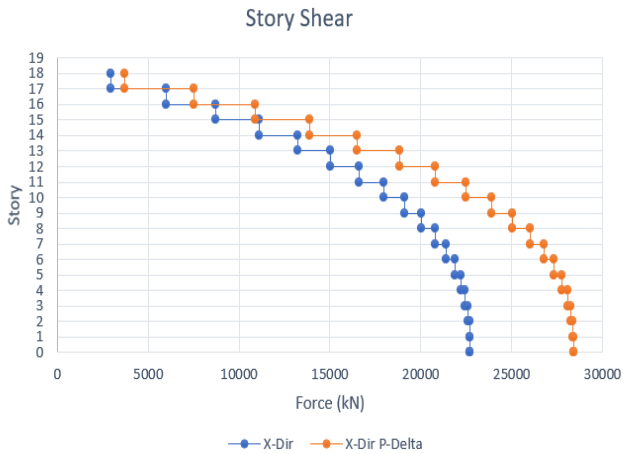
Maximum Story Drifts



Maximum Story Drifts of Regular structure

The variation of story drift can be observed in Figure , with the maximum value occurring at the lower story. Additionally, the inclusion of the P-Δ effect leads to slightly higher results compared to the model without P-Δ, particularly as the number of stories increases.

Story Shear



Story Shear of Regular structure

illustrates that the story shear decreases as we move from the bottom story to the top story. Moreover, the presence of the P-Δ effect contributes to a higher value of story shear compared to the result without considering the P-Δ effect.

Properties of model V1 & V1 P-Δ

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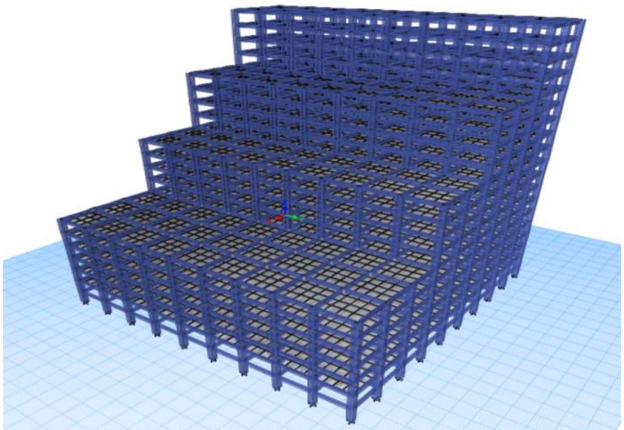
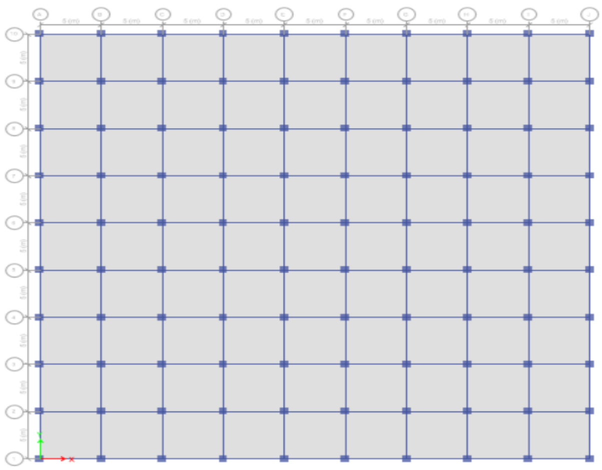
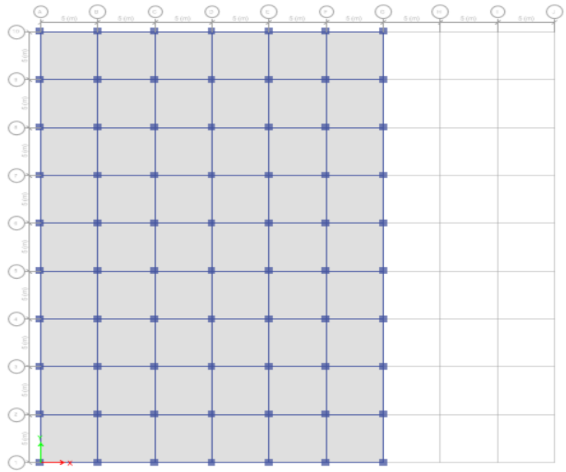
- Type of structure G+18 stories: G+18 stories (RC moment resisting frame)
- Seismic zone: V, as per IS 1893 Part I, Z=0.36
- Importance Factor: 1
- Damping Ratio: 0.05
- Imposed load for commercial floor: 4 kN/m2
- Story Height: 3.0 m
- Floor load: 3.75 kN/m2.
- Floor finish: 1.5 kN/m2.
- Specific Weight of RCC: 25 kN/m3
- Specific Weight of Brick infill: 21 kN/m3
- Basic Wind Speed: 39 m/s
- Infill Wall: 115 mm
- Outer wall: 230 mm
- Column size: 500 X 500 mm
- Column size: 700 X 700 mm
- Beam size: 230X600 mm
- P-Δ scale factor for dead load: 1.2
- P-Δ scale factor for live load: 0.6



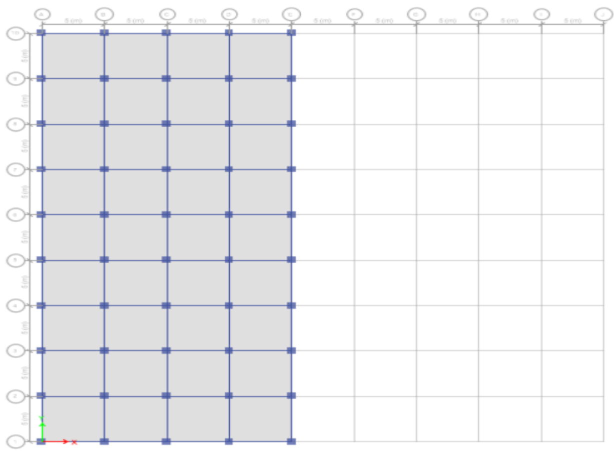
3D View of Model V1



Plan View up to 6th floor



Plan View of 7th to 10th floor



Plan View of 11th to 14th floor

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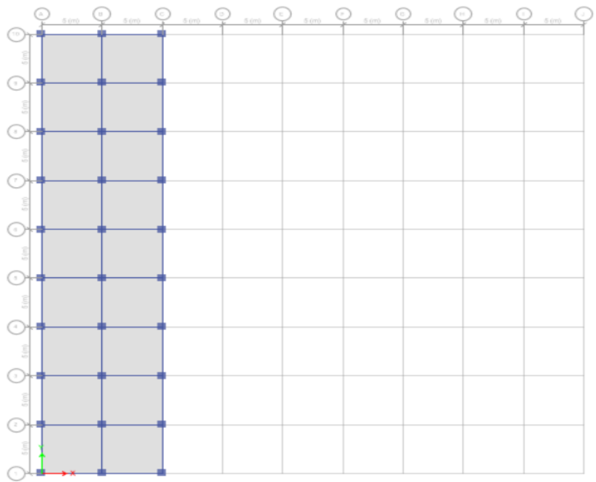
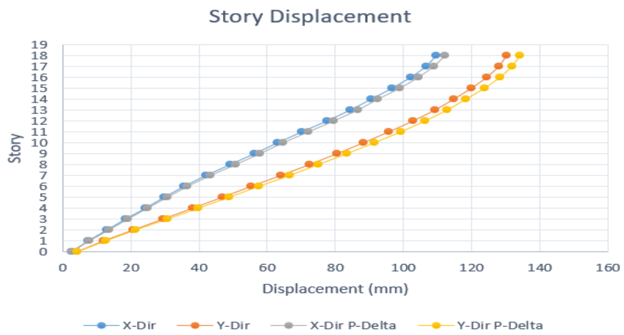


Plan View of 15th to 18th floor

Results

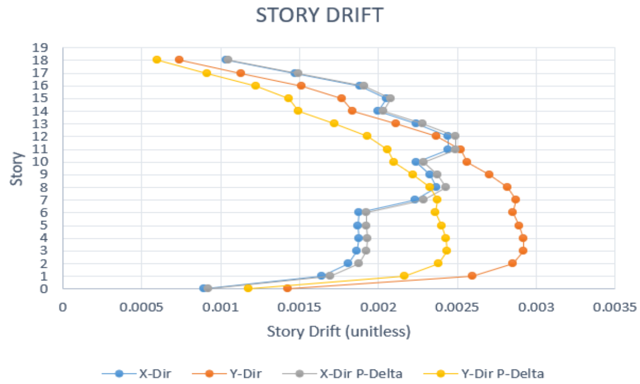
Maximum Story Displacement



Maximum Story Displacement of model V1 with P-Δ & without P-Δ

displays the maximum story displacement for models V1 and V1 P-Δ, both in the X-direction and the Y-direction. As the story height increases, the displacement value also increases. Additionally, incorporating the P-Δ effect yields slightly higher results compared to the model without considering P-Δ, particularly as the number of stories increases.

Maximum Story Drifts



Maximum Story Drifts V1 with P-Δ & without P-Δ

demonstrates the presence of varying story drifts, as shown in the graph. The X-direction and Y-direction maximum story drift values are observed at the lower story for both models V1 and V1 P-Δ. However, due to structural irregularities, the Y-direction exhibits a higher drift value. Moreover, incorporating the P-Δ effect yields slightly higher results compared to the model without P-Δ, especially as the number of stories increases.

Story Shear

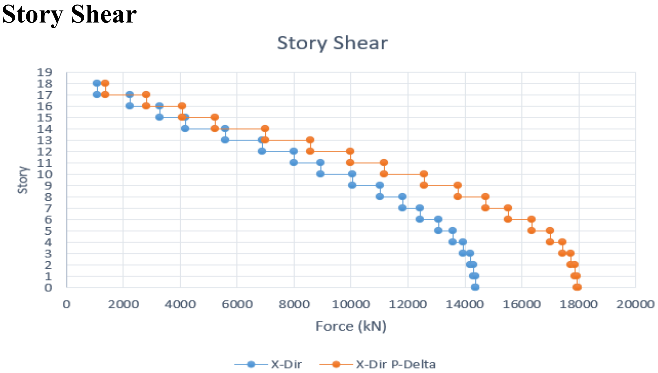


Figure II.13 Story Shear V1 with P-Δ & without P-Δ

illustrates that the story shear decreases as we move from the bottom story to the top story. Moreover, the presence of the P-Δ effect contributes to a higher value of story shear compared to the result without considering the P-Δ effect.

III.CONCLUSION

The nonlinear dynamic time history was carried out for high rise structures having vertical and mass irregularities to study the behavior of structures. Also, the impact of P-Δ effect has been studied out. The responses like story shear, displacement and story drift are found out under El-Centro earthquake. The drift demand in upper stories is much more sensitive as irregularities has been increased by increasing height. It has indicated that the displacements in structures are large while considering vertical irregularities rather to normal one. Similarly, the same response outcome we got in mass irregularities with P-Δ effect.

Based on the above analysis results, the conclusions are as following:

1. The drift in the stories is large for the building with P-Δ effect and irregularities.
2. As the number of floors in a structure increases, the significance of the P-Δ effect becomes more noticeable.
3. As the floor level increases, displacement increases, with maximum displacement is observed in P-Δ case.
4. In most cases, P-Δ effects are insignificant in structures with up to seven stories with solely gravity loads as the controlling load factors. The impact of irregularities in the lower stories has a more pronounced influence on the drift demands in the upper stories compared to the effect of irregularities in the upper stories on the responses of lower stories.

IV.ANNEXURE – A VALIDATION OF WORK

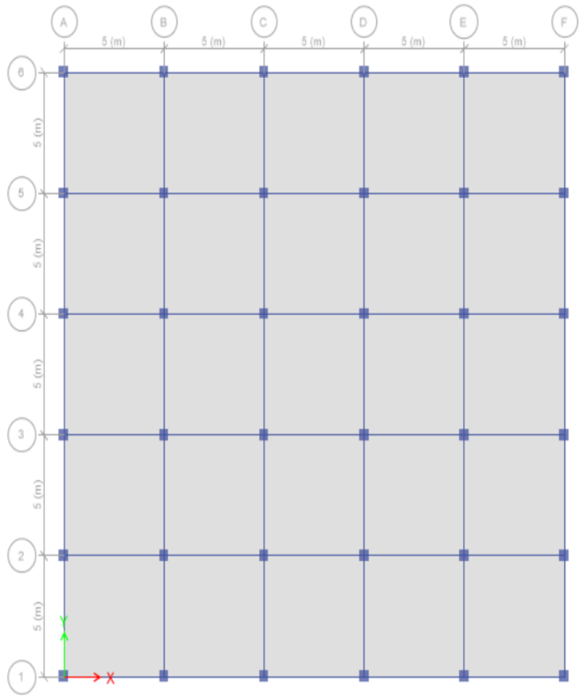
General

1. To validate the credibility of my work, I have chosen a research paper from the International Research Journal of Engineering and Technology (IRJET) as a reference.

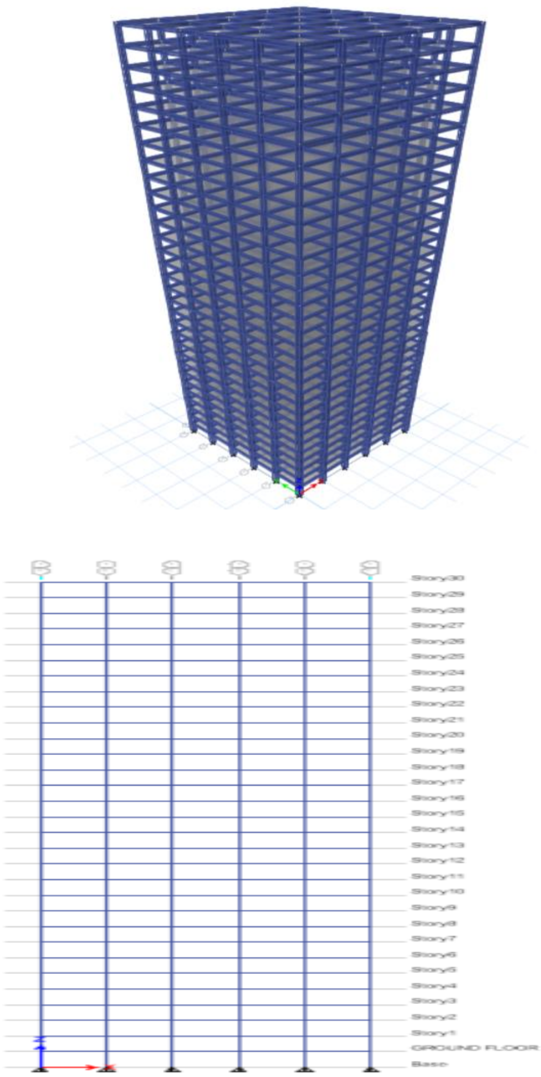
2. A numerical Study of RC frame irregular building is analyzed with the same parameter given in the paper entitled "Seismic Behaviour of Vertically Irregular Reinforced Concrete Buildings with P-Δ Effect".

Parameter of Buildings

- Type of structure: G+30 storied (RC moment resisting frame)
- Plan Dimensions: 25 m x 25 m
- Bay Spacing: 5 m
- Grade of concrete: M25
- Elasticity Modulus, Ec: 25000 Mpa
- Density of concrete: 25 KN/m3
- Grade of steel: Fe415
- Modulus of elasticity, Es: 210000 Mpa
- Density of brick wall including plaster: 20 KN/m3
- Beam size: 300mm x 475mm
- Column dimensions: 600 mm x 800 mm ((Story 1 to Story 10)
- Column dimensions: 450 mm x 650 mm (Story 11 to Story 20)
- Column dimensions: 450 mm x 450 mm (Story 21 to Story 30)
- Brick wall on external beams: 230 mm thick
- Brick wall on internal beams: 150 mm thick
- Parapet wall on roof: 150 mm thick
- Story height: 3m
- Zone: V
- Importance Factor: 1
- Building system with response reduction factor (R) :5
- Damping Ratio: 0.05
- Live load on roof and floor: 3 kN/m3
- Roof/floor finish: 1.5 kN/m3
- Load from brick wall on external beams: 13.8 kN/m3
- Load from brick wall on internal beams: 9 kN/m3
- Load from parapet wall on roof: 3 kN/m3



Plan view



3D Elevation & Elevation view

Results

Represents without P- Δ effect

Parameter	Data from paper	Data from ETABS model
Max. Displacement (mm)	206.98	217.321
Max. Story Drift	0.002857	0.003011
Stiffness (kN/M)	1779022	1839218

Represents with P-Δ effect

Parameter	Data from paper	Data from ETABS model
Max. Displacement (mm)	232.11	239.87
Max. Story Drift	0.00325	0.00339
Stiffness (kN/M)	1597300	1680256

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