Dynamic Behavior of Reinforced Concrete Framed Buildings under Non Linear Analysis

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***Abstract* - The demand of high rise building is increasing day by day to accommodate more people in less space. In the design and analysis of Reinforced Concrete framed structure linear static analysis is performed. High rise structure may collapse under severe displacement, axial force and moments if "P-Delta" analysis is not considered in analysis and design phase.. Due to defective construction practices and ignorance for earthquake resistant design of buildings in our country, most of the existing buildings are exposed to future earthquakes. The present study deals with the analysis of RC framed Symmetric and Asymmetric buildings in Zone-III and IV using inelastic method (P-Delta Analysis).The objective of present study is to find out the effect on Response quantities (Story Drift, Story Displacement and Nodal Displacement) due to "P-Delta" analysis on the RC framed structure and also find out the effect of asymmetry on this analysis. "P-Delta" Analysis is Non-Linear Static Analysis, so the structural response are include the additional response produced due to simultaneously action of lateral and gravity load on undeformed as well as deformed geometry. After doing the whole analysis it is found that the Response quantities are higher if "P-Delta" analysis is performed and in case of Asymmetric structure the Response quantities is higher in compare to the Symmetric structure.**

***Key Words* - "P-Delta analysis", Symmetric and Asymmetric structures, Dynamic analysis (Response spectrum method), Static analysis**

I. INTRODUCTION

"P-Delta" is a non-linear effect that occurs in every structure where elements are subject to axial load. "P-Delta" is actually second-order effects. It is a genuine "effect" that is associated with the magnitude of the applied axial load (P) and a displacement (delta).[4]

"In structures responding elastically, the P–Δ(P=Axial load, Δ=Displacement due to horizontal load) effect produces a reduction of the initial elastic stiffness, and corresponding elongation of the periods of vibration. In those responding in-elastically, there are also reductions of their strength. These reductions in strength and stiffness are measured with respect to their values when the P–Δ effects are ignored."

In the first-order analysis, the equilibrium and kinematic relationship are taken with respect to the unreformed geometry of the structure is simple to perform but is not a systematic analysis since it neglects additional loading caused by the deflection of the structure .For most of the structure like Tall buildings, Water tanks ,a second order analysis ,which imposes equilibrium and kinematic relationships on the deformed geometry of the structure is required for stability design. "P-Delta" is a second order analysis which includes the effect of deformed shape of the structure.

In this paper Static, Dynamic and P-Delta analysis is performed on Thirty Story Symmetric and Asymmetric structure and Response Quantities are compared of all three analysis. The analysis is done by using Staad-Pro Software for two seismic Zones i.e. III and IV. In the Zone-III the Zone factor value Z=0.16 and seismic intensity moderate intensity and in Zone-IV the value of Z=0.24 and seismic intensity is severe.[7]

II. LITERATURE REVIEW

The effect of P-Delta is mainly dependent on the applied load and building characteristics In addition to this it is also depends upon the height ,stiffness and asymmetry of the building .The building asymmetry may be unbalanced mass ,stiffness ,in plane e. if torsion is included in the building it causes damage of lateral resisting system of the building therefore this type of building is more liable to earthquake damages. The deformation caused by torsion can affect the P-Delta .It can be observed that effect of torsion means increase of eccentricity will also increasing the P-Delta effect. The type of lateral load resisting system plays an important role in degree that torsion modifies the P-Delta effect so it is concluded that the lateral load resisting system has importance in case of torsion deformation.

In the elastic or inelastic dynamic analyses, the effects of P-Delta sometimes increase the responses and sometimes decrease the responses. The reason is that implementing P-Delta effects in analysis causes change in stiffness matrix of building, thus the natural periods and other dynamic properties of the building will change. If acceleration response corresponding to the new natural period of building, in response spectrum of the earthquake, is less than acceleration response corresponding to the original natural period, then reduction in building responses for the case with P-Delta can be expected. The effects of P-Delta are quite sensitive to ground motion characteristics such as the frequency content of earthquake. In inelastic analyses, the sensitivity is still important but less than the elastic dynamic cases. In general, the sensitivity to ground motion increases, as the eccentricity increases.[3]

III. METODOLOGY

The analysis of multistory buildings for the gravity loads or vertical loads and horizontal loads can be done as followings: [11]

- Portal frame method
- Substitute frame method
- Cantilever method
- Kani's method

The portal method

It is assumed that a point of contra flexure occur at the middle points of the members of the frame and horizontal shear taken by each interior columns is double the horizontal shear taken by each of the external columns. Thus by making the above two assumptions, the structure can be easily analyzed. It is also assumed that the horizontal force on each storey height is equally divided and transmitted to the top and bottom of the storey.

The cantilever method

It is assumed that a point of contra flexure occur at the middle points of the members of the frame and horizontal shear taken by each interior columns is double the horizontal shear taken by each of the external columns. Thus by making the above two assumptions, the structure can be easily analyzed. It is also assumed that the horizontal force on each storey height is equally divided and transmitted to the top and bottom of the storey. In this method minor difference in assumption in considering the moments and shear force in load bearings members.

Method of substitute frames

In this method only a part of the frame is considered, called a substitute frame. The moment's for each floor is separately computed. It will be assumed that the moment transferred from one floor to another is small. Each floor will be taken as connected to columns above and below with their far end fixed. The frame taken this way is analyzed for the moments and shears in the beams and columns. The moment distribution for the substitute frame is performed only for two cycles and hence the method is sometimes referred to as the two cycle method. When it is required to find out the maximum negative moment at a joint, then the other spans are loaded with load alone. Similarly for maximum positive bending moments the mid span, it will be reverse loading than for negative maximum bending moments.

Kani's method

In this method can be considered by taking a beam "AB" represent one of the spans of a frame or continuous structure and after it's loading it will deform. Lets the ends A and B undergo deformation Qa and Qb respectively. It is also assume that lateral displacements of the ends do not occur. Let Mab and Mb represents the ends moments for the span AB using the below conventions regarding end moments and rotations.

1. Clock wise moments are positive.
2. Clock wise rotations at ends are positive.

As per Kani's method- moments at the near end of a member will be sum of

1. The fixed end moments at the near end due to this loading on the member.
2. Twice the rotations contribution of the near end.
3. The rotation contribution of the far end.

$M_{ab} = M\_{ab} + 2M\text{-}_{ab} + M\text{-}_{ba}$ ---------- (1)

$M_{ba} = M\_{ba} + 2\,M\text{-}_{ba} + M\text{-}_{ab}$ ---------.(2)

Where M_{ab} = final end moments at point A.
M_{ba} = final end moments at point B
M_{ab} = fixed end moments at A
M_{ba} = fixed end moments at B
$M\text{-}_{ab}$ = rotation contribution of end A
$M\text{-}_{ba}$ = rotation contribution of end B

The "P-Delta" analysis of multistory buildings can be done as following. Four different analytical methods are considered below. The first two approximate the"P-Delta" effect using first order elastic analysis, thus care is needed in their use:

- A "pseudo load" approach,
- A "pseudo displacement" approach, (fictitious load)
- The two cycle iterative method – accounting for geometric stress stiffness,
- Non-linear static analysis - full Newton Raphson.
- For the Static, Dynamic and P-Delta analysis of multistory buildings following methods are used by STAAD PRO software
- Equivalent static lateral force method –For Static analysis only.
- Response spectrum method–For Dynamic analysis only

– Non-linear static analysis - full Newton Raphson – For "P-Delta" analysis

Response spectrum method

From this method analysis shall be performed using the design spectrum for rocky and soil sites. Time history methods require large computational efforts and are thus time consuming. Hence spectrum method is generally adopted for the dynamic analysis of structures. The response spectrum is a representation of the maximum responses of the idealized single degree of freedom system as a function of natural frequencies the individual modal responses of any system is thus obtained from the response spectra. The response is further obtained by combining all the modal responses using the method such. As SRSS or by CQC.[7]

Non-Linear Static (Full Newton Raphson) Analysis

A full non-linear iterative solution allows for all sorts of non-linear conditions to be accounted for simultaneously, including "stress stiffening" and both the P-Δ and P-δ effects. The non-linear solution is carried out in an incremental step-by-step analysis with the total applied loads divided into a number of load steps. The most popular method of solution for non-linear equations is the Newton Raphson method. When a general "geometric (stress) stiffness matrix" is used in the method, there are no significant limitations on its use or applicability.[8]

For Static, Dynamic and "P-Delta" analysis STAAD-Pro software used. The result obtained by each methods for static and dynamic response of the selected buildings plan has analyzed and its comparison has also done.

IV. MODEL DISCRIPTION

Here in this paper a 30 story Symmetric and Asymmetric RC frame building is analyzed using computerized solution of analysis with the following assumption.

1.	Type of structure--	Multistory rigid jointed space frames
2.	No of storey--	G+30, G+29
3.	Seismic Zones-	3^{rd} and 4^{th}
4.	Floor height--	3.0m 4b. Depth of foundation 5.0m
5.	Building height--	95 .00m
6.	Plan size--	24.00 x 24.00m and 18.00m x 15.00m
7.	Size of columns--	0.50m x 0.50 m
8.	Size of beams--	0.30m x 0.60m
9.	Walls-	0.20m
10.	Thickness of slab-	125 mm
11.	Imposed load-	3.00kN/ m^2
12.	Floor finish -	1.00kN/ m^2
13.	Unit Weight of RCC--	25.00 kN/ m^3
14.	Unit Weight of infill -	20.00 kN/ m^3
15.	Material used -	Concrete M-30 and Reinforcement Fe-415(HYSD
		Confirming to IS-1786)
16	Earthquake load -	As per IS-1893-2002
17	Type of soil -	Type -II, Medium soil as per IS-1893
18	Ec -	$= 5000\sqrt{fck}$ N/ mm^2
	(Ec is short term static modulus of elasticity in N/mm^2)	
19	Fcr	$= 0.7\sqrt{fc}$ k N/ mm^2
	(Fck is characteristic cube strength of concrete in N/ mm^2)	
22	Static analysis -	Equivalent static lateral force method.
21	Dynamic analysis -	Response spectrum method
22	"P- Delta" analysis -	full Newton Raphson method
23	Software used -	STAAD-Pro for Static, Dynamic analysis and P-Delta analysis

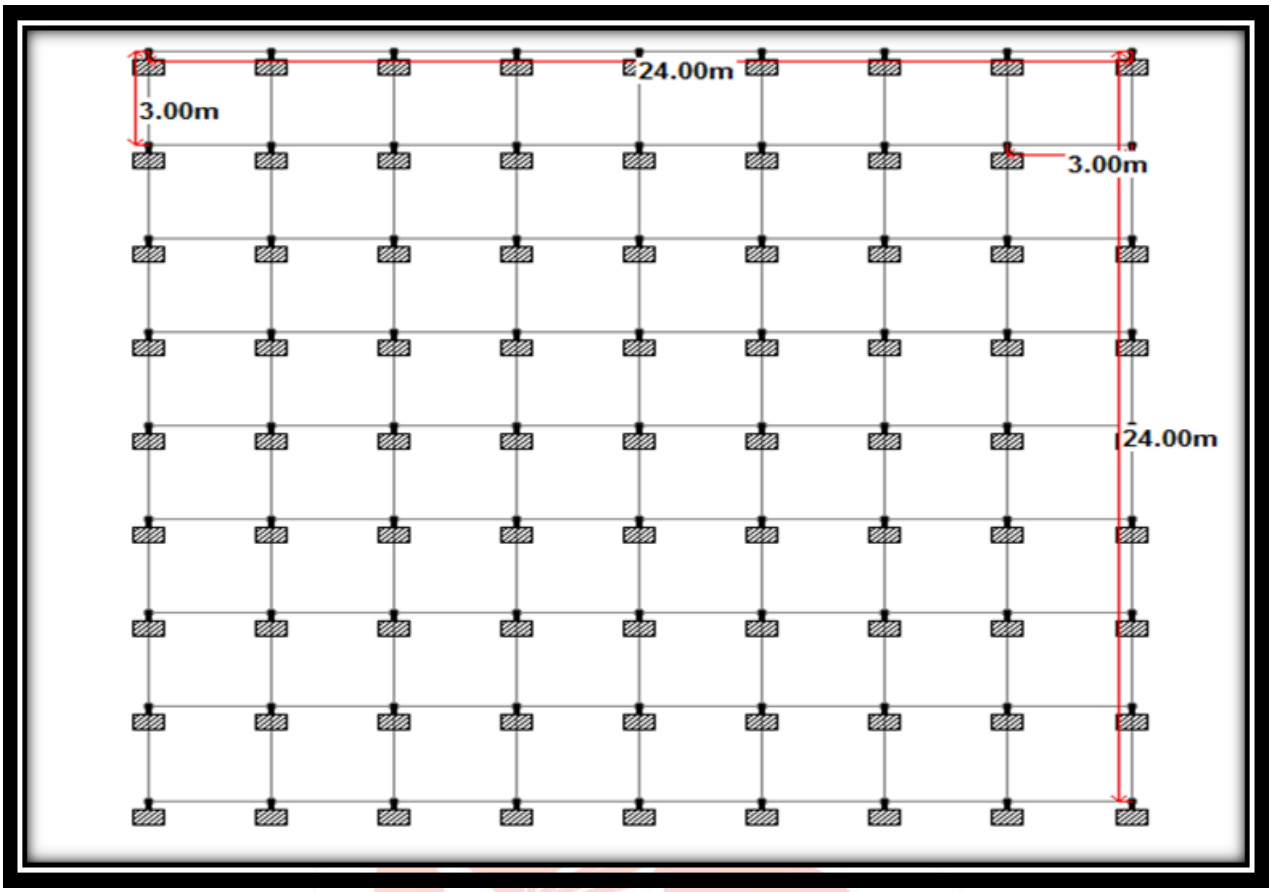


Fig. No. 1 Nodal Plan of symmetric structure

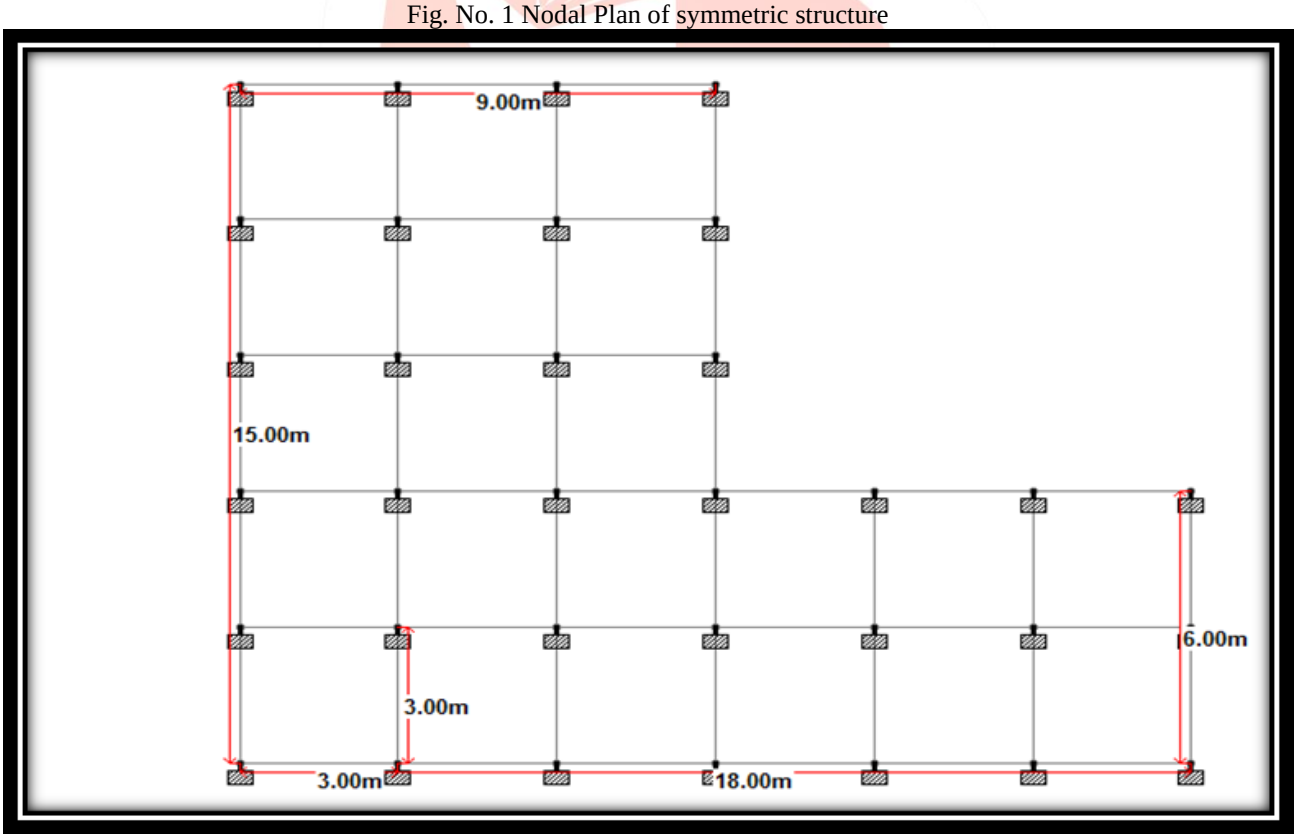


Fig. No. 2 Nodal Plan of Asymmetric structure

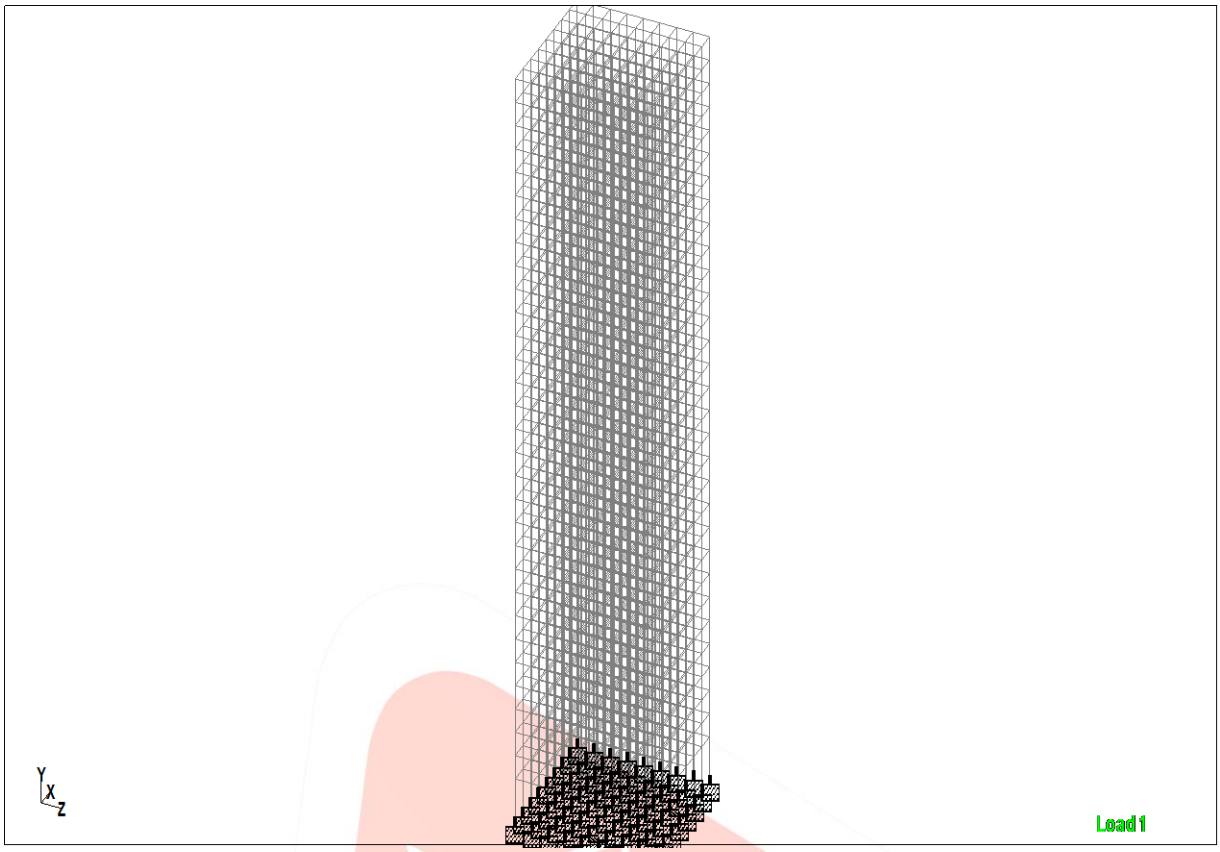


Fig. No. 3 Isometric view of Asymmetric structure

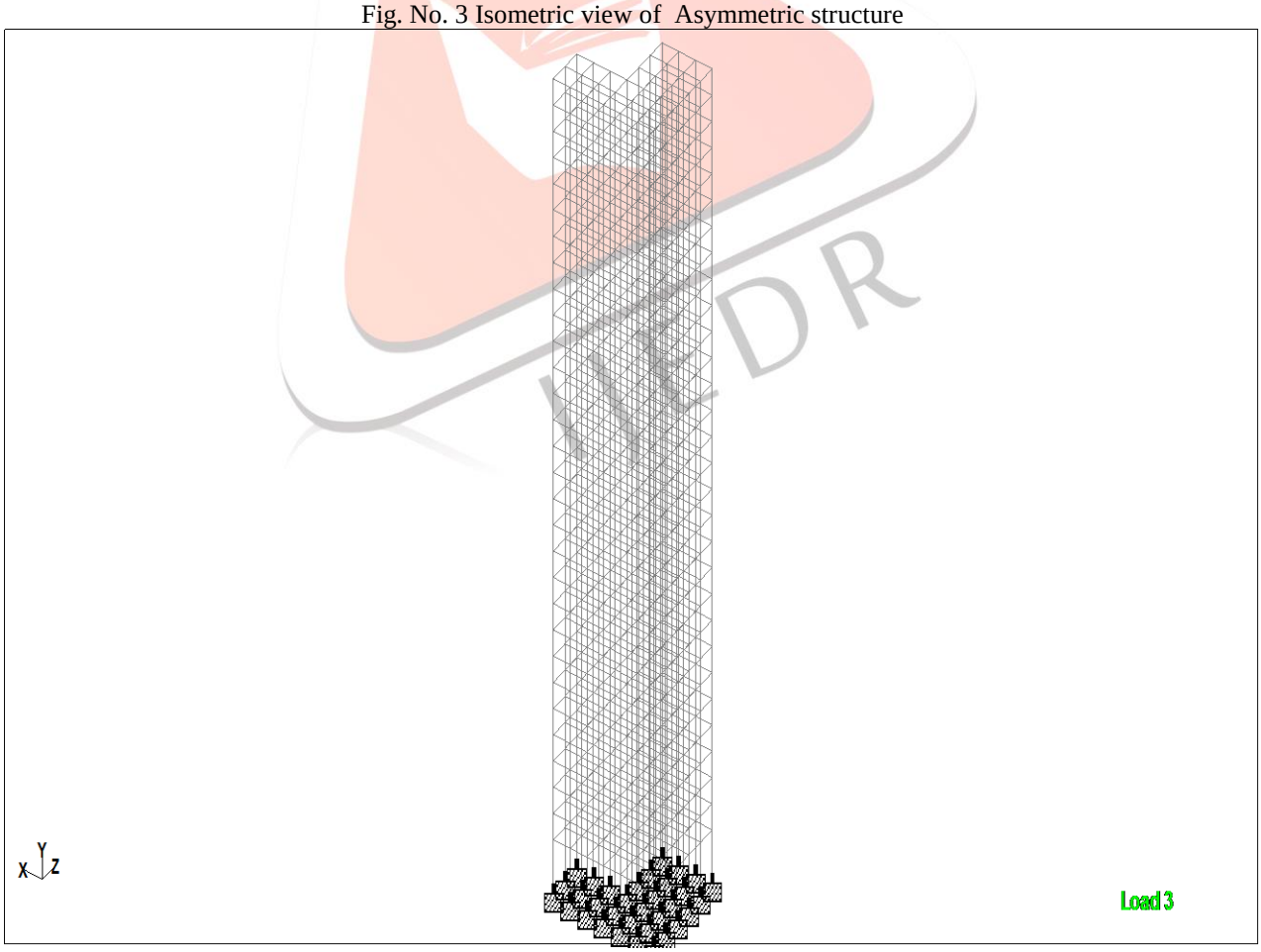


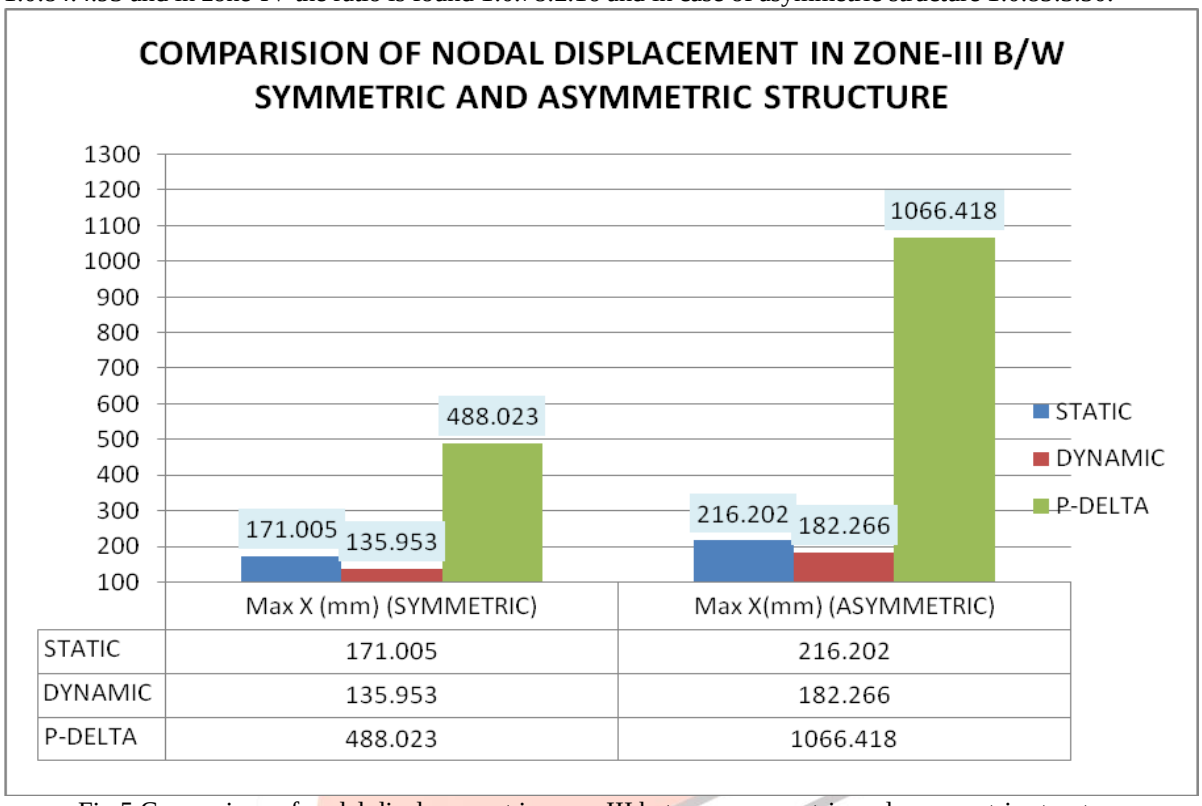
Fig-4 Isometric view of Asymmetric structure

V. RESULTS

Static, Dynamic and "P- Delta" analysis is carried out on symmetric and asymmetric buildings in Zone-III and IV and results are summarized below

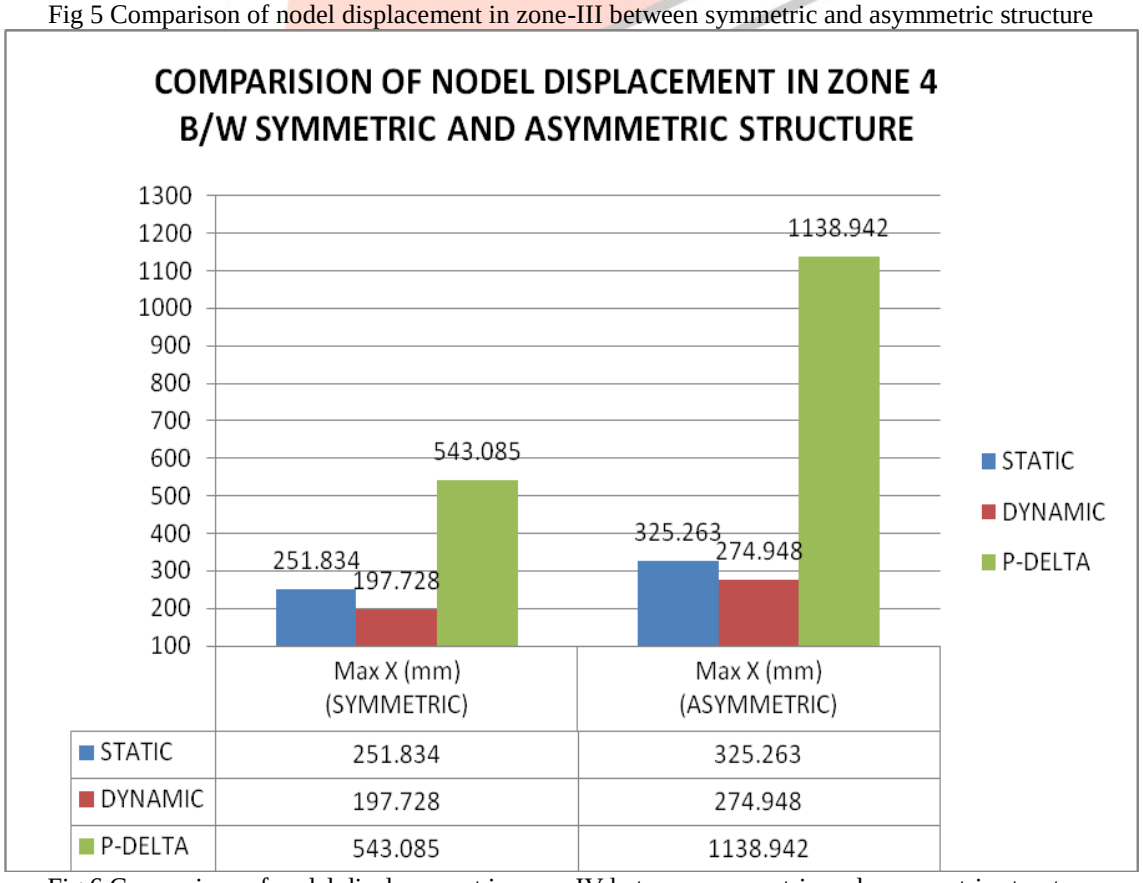
Nodel Displacement

From the below Fig. it can be conclude that the Nodel displacement is higher in case of both symmetric and asymmetric building when p delta analysis is performed on the building. It is also clear that the nodel displacement ratio in zone-III in case of symmetric building in comparison to Static: Dynamic :P Delta analysis are obtained 1: 0.79:2.85 and in case of asymmetric structure 1:0.84:4.93 and in zone-IV the ratio is found 1:0.78:2.16 and in case of asymmetric structure 1:0.85:3.50.



	Max X (mm) (SYMMETRIC)	Max X(mm) (ASYMMETRIC)
STATIC	171.005	216.202
DYNAMIC	135.953	182.266
P-DELTA	488.023	1066.418

Fig 5 Comparison of nodel displacement in zone-III between symmetric and asymmetric structure



	Max X (mm) (SYMMETRIC)	Max X (mm) (ASYMMETRIC)
STATIC	251.834	325.263
DYNAMIC	197.728	274.948
P-DELTA	543.085	1138.942

Fig 6 Comparison of nodel displacement in zone-IV between symmetric and asymmetric structure

Storey Displacement

Top storey Displacement is found very much higher in P Delta analysis in both Symmetric and Asymmetric buildings. Comparison of storey displacement ratio between various analysis Static : Dynamic : P Delta in case of zone-III symmetric building are 1:0.79:2.77 and in case of asymmetric building are 1:0.82:2.62. In case of zone-IV symmetric building are 1:0.78:2.11 and in case of asymmetric building are 1:0.82:2.95.

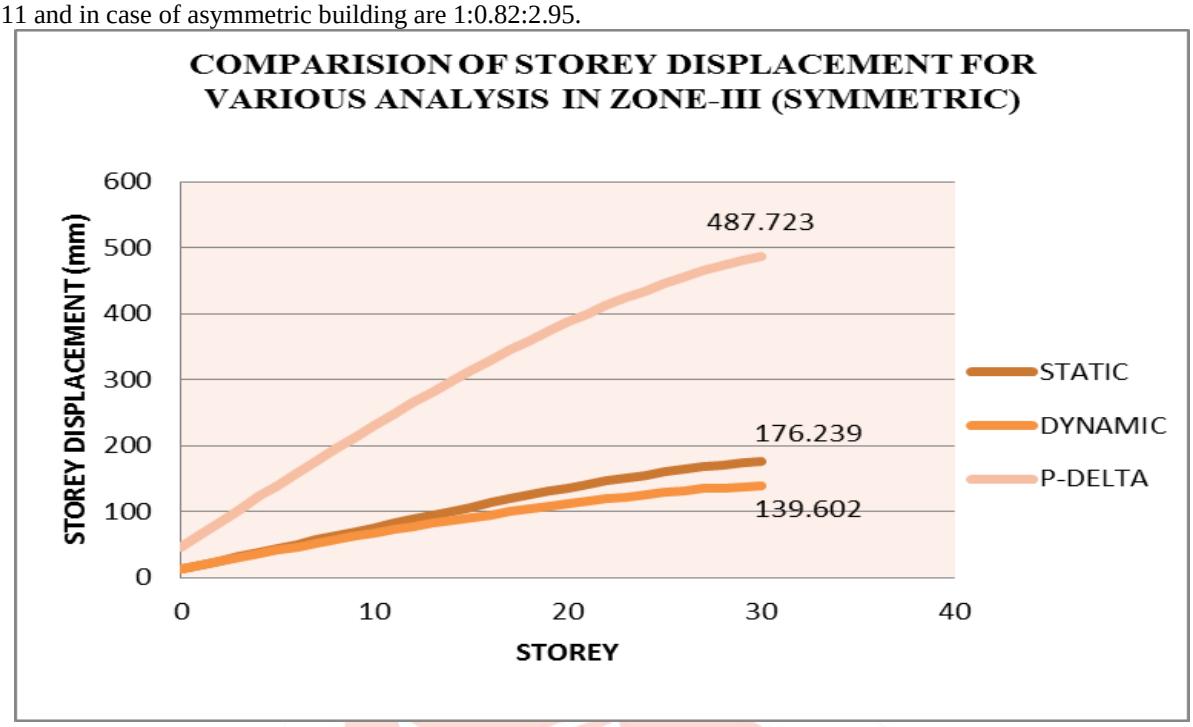


Fig 7 Comparison of storey displacement for various analysis in Zone-III (Symmetric building)

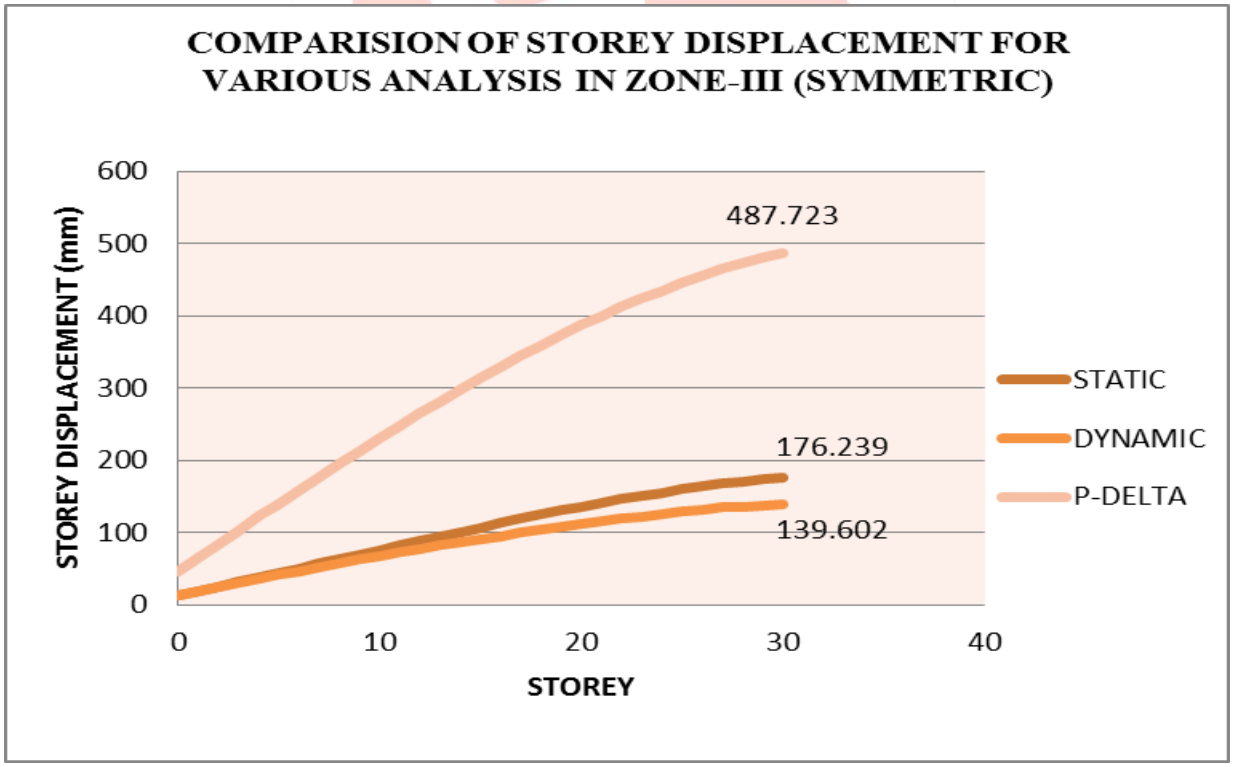


Fig 8 Comparison of storey displacement for various analysis in Zone-III (Asymmetric building)

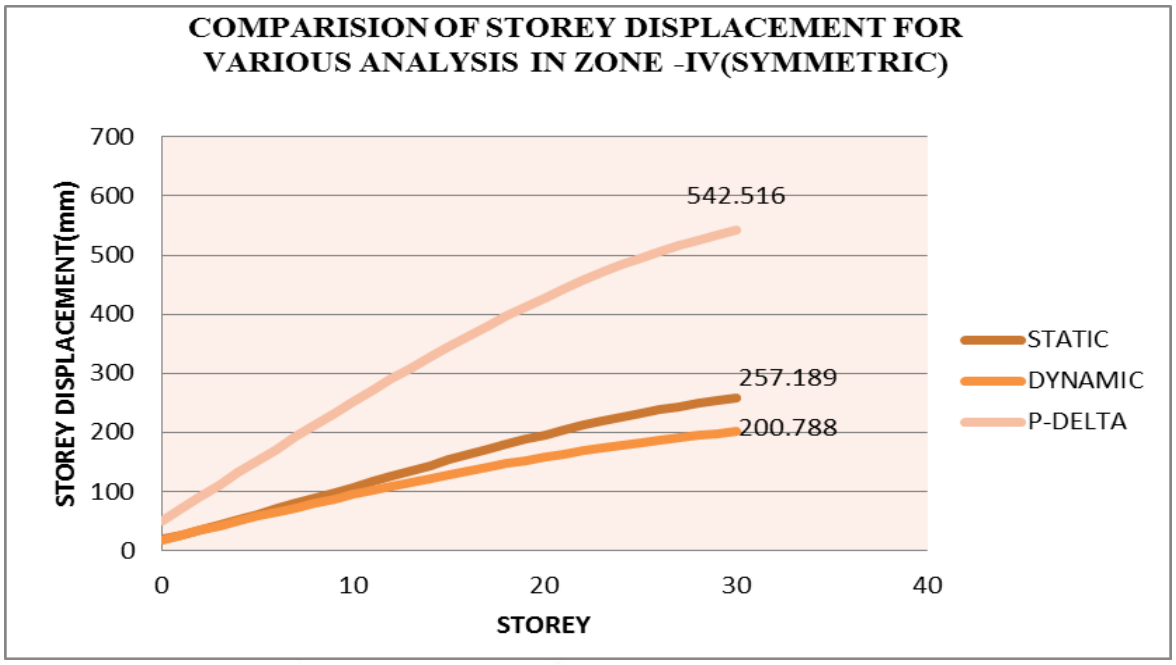


Fig 9 Comparison of storey displacement for various analysis in Zone-IV (Symmetric building)

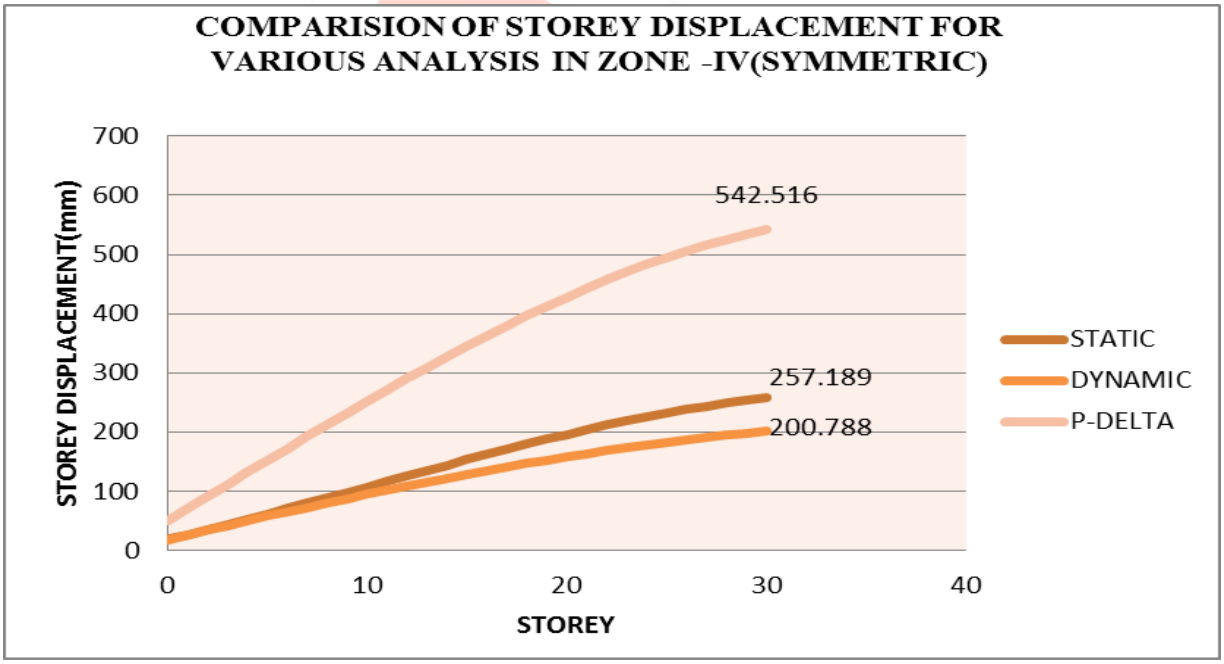


Fig 10 Comparison of storey displacement for various analysis in Zone-IV (Asymmetric building)

Storey Drift

From the below graph the max storey drift ratio for various analysis in case of zone-III symmetric building for stataic :dynamic:P Delta is 1:0.83:3.13and in case Asymmetric is 1:0.89:3.24.In case of of zone-IV symmetric building the ratio is 1:0.88:2.25 and for Asymmetric building 1:.076:2.82.

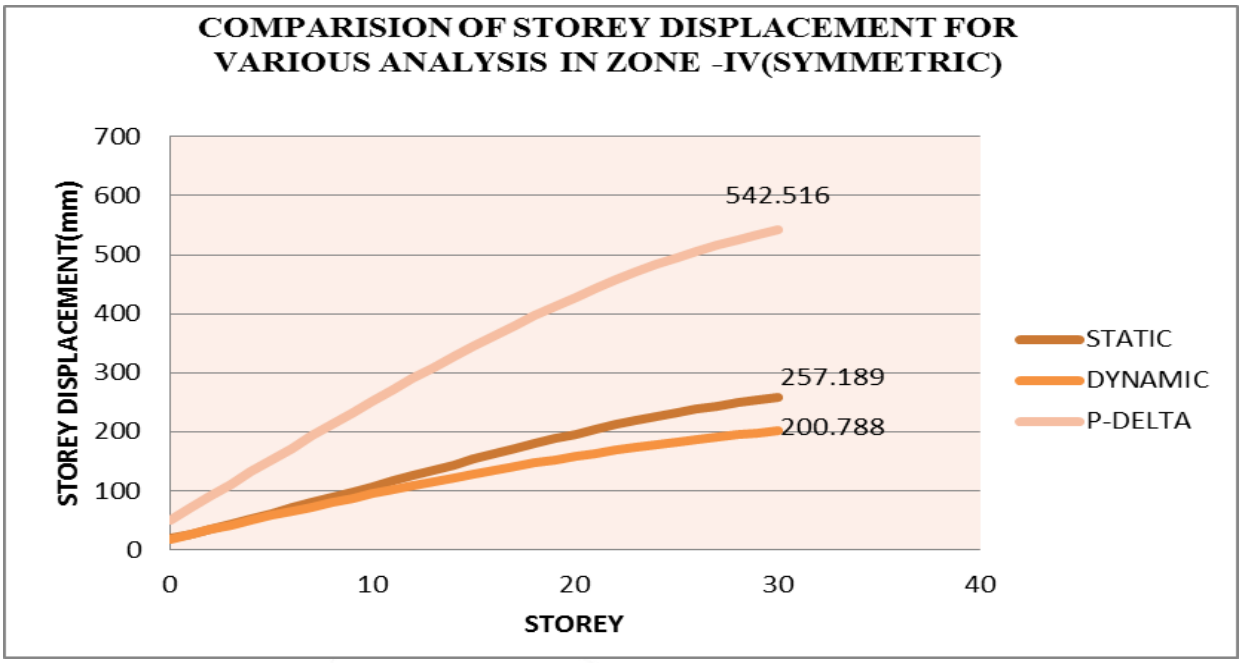


Fig 11 Comparison of storey drift for various analysis in Zone-III (symmetric building)

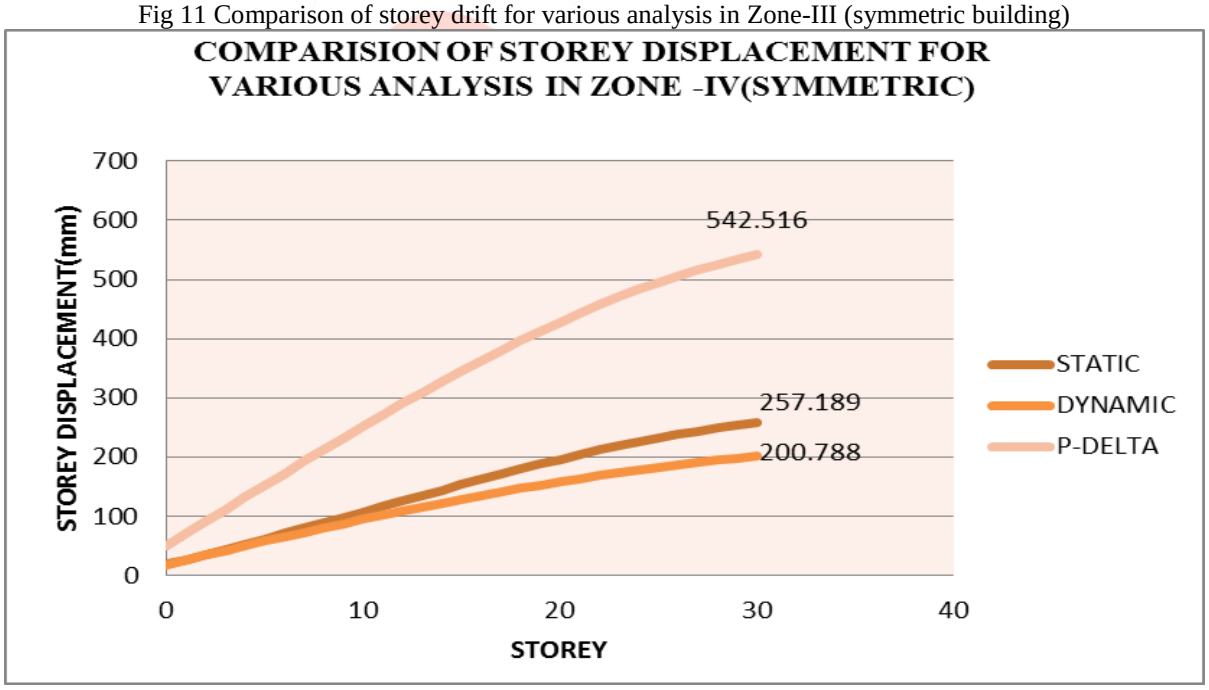


Fig 12 Comparison of storey drift for various analysis in Zone-III (Asymmetric building)

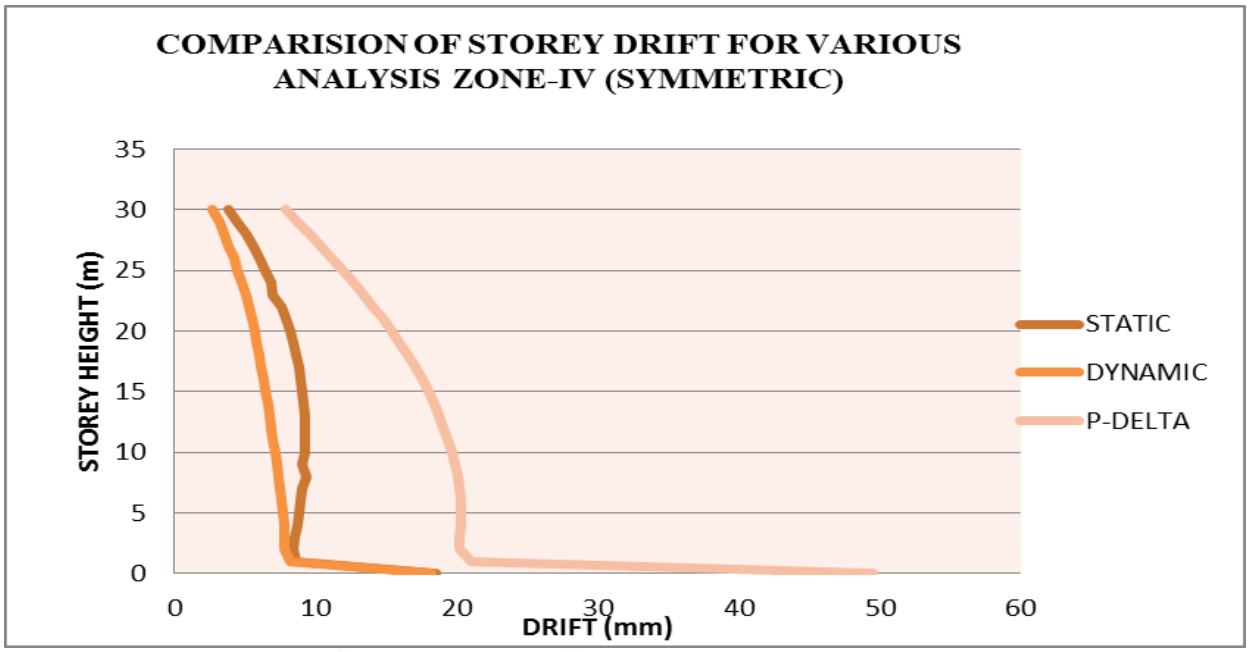


Fig 13 Comparison of storey drift for various analysis in Zone-IV (symmetric building

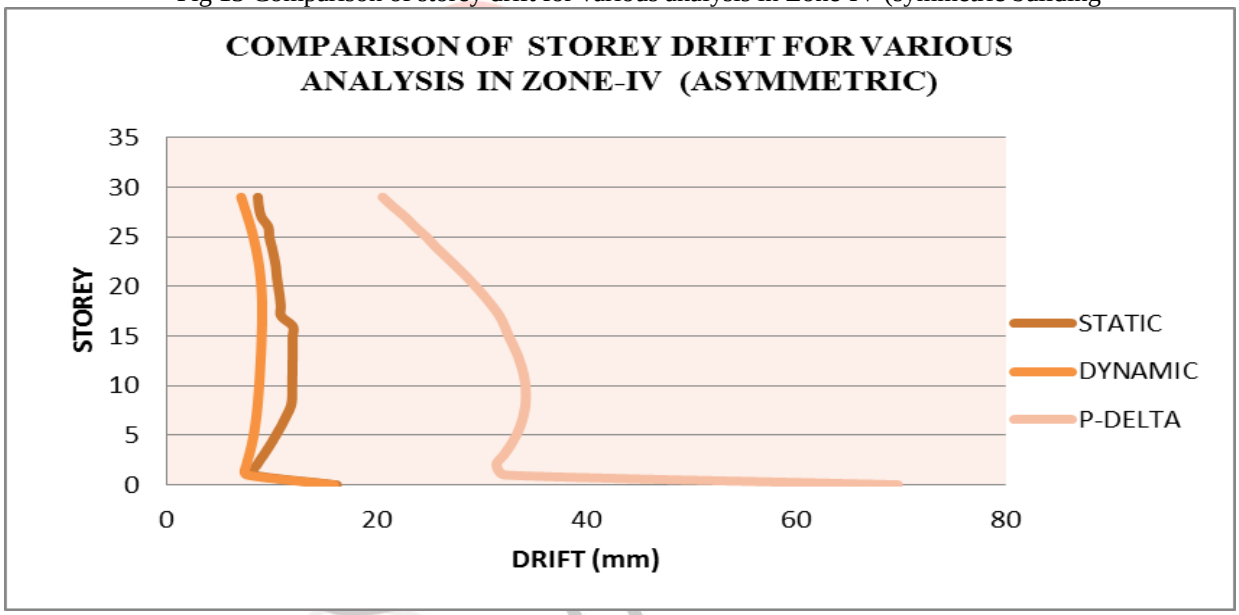


Fig 14 Comparison of storey displacement for various analysis in Zone-IV (Asymmetric building)

VI. DISCUSSION

It could be summarized that analysis and design of high rise RC framed structure required expert observation and understanding.

From the graph No.5 and 6 the Nodal displacement in zone-III 2.85 and 3.59 times and 4.93 and 5.85 and for zone-IV 2.15 and 2.75 times and 3.50 and 4.14 times higher times higher in case of "P-Delta" analysis in compare to static and dynamic analysis respectively for symmetric and asymmetric buildings .

From the graph No. 7 to 10 the Top storey displacement in zone –III 2.76 and 3.43 times and 2.62 and 3.18 times and for zone-IV 2.11 and 2.70 times and 2.95 and 3.62 times higher times higher in case of "P- Delta" analysis in compare to static and dynamic analysis respectively for symmetric and asymmetric buildings.

From the graph No.11 to 14 the Story drift curves change earlier in 4th storey in case of "P-Delta" analysis for zone-III and 1st and 8th storey respectively symmetric and asymmetric building but in case of static and dynamic analysis the curves change in 14th and 4th storey and 17th and 5th storey for zone-III and 8th and 1st storey and 16th and 17th storey respectively for symmetric and asymmetric buildings.

VII. CONCLUSION

From the above results it can be concluded that the effect of "P-Delta" analysis is found higher in comparison to static and dynamic analysis and the effect of "P-Delta" analysis is much higher when the plan of building is asymmetric in compare to symmetric building.

Following conclusions are made after doing whole analysis:

1. Nodal displacement in Zone-III 2.85 and 3.59 times and 4.93 and 5.85 and for Zone-IV 2.15 and 2.75 times and 3.50 and 4.14 times higher times higher in case of "P-Delta" analysis in compare to static and dynamic analysis respectively for symmetric and asymmetric buildings.
2. Top storey displacement in Zone –III 2.76 and 3.43 times and 2.62 and 3.18 times and for Zone-IV 2.11 and 2.70 times and 2.95 and 3.62 times higher times higher in case of "P- Delta" analysis in compare to static and dynamic analysis respectively for symmetric and asymmetric buildings.
3. Story drift curves change earlier in 4^{th} storey in case of P Delta analysis for Zone-III and 1^{st} and 8^{th} storey respectively symmetric and asymmetric building but in case of static and dynamic analysis the curves change in 14^{th} and 4^{th} storey and 17^{th} and 5^{th} storey for Zone-III and 8^{th} and 1^{st} storey and 16^{th} and 17^{th} storey respectively for symmetric and asymmetric buildings.

In India Methods of analysis presently used include the dynamic Response Spectrum Method and the Equivalent Lateral Static Load Method, which generally provide a linear elastically response and not consider any response due to deformed geometry. As in actual condition loads simultaneously work on structure which are responsible for additional moments due to non linearity of the structure, to incorporate those additional response non liner analysis is very necessary to make the structures more sustainable against deformation

REFERENCE

[1] A. Rutenberg, "Simplified P-Delta Analysis for Asymmetric Structures", structure Div. ASCE, PP1993-2013 (1987).
[2] Annan K. Bhowmick, Robert G. Driver, Gilbert Y. Grondin, "Seismic analysis of steel plate shear walls considering strain rate and P-delta effects**".** (2009)
[3] A.S. Moghadam and A. Aziminejad, "Interaction of Torsion and P-delta effects in tall buildings".13th World Conference on Earthquake Engineering, Vancouver, B.C., Canada, August 1-6, 2004 Paper No. 799
[4] Chen, W. F. and Lui, E. M. (1987) "Structural Stability: Theory and Implementation", Elsevier Science Publishing Company Inc., New York, NY
[5] E.F. Black, "Use of stability coefficients for evaluating the "P–Delta" effect in regular steel moment", Engineering Structures 33 (2011) 1205–1216.
[6] E. L. Wilson and A. Habibullah, "Static and Dynamic Analysis of Multi-Story Buildings Including P-Delta Effects**,"** (1987).
[7] IS 1893 (Part 2&3): 2002," Criteria for Earthquake Resistant Design of Structures", Bureau of Indian Standards, New Delhi.
[8] M.M Mol lick, "Experimental study of P-delta effect in RC High-rise Structure", journel of civil engineering, institute of engineer, Bangladesh Vol.CE.25 1994.
[9] Montgomery CJ. "Influence of "P-Delta" effects on seismic design", Canadian Journal of Civil Engineering 1981; 8: pp31-43.
[10] Murty, C., V., R."Quantitative Approach to Seismic Strengthening of RC Frame Buildings", Seminar Proc. On Seismic Assessment and Retrofitting of Buildings, Mumbai, Feb., 2002, pp 19-27. Nat Soc Earthq Eng 1977; 10 pp154–8
[11] Sumit verma "Seismic evolution of RC framed structure using "P-Delta analysis" Masters Of Technology in Structural Engineering thesis, MANIT Bhopal 2013