Seismic Analysis of Vertical Geometric Irregular RC Frames with Respect to Different Seismic Zones using ETSBS

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***Abstract*—The structural design affects how multi-story structures behave during powerful earthquakes. The structural orientation depends on aspects like geometry, size and shape of the building. Irregularities in structures are introduced mainly for aesthetic purposes. In the present work we have modeled three vertical geometric irregular RC frames of G+15 storey using ETABS. The models consist of setback in X-direction, Y-direction and both directions were considered. Three analysis methods were adopted those are linear static method of analysis, response spectrum and time history analysis methods. Considering medium soil strata with all the four seismic zones (Zone II, Zone III, Zone IV and Zone V) analysis has been carried out. Analysis results were tabulated and represented in the graphs format for the sake of comparison. The main results compared were storey drift, storey displacement and base shear of all the three models under different seismic zones by adopting different analysis methods**

Keywords—Vertical geometric irregularity; storey drift; storey displacement; base shear

I. INTRODUCTION

The structural design impacts how multi-story structures perform in devastating earthquakes. Nowadays, irregularities in both layout and height arrangements define the majority of buildings. Buildings are introduced with irregularities primarily for aesthetic reasons. Structures with irregularities do have lack of symmetry, which means a crucial eccentricity between the mass and stiffness centres of the building, which results in a harmful coupled lateral response. For irregular structures to enhance their dynamic behavior during an earthquake, careful analysis is necessary.

VERTICAL IRREGULARITIES:

i. Stiffness Irregularity - Soft Storey-A soft storey is one in which the lateral stiffness is less than 70 percent of the storey above or less than 80 percent of the average lateral stiffness of the three storeys above.

ii. Mass Irregularity-Mass irregularity shall be considered to exist where the seismic weight of any storey is more than 200 percent of that of its adjacent storeys. In case of roofs irregularity need not be considered.

iii. Vertical Geometric Irregularity- A structure is considered to be Vertical geometric irregular when the horizontal dimension of the lateral force resisting system in any storey is more than 150 percent of that in its adjacent storey.

iv. In-Plane Discontinuity in Vertical Elements Resisting Lateral Force-An in-plane offset of the lateral force resisting elements greater than the length of those elements

v. Discontinuity in Capacity - Weak Storey-A weak storey is one in which the storey lateral strength is less than 80 percent of that in the storey above.

II. LITERATURE REVIEW

Mohamed Mouhine et.al, (2022), Their study's objective is to conduct a fragility analysis of reinforced concrete structures under seismic loading. For this objective, 20 models with various setbacks have their vulnerability peaks constructed. The nonlinear static evaluation has carried out by finite element computation tool. According to the results, the setback has an impact on the building's performance. Poor seismic performance in the fourth-floor setback buildings implies a high likelihood of damage.

Kyoung Min Ro et.al (2021), They suggested the streamlined modeling approach for irrational vertical structures. By applying a narrative stiffness equation to transform vertically uneven structures into geometrically regular ones, the method was invented or proposed. Through the approximation of approximate nonlinear seismic outcomes, like storey shear, storey drift of vertical uneven structures, the proposed method can be used in the early stages of structural design to speed up project completion.

R M Tejashwini et.al (2021), They conducted experimental and mathematical investigations to examine the seismic response of setback buildings while taking into account the evaluation of soil structure interaction. Different building setback configurations were taken into account when creating the piling foundation codal requirements.

Pranab Kumar Das et.al (2020), They have recorded the observations from two relatively late earthquakes in Nepal and Imphal (India) in 2015 and 2016, as well as earthquakes that happened in Kern County in 1954. Although a lot of research has been done on asymmetric buildings, there are still no generally accepted rules for multistory asymmetric structures.

Anjali Raw et.al (2019), Their research focuses on how different vertical imperfections affect the structure's seismic response. Their goal is to analyse vertically uneven RC frames' response spectrum and temporal history, as well as to implement ductility-based design.

Objectives of Present work

1) To model the different vertical geometric irregular RC frames using Etabs.

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2) To analyze and compare vertical geometric irregular RC frames with respect to different seismic zones by adopting linear static, response spectrum and time history analysis methods as per IS Codes.

3) To evaluate and compare the results of irregular frames for different methods with respect to different seismic zones.

III. METHODOLOGY

In the current study, examination of three vertical geometric irregular RC frames with storeys (G+15) has been taken into consideration. As we were concentrating on vertical irregularities we have considered the plan dimension same for all the three models. The number of bays for both directions that were taken into consideration, for the analysis purpose setbacks along x and y directions were varied.

Considerations included four numbers of bays of 4m each along the Y direction and five numbers of bays of 4m each along the X direction. Plan dimension is 20m X 16m as shown in Fig.1

Model-1 has setback in fifth floor and tenth floor along X-direction as shown in Fig.2 (a) and Fig.2 (b)

Model-2 has setback in fifth floor and tenth floor along Y-direction as shown in Fig.3 (a) and Fig.3 (b)

Model-3 has setback in fifth and tenth floors along both directions the model is of Tower shape as shown in Fig.4 (a) and Fig.4 (b)

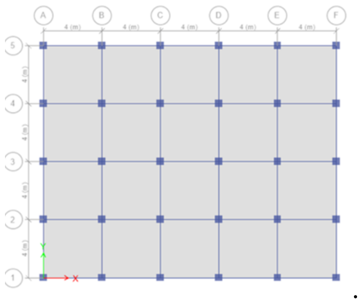

Fig. 1.*Plan of Frames*

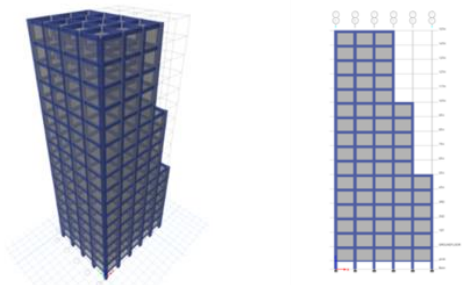

Fig. 2. (a):*3D Model and* b) *Elevation of Model-1*

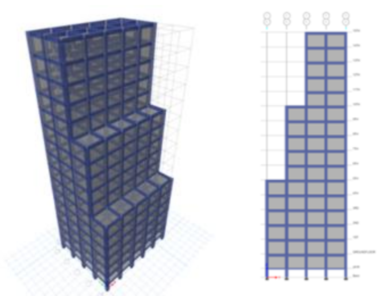

Fig. 3. (a):*3D Model and* b) *Elevation of Model-2*

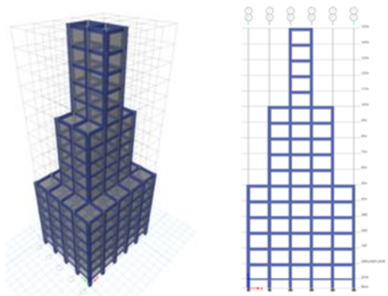

Fig. 4. (a):*3D Model and* b) *Elevation of Model-3*

A. *Materials and Section property for the models*

Length X Width=20m X16m
Number of Stories=16 (G+15)
Support condition=Fixed
Storey Height=3m
Grade of Concrete (fck)=25 N/mm2
Grade of Steel (fy) =415 N/mm2
Column size=650mm X 650mm
Plinth Beam size=230mm X 300mm
Main Beam size=300mm X 600mm
Width of Bearing =250mm
Brick Infill=20kN/m2
Slab thickness=150mm
Bottom storey height (Plinth)=1.8m
Total height of structure=49.8m

B. *Load details*

Wall load=15 kN/m
Live load=3 kN/m^2
Earthquake load in X and Y direction (EQX and EQY) = 1.5 kN/m^2
Soil type =II (medium or stiff soil)
Importance factor (I) =1
Response reduction factor (R) =5
Seismic Zone and Zone Factor (Z)
Zone-II (0.1), Zone-III (0.16),
Zone-IV (0.24), Zone-V (0.36)
Wind speed=50m/s, Terrain Category=2
Windward Coefficient (Cp) =0.8
Leeward Coefficient=0.5
Risk coefficient (k1 factor) =1
Topography coefficient (k3 factor) =1

IV. RESULTS AND DISCUSSION

A. *Model-1 Storey Responses*

1) Storey Drift

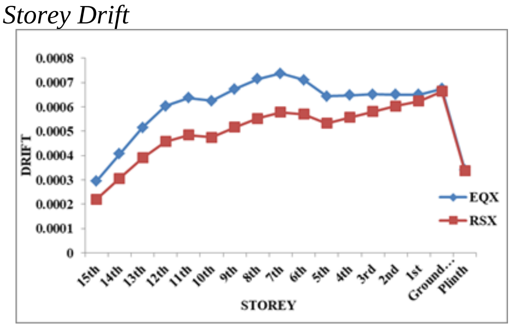

Fig.5 (a): *Storey Drift EQX and RSX*

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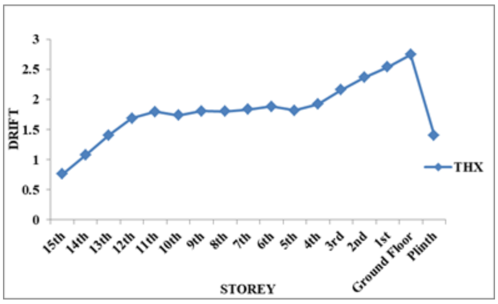

Fig.5 (b): *Storey Drift THX*

Observation**:** From the above comparative graphs structure has maximum drift value in Zone V, at mid storey i.e. 7th floor that is 0.000737 from linear static analysis, in ground floor 0.000134 from response spectrum analysis and in ground floor 0.498875 from time history analysis along X-direction.

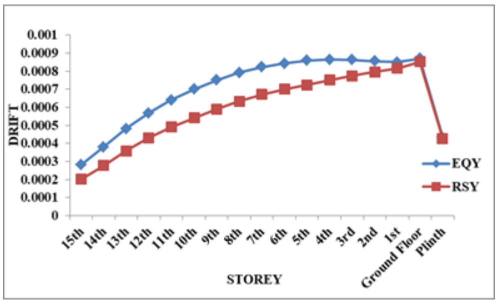

Fig.5 (c): *Storey Drift EQY and RSY*

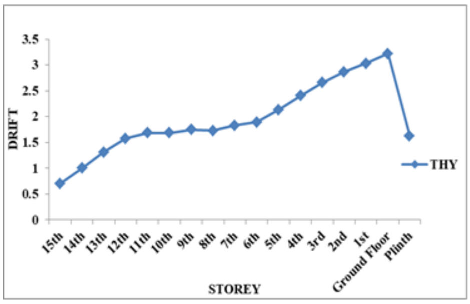

Fig.5 (d): *Storey Drift THY*

Observation**:** From the above comparative graphs the storey drift for the structure is maximum in Zone V at ground floor that is 0.00087 from linear static analysis, 0.000852 from response spectrum analysis and 3.220484 from time history analysis in Y-direction.

2) *Storey Displacement*

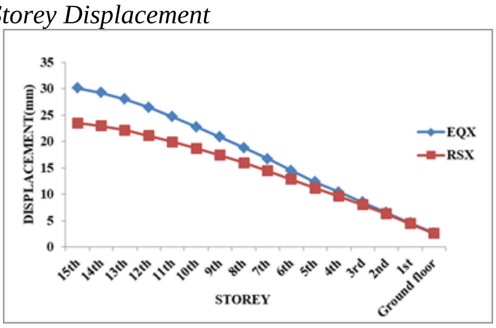

Fig.6 (a): *Storey Displacement EQX and RSX*

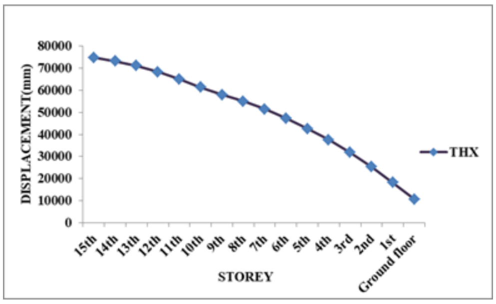

Fig.6 (b): *Storey Displacement THX*

Observation: From the above comparative graphs storey displacement is maximum at top floor for all zones and maximum for Zone V the value 30.09mm from linear static analysis, 23.5mm from response spectrum analysis and 74820.37mm from time history analysis in X-direction.

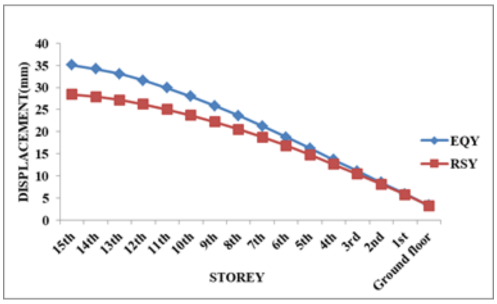

Fig.6 (c): *Storey Displacement EQY and RSY*

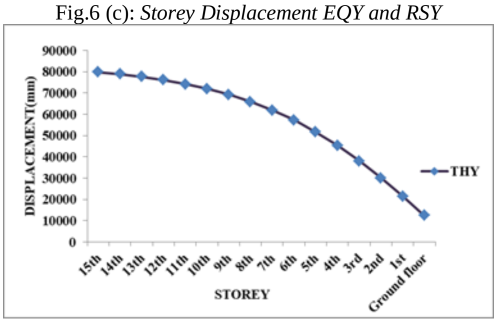

Fig.6 (d): *Storey Displacement THY*

Observation**:** From the above comparative graphs storey displacement is maximum at top floor for all zones and maximum for Zone V the value 35.038mm from linear static analysis, 28.457mm from response spectrum analysis and 79864.01mm from time history analysis in Y-direction.

3) *Base Shear*

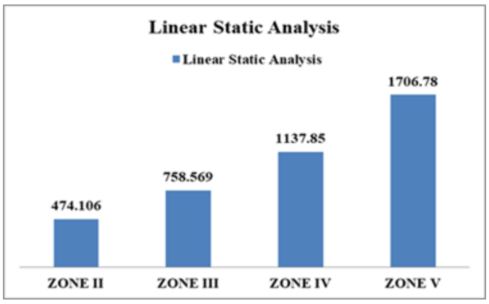

Fig.7 (a): *Base shear (Linear Static Analysis)*

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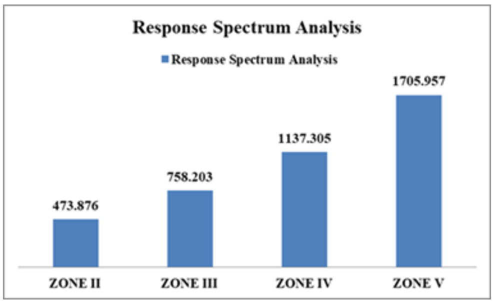

Fig.7 (b): *Base shear (Response Spectrum Analysis)*

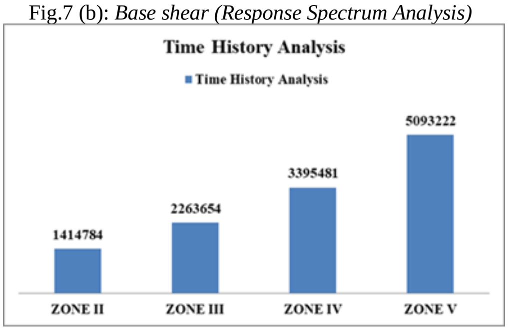

Fig.7(c): *Base shear (Time History Analysis)*

Observation**:**

- For Model-1 from the graphs Base Shear is maximum in Zone V 1706.75 kN and minimum for Zone II 474.106 kN from the linear static analysis.
- From response spectrum analysis 473.876 kN for Zone II and 1705.957 kN for Zone V minimum and maximum respectively
- From time history analysis 1414784kN for Zone II and 5093222kN for Zone V minimum and maximum respectively.

B. Model-2 Storey Responses

1) Storey Drift

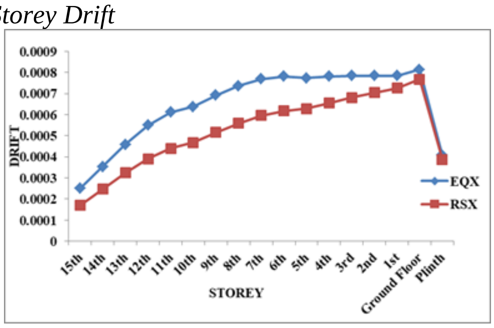

Fig.8 (a): *Storey Drift EQX and RSX*

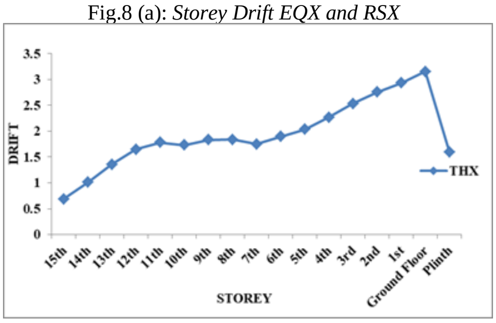

Fig.8 (b): *Storey Drift THX*

Observation**:** From the above comparative graphs the storey drift for the structure is maximum in Zone V,at ground floor the value 0.000813 from linear static analysis, 0.000767 from response spectrum analysis and 3.15427 from time history analysis in X-direction.

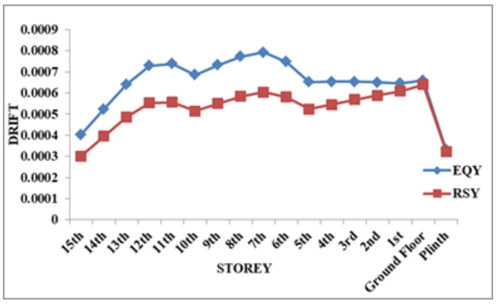

Fig.8 (c): *Storey Drift EQY and RSY*

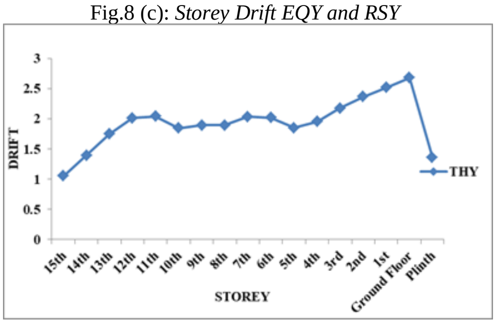

Fig.8 (d): *Storey Drift THY*

Observation**:** From the above comparative graphs structure has maximum drift value in Zone V at mid storey, the value 0.000792 from linear static analysis, 0.000639 from response spectrum analysis and 2.67933 from time history analysis in Y-direction.

2) Storey Displacement

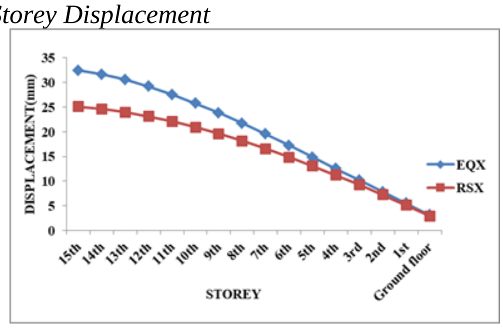

Fig.9 (a): *Storey Displacement EQX and RSX*

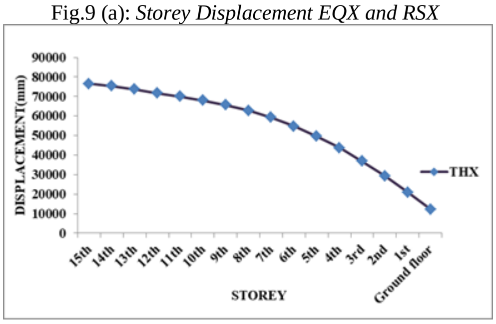

Fig.9 (b): *Storey Displacement THX*

Observation: From the above comparative graphs storey displacement is maximum at top floor for all zones and maximum for Zone V, the value 32.397mm from linear static analysis, 25.083mm from response spectrum analysis and 76576.03mm from time history analysis in X-direction

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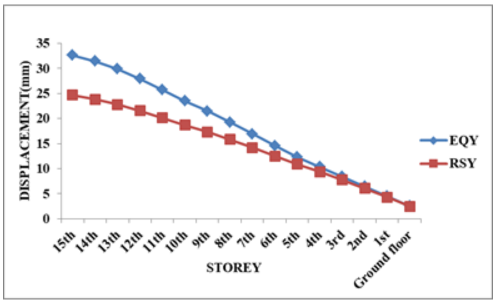

Fig.9 (c): *Storey Displacement EQY and RSY*

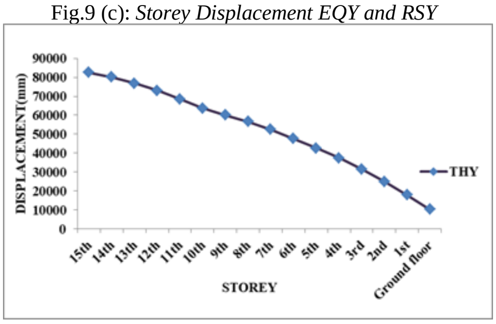

Fig.9 (d): *Storey Displacement THY*

Observation: From the above comparative graphs storey displacement is maximum at top floor for all zones and maximum for Zone V, the value 32.627 from linear static analysis, 24.654mm from response spectrum analysis and 82559.19mm from time history analysis in Y-direction

3) Base Shear

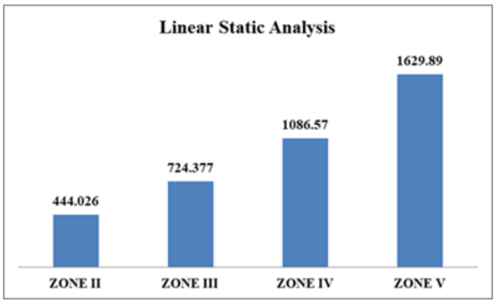

Fig.10 (a): *Base shear (Linear Static Analysis)*

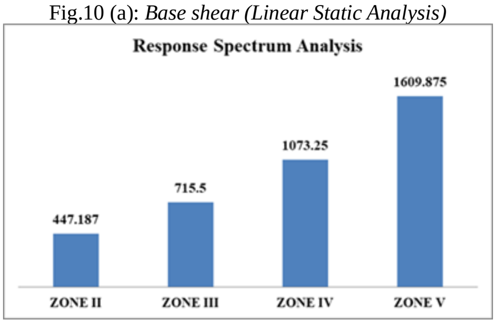

Fig.10 (b): *Base shear (Response Spectrum Analysis)*

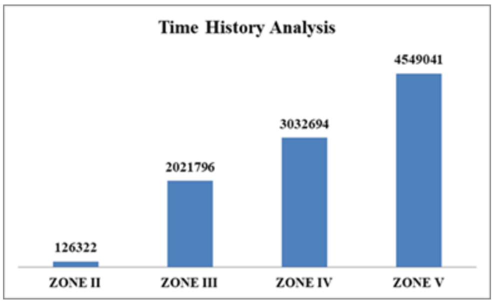

Fig.10(c): *Base shear (Time History Analysis)*

Observation:

- For Model-2 from the graphs Base Shear is maximum in Zone V 1629.89 kN and minimum for Zone II 444.026 kN from the linear static analysis.
- From response spectrum analysis 447.187kN for Zone II and 1609.875kN for Zone V minimum and maximum respectively
- From time history analysis 126322kN for Zone II and 4549041kN for Zone V minimum and maximum respectively.

C. Model-3 Storey Responses

1) Storey Drift

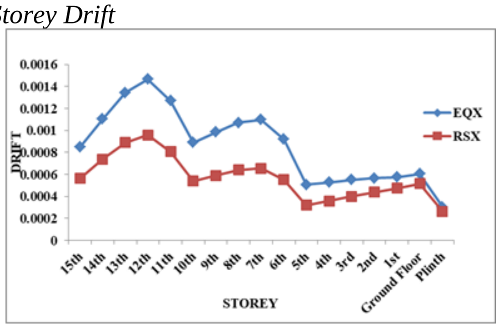

Fig.11 (a): *Storey Drift EQX and RSX*

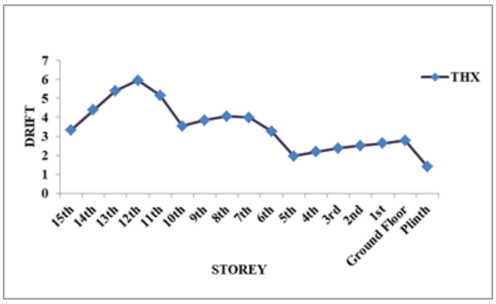

Fig.11 (b): *Storey Drift THX*

Observation**:** From the above comparative graphs the storey drift for the structure is maximum in Zone V ,at 11th floor the value 0.001466 from linear static analysis, at 12th floor 0.000957 from response spectrum analysis and at 12th floor is 5.94585 from time history analysis along X- direction

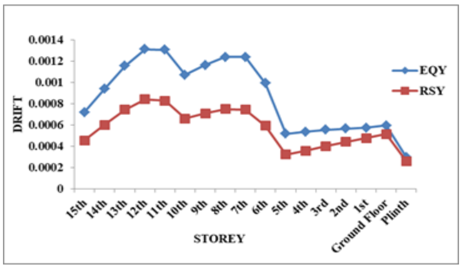

Fig.11 (c): *Storey Drift EQY and RSY*

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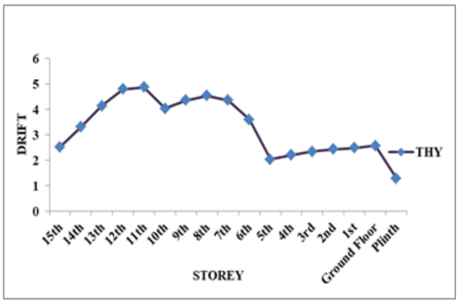

Fig.11 (d): *Storey Drift THY*

Observation: From the above comparative graphs the storey drift for the structure is maximum in Zone V, at 12th floor the value 0.001311 from linear static analysis, at 12th floor is 0.000841 from response spectrum analysis and at 11th floor is 4.853536 from time history analysis in Y- direction.

2) *Storey Displacement*

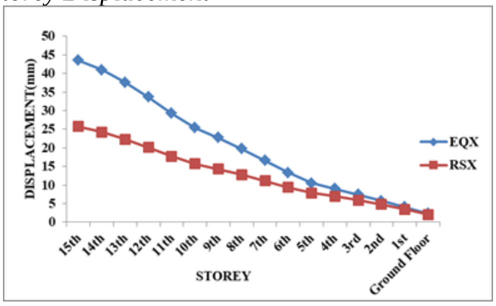

Fig.12 (a): *Storey Displacement EQX and RSX*

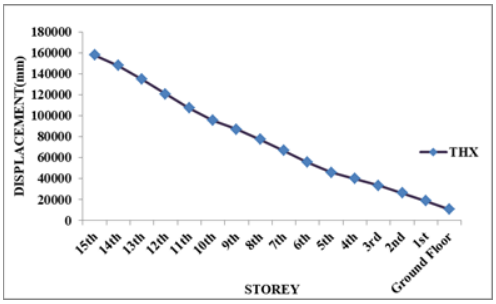

Fig.12 (b): *Storey Displacement THX*

Observation: From the above comparative graph Storey displacement is maximum at top floor for all zones and maximum for Zone V, the value 43.99mm from linear static analysis, 25.737mm from response spectrum analysis and 157696.5mm from time history analysis along X-direction.

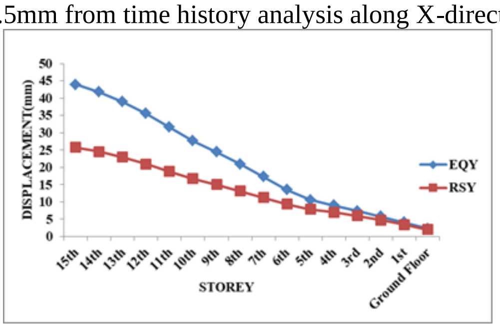

Fig.12 (c): *Storey Displacement EQY and RSY*

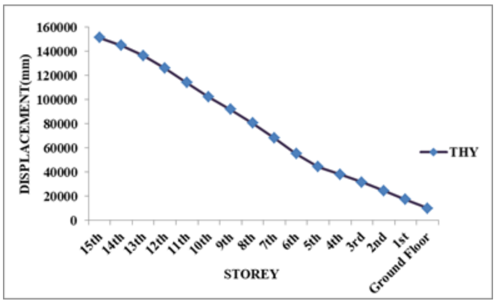

Fig.12 (d): *Storey Displacement THY*

Observation: From the above comparative graphs Storey displacement is maximum at top floor for all zones and maximum for Zone V, the value 43.95mm from linear static analysis, 25.755mm from response spectrum analysis, and 151054mm from time history analysis in Y-direction.

3) *Base Shear*

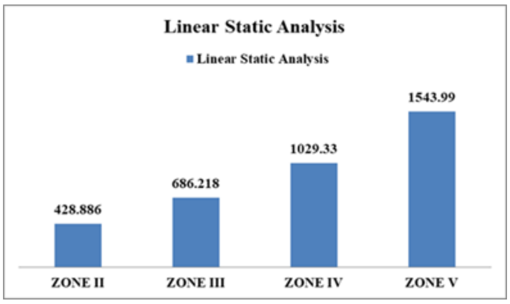

Fig.13 (a): *Base shear (Linear Static Analysis)*

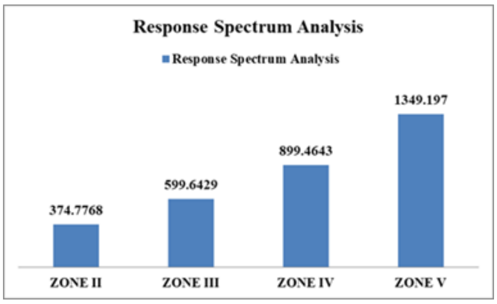

Fig.13 (b): *Base shear (Response Spectrum Analysis)*

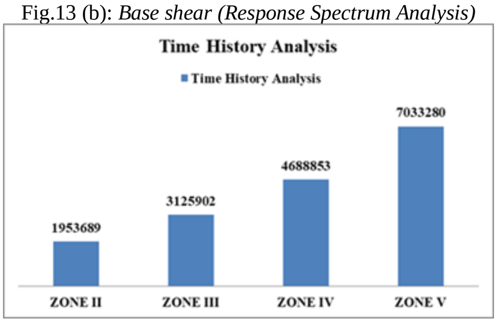

Fig.13 (c): *Base shear (Time History Analysis)*

Observation**:**

- For Model-3 from the graphs Base Shear is maximum in Zone V 1543.99 kN and minimum for Zone II 428.8860 kN from the linear static analysis.
- From response spectrum analysis 374.7768kN for Zone II and 1349.197kN for Zone V minimum and maximum respectively
- From time history analysis 1953689kN for Zone II and 7033280 kN for Zone V minimum and maximum respectively.

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V. CONCLUSIONS

1) Among all the three models the drift value in Model-3 is more when compared to Model-1 and Model-2. The average percentage variation of drift is in the range of 52.23% in X-direction and 78.003% in Y-direction with respect to Model-1, and the average percentage variation with respect to Model-2 were 62.008% and 63.86% in X and Y direction respectively.
2) As setback is in X-direction, number of bays in Y-direction were more storey drift for model-1 is more in Y-direction for all the three analysis methods. As setback is in Y-direction for Model-2 and in both direction for Model-3 the storey drift is more in X-direction
3) Storey displacement value increases from ground floor to top floor in all the three models for all the analysis methods considered.
4) Among all the three Models the displacement value in Model-3 is more when compared to Model-1 and Model-2. The percentage variation of displacement is in the range of 69.05% in X-direction and 81.027% in Y-direction with respect to Model-1, and the percentage variation with respect to Model-2 were 73.21% and 74.86% in X and Y directions respectively.
5) Among the three models base shear value in Model-1 is more when compared to Model-2 and Model-3 is due to mass variation. The percentage variation of base shear is in the range of 4.5% , 5.63% and 10.68% decrease with respect to Model-2, and the percentage variation with respect to Model-3 were 9.53%,20.913% and -38.09% decrease, for linear static analysis, response spectrum analysis and time history analysis methods respectively.
6) All the parameters are more for seismic Zone V compared to other zones, for all the three analysis methods. For the safety purpose of structure it is to avoid construction of vertical irregular buildings in earthquake prone areas, as irregularities affect the seismic performance of the structure.

REFERENCES

[1] Mohamed Mouhine and Elmokhtar Hilali, ”On Seismic vulnerability assessment of RC buildings with setback” of Ain Shams Engineering Journal 13, May 2021.

[2] Kyoung Min Ro, Min Sook Kim and Young Hak Lee, ”On A simplified approach to modelling vertically irregular structures for dynamic assessment of Journal” of Architectural Engineering and Building Engineering KyoungHee University, Young in, Republic of Korea, August 2021.

[3] R. M. Thejaswini, L. Govindaraju and V. Devaraj , “On Experimental and Numerical Studies on Setback Buildings Considering the SSI Effect under Seismic Response” of Civil Engineering Journal (EISSN: 2476-3055; ISSN: 2676-6957) Vol. 7, No. 03,pp. 431-448, March 2021.

[4] Pranab Kumar Das, Sekhar Chandra Dutta and Tushar Kumar Datta, “On Seismic Behavior of Plan and Vertically Irregular Structures”, State of Art and Future Challenges of American Society of Civil Engineers, December 2020.

[5] Anjali Raw and AshishVerma, “On Seismic analysis and Design of Vertically Irregular RC concrete buildings using Staad Pro V81” of IJTSRD Vol.4, Issue 1. ISSN:2456-6470, pp. 237-242, December 2019.

[6] IS Code book 1893 (Part 1) 2002, Indian standard criteria for Earthquake resistant design of structures.

[7] IS 875 Part-3, Indian Standard Criteria for Wind load resistant design of structures.