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Comparative Study Of Multistorey RCC And Composite Structure For Different Plan Configurations In Various Seismic Zones

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Abstract: This study evaluates the seismic performance of G+16 reinforced concrete (RCC) and composite structures using ETABS-2021 and Indian design codes. RCC, a popular choice for its durability and adaptability, combines steel's tensile strength with concrete's compressive strength, but its heavy weight and labour-intensive construction can be limiting. Composite structures, integrating materials like steel and concrete, provide a higher strength-to-weight ratio, lighter designs, and improved seismic performance, particularly in high-rise buildings and long-span bridges. The research focuses on base shear, story stiffness, lateral displacement, and story drift, comparing performance across seismic zones II, III, IV, and V. Through case studies of C-shaped and H-shaped buildings, the findings reveal that composite structures outperform RCC in terms of reliability and efficiency, making them a preferable choice in regions requiring seismic resilience and cost-effective foundation solutions.

***Index Terms* -** ETABS, RCC Structure, Composite Structure, Seismic Zone.

I. INTRODUCTION

Souhaibou and L. Zhi Li compare wind and seismic stresses on a six-story reinforced concrete (RC) building by analysing story drifts and lateral displacements using the base shear method and ETABS, following the Chinese building design code. The base shear method, a simplified approach assuming structural linearity, proves reliable for buildings under 40 meters with uniform mass and stiffness. Results show minimal differences between the base shear method and ETABS, validating its effectiveness in predicting lateral displacements and story drifts. The authors emphasize using proper design codes for safety and recommend further research on complex structural designs.
M. Suresh Kumawat and L. G. Kalurukar analyse steel-concrete composite construction, which integrates steel beams and concrete slabs with shear connectors for enhanced structural performance. The study compares RCC and composite solutions for a nine-story building in seismic zone III. Results reveal that composite structures outperform RCC with better seismic resilience, faster construction, and reduced material use, making them a cost-effective, efficient alternative in earthquake-prone areas.
A. Guleria examines the structural behaviour of multi-story RCC buildings with various plan configurations (rectangular, C, L, and I shape) using ETABS. A 15-story building is modelled to analyse and compare maximum shear forces, bending moments, and story displacements across configurations for insights into structural performance.
D. Rao analyses the seismic and wind response of a G+11 residential building using STAAD PRO V8i and ETABS. The study evaluates base shear, story drift, and displacements across soil types and seismic zones, highlighting the importance of accurate modelling for robust, safe designs under combined environmental pressures in earthquake-prone areas.

S. Badami and M. R. Suresh analyse structural systems for tall reinforced concrete buildings under wind and gravity loads using ETABS, following Indian Standards. The study evaluates systems like Rigid Frame, Shear Wall, Wall Frame Interaction, and Outrigger, focusing on metrics such as drift, displacement, and base shear. It highlights the critical role of lateral loads, particularly wind, in ensuring structural integrity and occupant comfort, emphasizing the importance of selecting efficient systems for safer, durable tall building designs.

1.1 RCC Structure

Modern construction relies heavily on reinforced concrete structures, which combine the tensile strength of steel reinforcement with the longevity of concrete. This composite material, which offers unmatched versatility and dependability in building design, has completely transformed the domains of engineering and architecture. Fundamentally, reinforced concrete is made of concrete, which is a cement, water, and aggregate mixture that is fortified by the addition of steel reinforcing bars, or rebars. While the steel rebars resist tensile forces that would otherwise cause the concrete to crack and break under stress, the concrete offers compressive strength. In order to improve the structural integrity of infrastructure and structures, steel and concrete work in harmony. Structures made of reinforced concrete are well known for their resilience to a variety of environmental factors, including severe weather and seismic activity. Because of their durability, they can be used for a wide range of structures, such as residential buildings, skyscrapers, bridges, and dams. With meticulous planning and design, reinforced concrete construction gets underway.

1.2 Composite Structure

Composite structures are an intricate combination of materials, primarily steel and concrete, designed to take advantage of the advantages of each part. By combining the high tensile strength and flexibility of steel with the compressive strength and durability of concrete, this hybrid building technology creates structures that perform better across a range of engineering applications. The fundamental components of composite structures are concrete-encased steel pieces, usually in the form of beams and columns. By facilitating effective load transfer between the steel and concrete components, this integration maximizes the overall strength and stability of the structural system. Compared to traditional reinforced concrete (RCC) constructions, steel's intrinsic qualities allow for larger spans and smaller columns, increasing architectural flexibility and design possibilities. The outstanding seismic performance of composite constructions is one of its main benefits. Steel elements have a high capacity for energy absorption and stiffness during seismic events, which helps to dissipate seismic forces and reduce structural damage. This capacity is essential in earthquake-prone areas where buildings need to be able to bear large lateral forces and ground vibrations without sacrificing structural integrity or safety. Additionally, because composite structures may be prefabricated and require less on-site assembly for steel components, they can be built faster.

2. METHODOLOGY

1. The Seismic analysis of G+16 Multi-Storey RCC and Composite building is carried by Response Spectrum method and Time History method in accordance with IS: 1893 (Part 1):2016.
2. The ETABS software is used to develop model and carry out the analysis.
3. The Gravity loads and Lateral loads (Seismic) to be applied on the buildings are based on the Indian Standards.
4. The study is carried out in all the four Seismic Zones as per IS 1893:2016.
5. The responses of these buildings in terms of Storey Displacement, Storey Drift, Base Shear and Storey Stiffness are presented and compared.
6. Results of two models (i.e. Concrete Structure and Composite Structure) in all four seismic zones are discussed and reliable results are opted.

3. MODELLING

1. As we are dealing with Seismic Analysis, one should familiarize with the seismic provisions in IS 1893:2016, including earthquake zones, importance factors and response spectrum.
2. Create the Model in ETABS, define the units (e.g., kN, m), define building geometry like modelling the floors of the building, including columns, beams, and slabs and also assign the storey heights.
3. Define Materials properties for concrete (e.g., grade, compressive strength) and steel (e.g., yield strength).

4. Create and assign cross-sectional properties for beams and columns.
5. Apply loads like Dead Load (e.g., finishes, partitions), Live Loads based on the building's function (e.g., residential, office), Wind Load parameters based on IS 875 Part 3 and Seismic Loads based on IS 1893:2016, specify the seismic zone of the building site. Also include Response Spectrum and Importance Factor parameters.
6. Apply different load combinations and analyse the structures and get the results and compare each model.

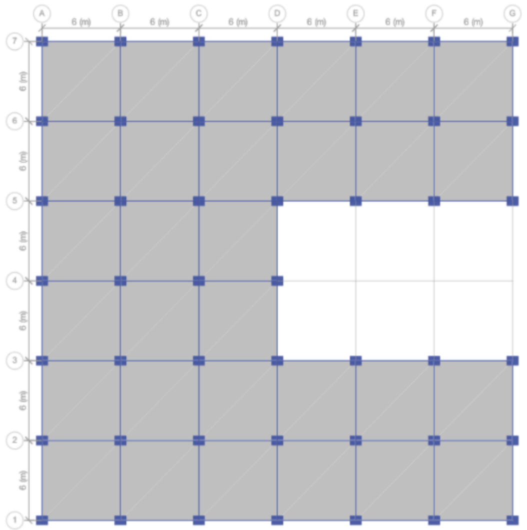

Fig.-1: C-shaped plan of G+16 multistorey RCC structure

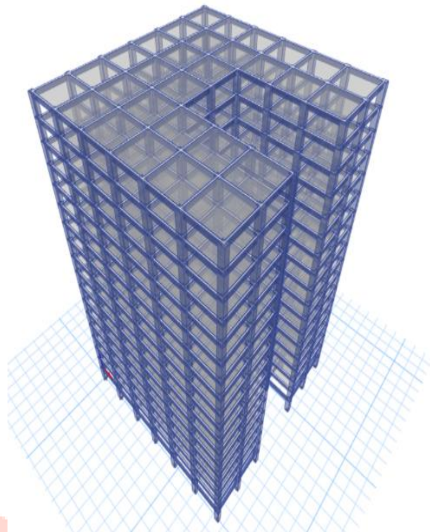

Fig.-2: C-shaped 3D view of G+16 multistorey RCC structure

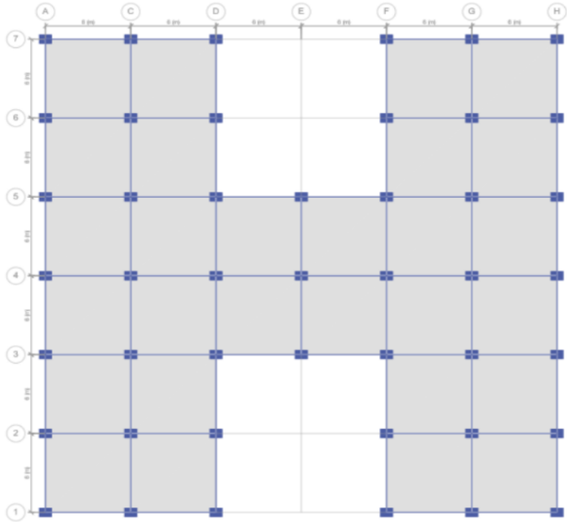

Fig-3: H-shaped plan of G+16 multistorey RCC structure

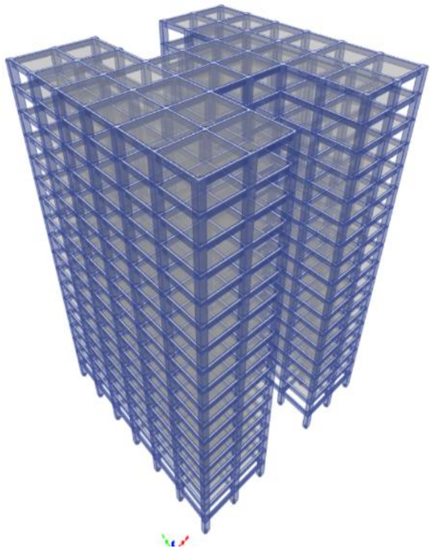

Fig-4: H-shaped 3D view of G+16 multistorey RCC structure

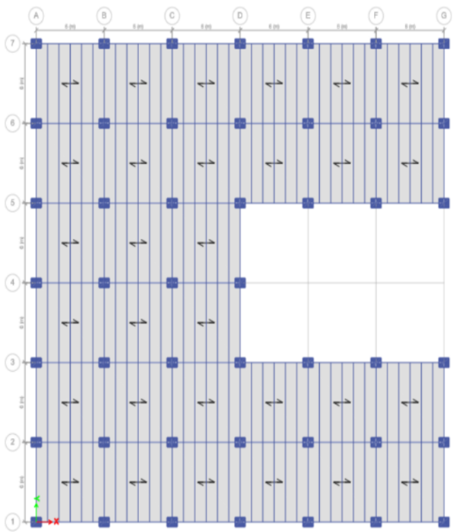

Fig.-5: C-shaped plan of G+16 multistorey Composite structure

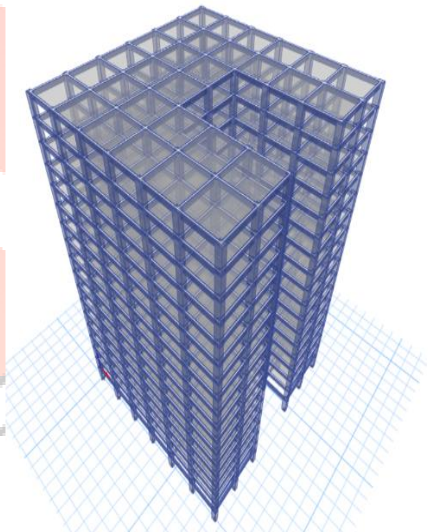

Fig.-6: C-shaped 3D view of G+16 multistorey Composite structure

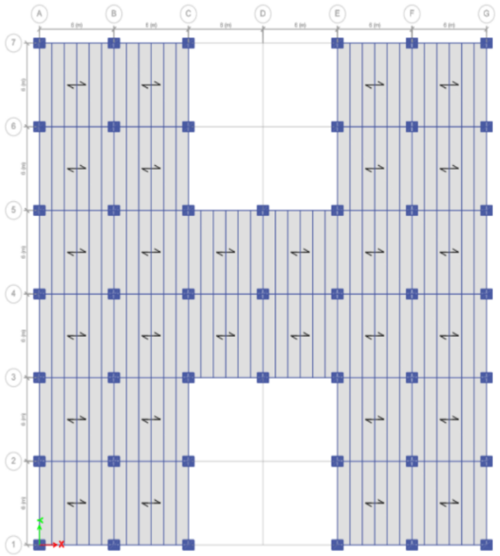

Fig.-7: H-shaped plan of G+16 multistorey Composite structure

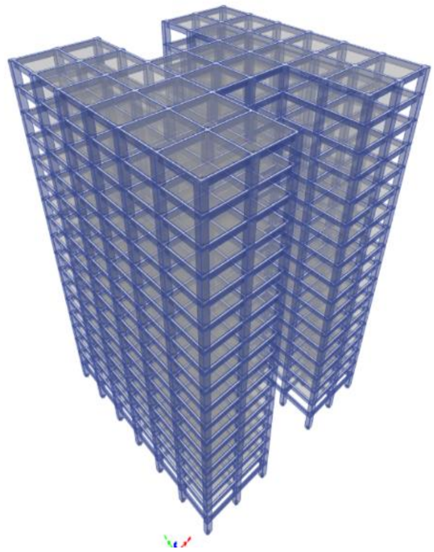

Fig.-8: H-shaped 3D view of G+16 multistorey Composite structure

Fig.1,2,3,4,5,6 represents the models which are considered for the analysis and the results of the following models is shown below.

Table 1: The below table contents are for G+16 Multistorey RCC structure of C-shaped and H-shaped plan.

Height of building	51m
Each Storey Height	3m
Plinth Height	3m
Grade of Concrete	M40
Grade of Steel	Fe500
Seismic Zones	II, III, IV and V
Live Load	$3kN/m^2$
Floor Finish Load	$1.5kN/m^2$
Soil Condition	Medium Hard Soil
Damping Ratio	5%
Size of Columns	700mmX900mm
Size of Beams	300mmX600mm
Slab Thickness	150mm
Type of Structure	SMRF
Importance Factor	1
Response Reduction Factor	5

Table 2: The below table contents are for G+16 Multistorey Composite structure of C-shaped and H-shaped plan.

Height of building	51m
Each Storey Height	3m
Plinth Height	3m
Grade of Concrete	M40
Grade of Steel	Fe345
Seismic Zones	II, III, IV and V
Live Load	$3kN/m^2$
Floor Finish Load	$1.5kN/m^2$
Soil Condition	Medium Hard Soil
Damping Ratio	5%
Size of Columns	700mmX900mm
Embedded section in Column	ISHB 450-2
Secondary Beams	ISLB 500
Slab Thickness	150mm
Type of Structure	SMRF
Importance Factor	1
Response Reduction Factor	5

Table 1,2 represents the building description which is adopted and Table 3,4,5,6 represents the specifications which are provided for the considered models.

4. RESULTS AND DISCUSSIONS

The study of results has been described below of the above specified specifications of the structure

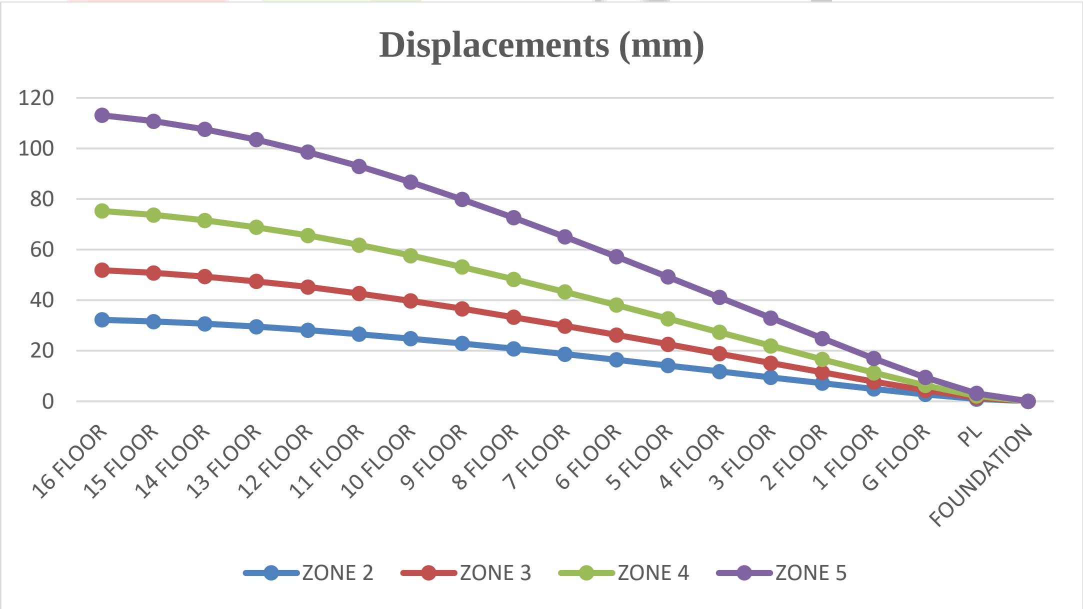

Fig.-9. Comparison of Displacements of C Shaped plan of Concrete Structure in all Zones.

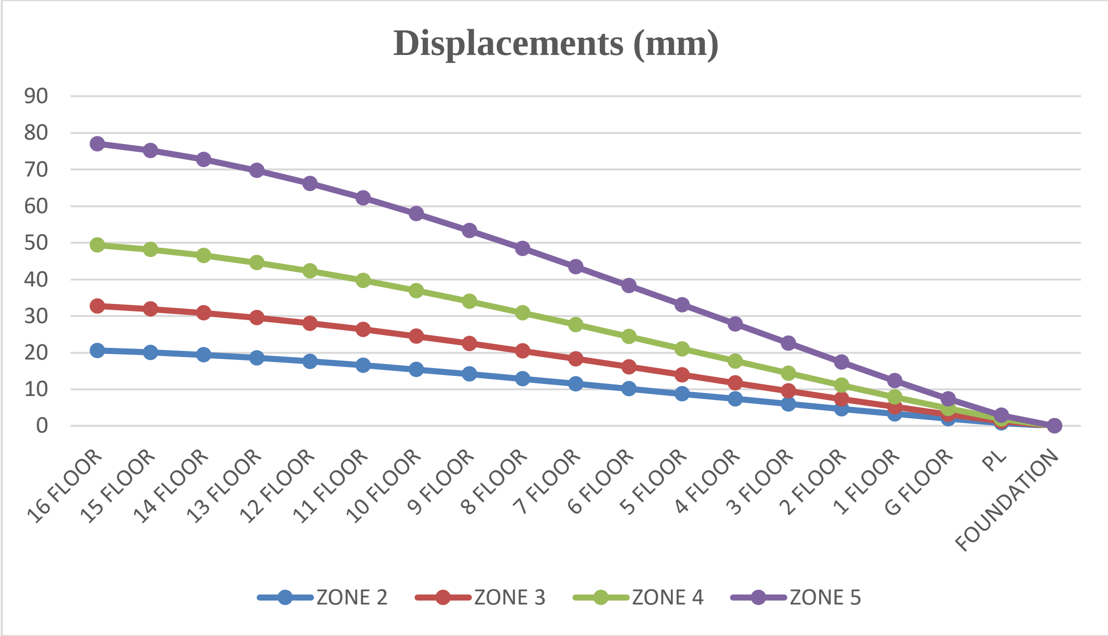

Fig.10. Comparison of Displacements of C Shaped plan of Composite Structure in all Zones.

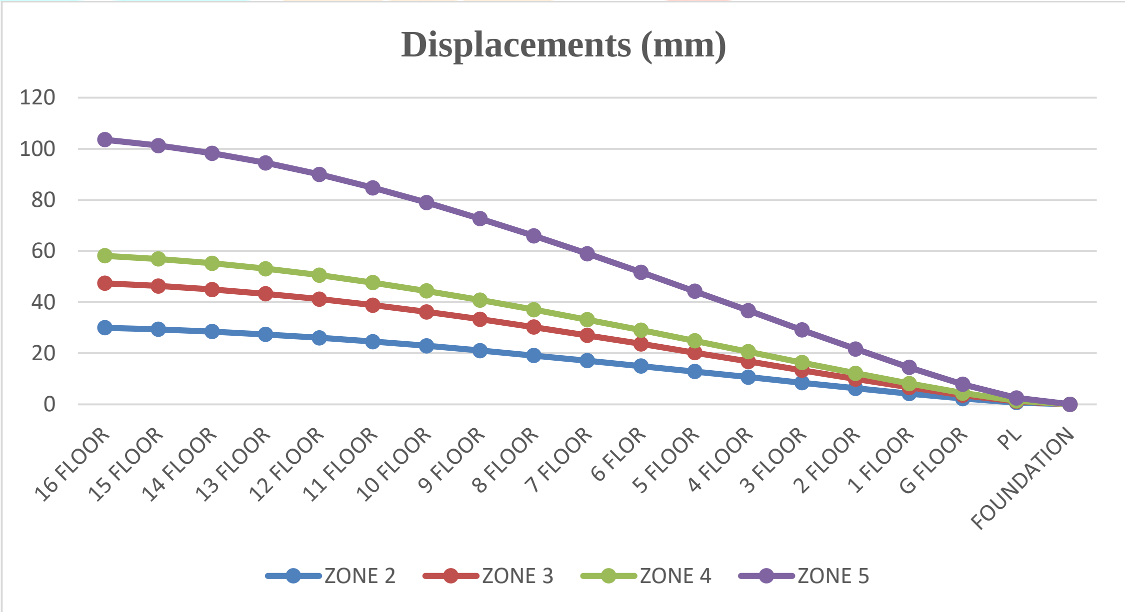

Fig.11. Comparison of Displacements of H Shaped plan of Composite Structure in all Zones.

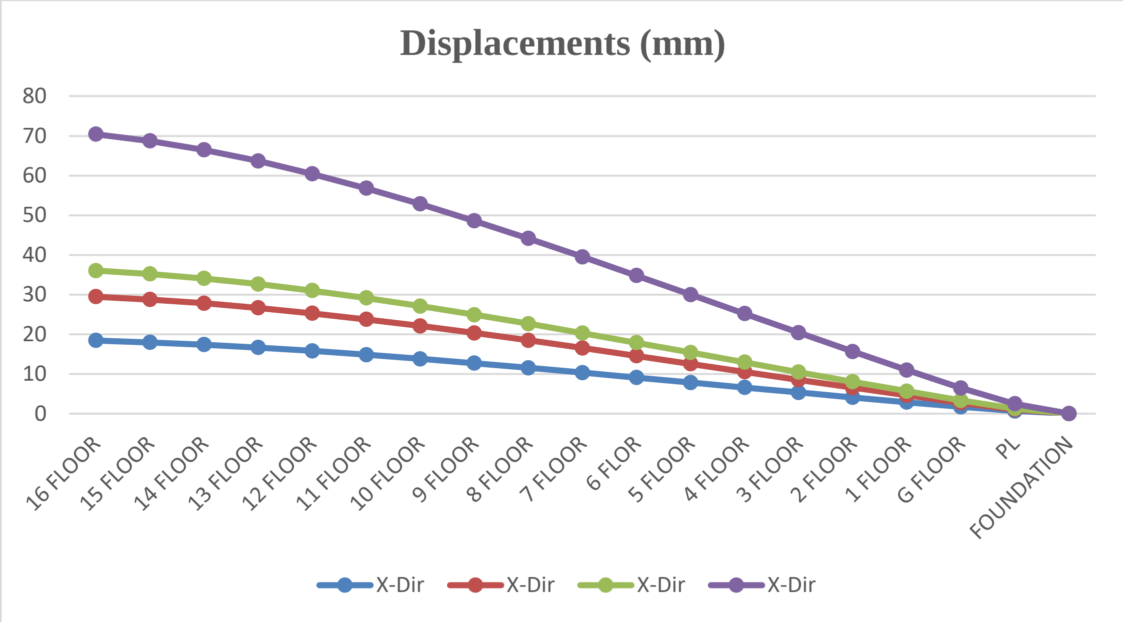

Fig.12. Comparison of Displacements of H Shaped plan of Composite Structure in all Zones.

In Fig.9 and Fig.10, In Seismic Zone II Displacement in Composite structure at top storey is 20.575mm and that in RCC structure is 32.255mm. So, the Displacement in Composite structure is reduced by 63.78% than that in RCC structure. In Seismic Zone III Displacement in Composite structure at top storey is 32.735mm and that in RCC structure is 51.873mm. So, the Displacement in Composite structure is reduced by 63.10% than that in RCC structure. In Seismic Zone IV Displacement in Composite structure at top storey is 49.38mm and that in RCC structure is 75.283mm. So, the Displacement in Composite structure is reduced by 65.55% than that in RCC structure. In Seismic Zone V Displacement in Composite structure at top storey is 77.045mm and that in RCC structure is 113.178mm. So, the Displacement in Composite structure is reduced by 68.07% than that in RCC structure.

In Fig.11 and Fig.12, In Seismic Zone II Displacement in Composite structure at top storey is 18.412mm and that in RCC structure is 32.255mm. So, the Displacement in Composite structure is reduced by 63.78% than that in RCC structure. In Seismic Zone III Displacement in Composite structure at top storey is 29.5mm and that in RCC structure is 47.4mm. So, the Displacement in Composite structure is reduced by 62.23% than that in RCC structure. In Seismic Zone IV Displacement in Composite structure at top storey is 36.06mm and that in RCC structure is 58.16mm. So, the Displacement in Composite structure is reduced by 62% than that in RCC structure. In Seismic Zone V Displacement in Composite structure at top storey is 70.43mm and that in RCC structure is 103.548mm. So, the Displacement in Composite structure is reduced by 68% than that in RCC structure.

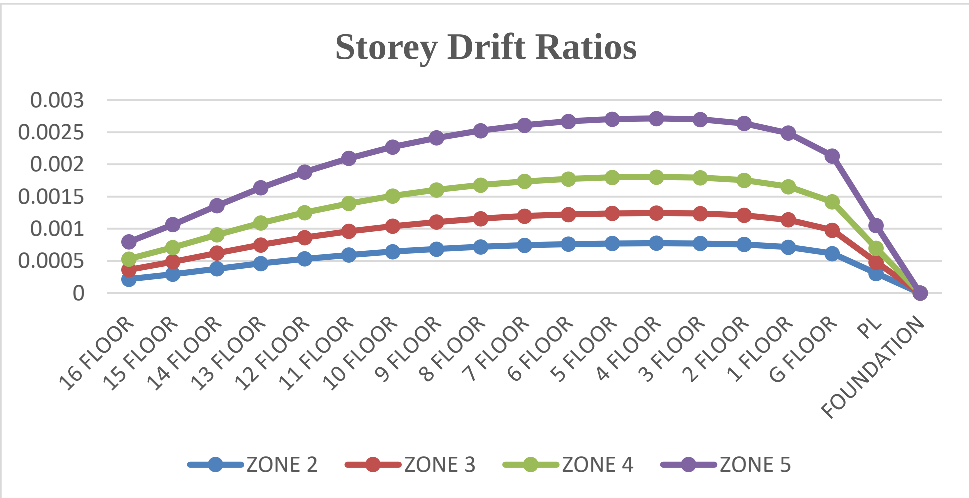

Fig.13. Comparison of Storey Drifts of C Shaped plan of Concrete Structure in all Zones.

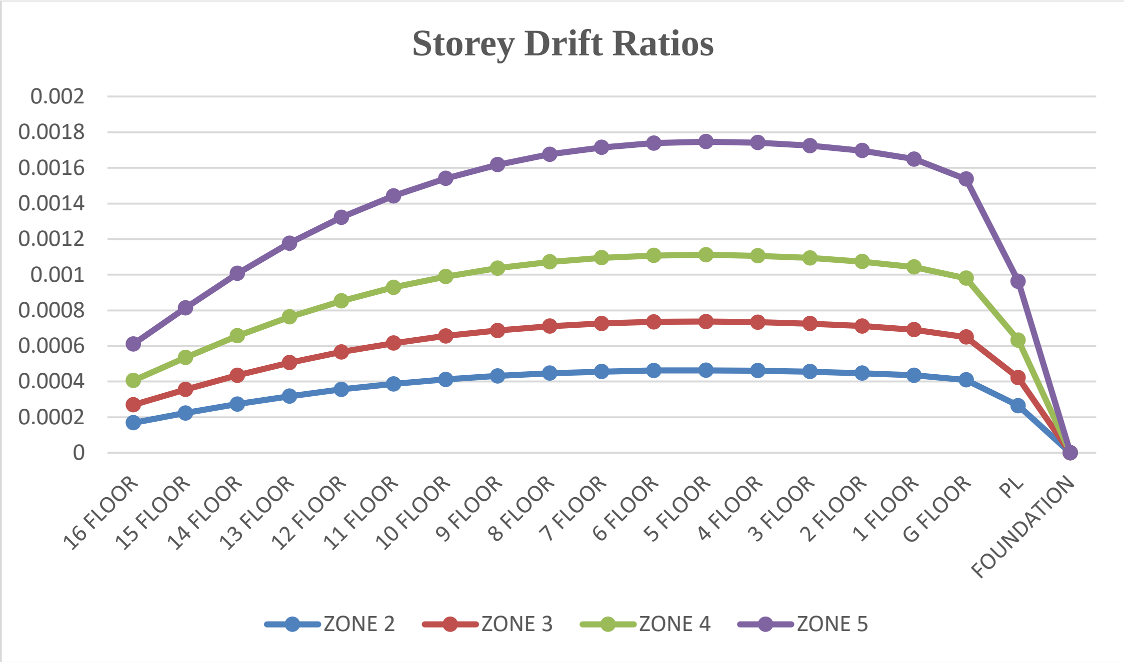

Fig.14. Comparison of Storey Drifts of C Shaped plan of Composite Structure in all Zones.

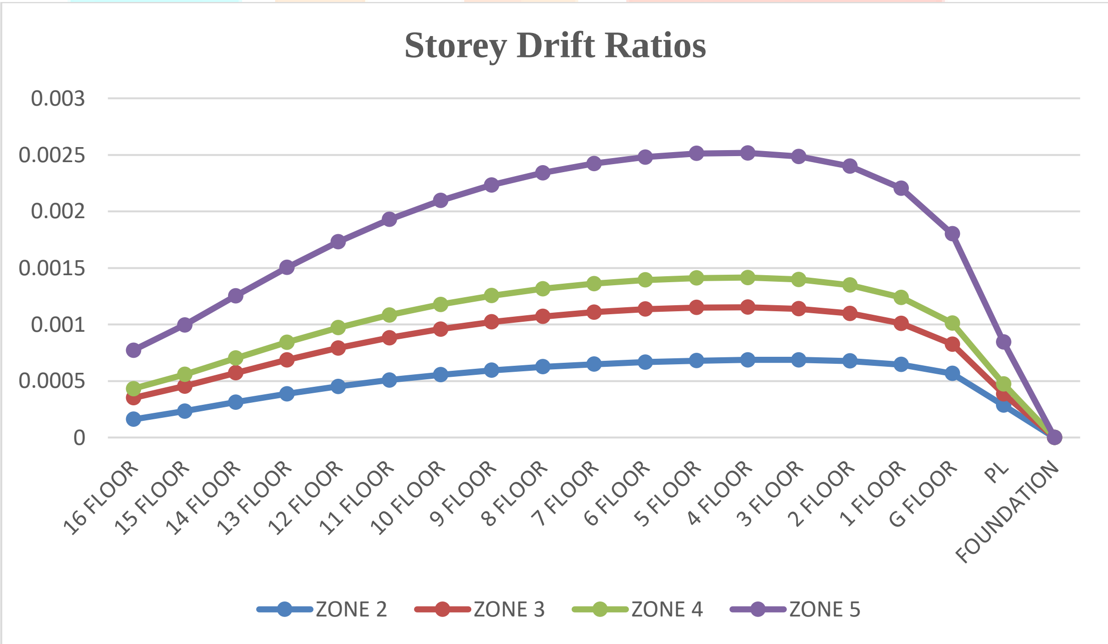

Fig.15. Comparison of Storey Drifts of H Shaped plan of Concrete Structure in all Zones.

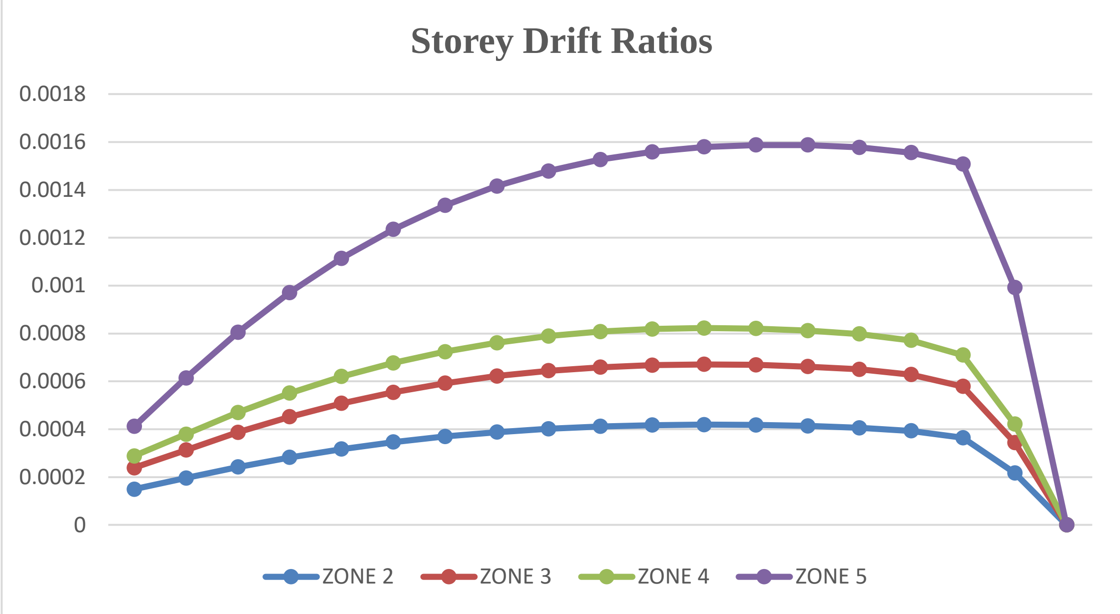

Fig.16. Comparison of Storey Drifts of H Shaped plan of Composite Structure in all Zones.

In Fig.13 and Fig.14**,** By studying the result shows that the inter storey drift follows the similar pattern. We can also observe that the as Seismic zone increases the Inter-storey values goes on increases and decreases as height increases. Though they follow similar patterns the result shows that the inter-storey drift for composite structure is comparatively less than RCC structure in both transverse (Y) and longitudinal direction (X) in all seismic zones. Maximum Drift ratios are observed at Storey 5 in RCC structure and at Storey 5 in Composite Structure and we can see the Inter-storey drift ratio is much lesser in the Composite Structure.

In Fig.15 and Fig.16, By studying the result shows that the inter storey drift follows the similar pattern. We can also observe that the as Seismic zone increases the Inter-storey values goes on increases and decreases as height increases. Though they follow similar patterns the result shows that the inter-storey drift for composite structure is comparatively less than RCC structure in both transverse (Y) and longitudinal direction (X) in all seismic zones. Maximum Drift ratios are observed at Storey 5 in RCC structure and at Storey 5 in Composite Structure and we can see the Inter-storey drift ratio is much lesser in the Composite Structure.

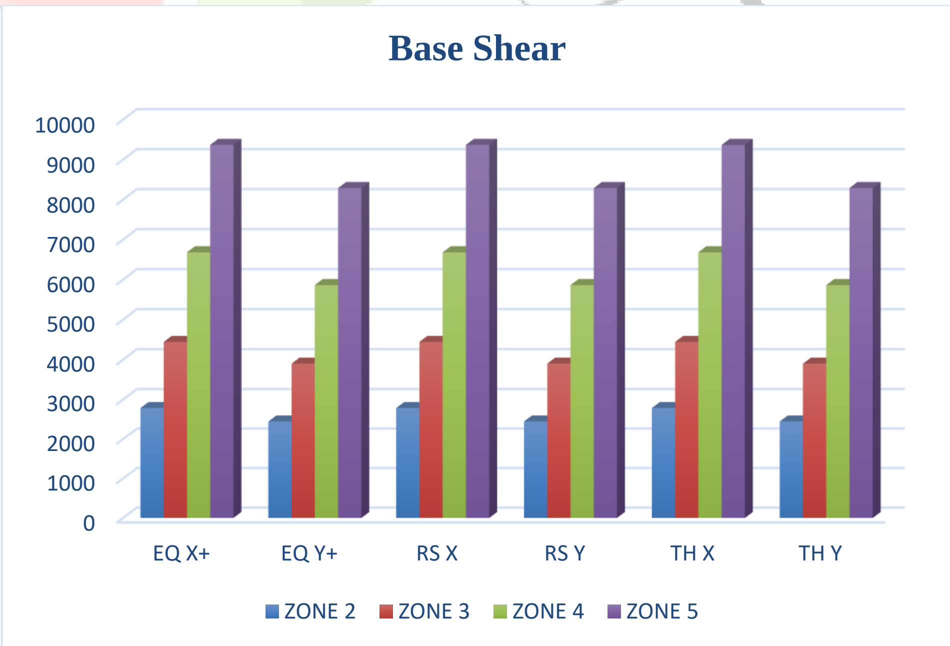

Fig.17. Comparison of Base Shear of C plan Concrete Structure in all zones.

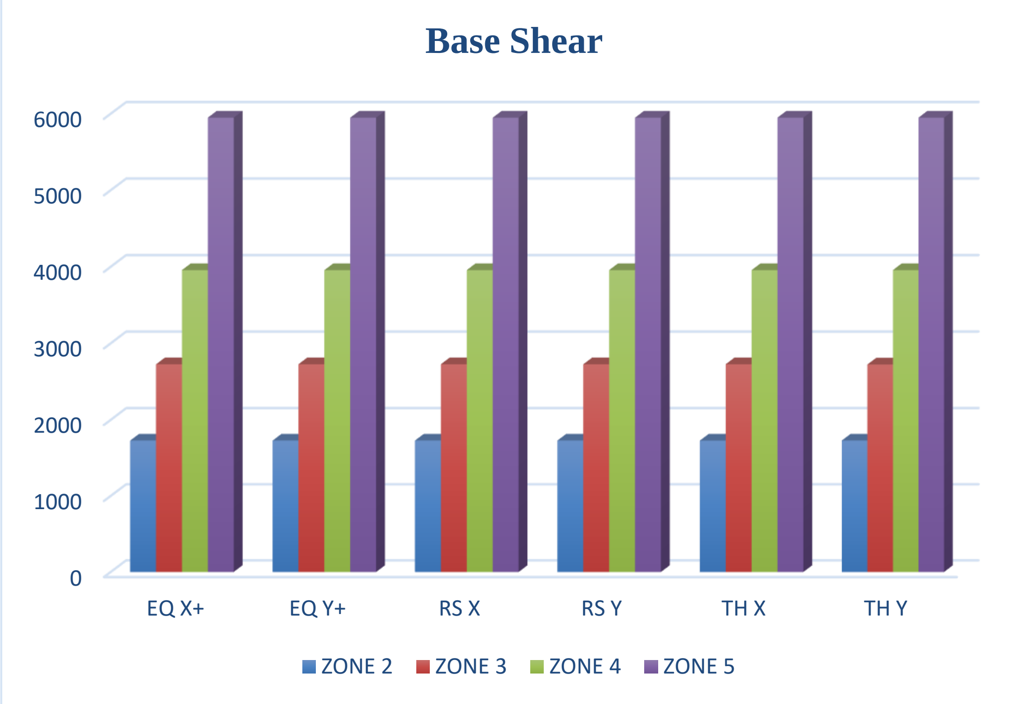

Fig.18. Comparison of Base Shear of C plan Composite Structure in all zones.

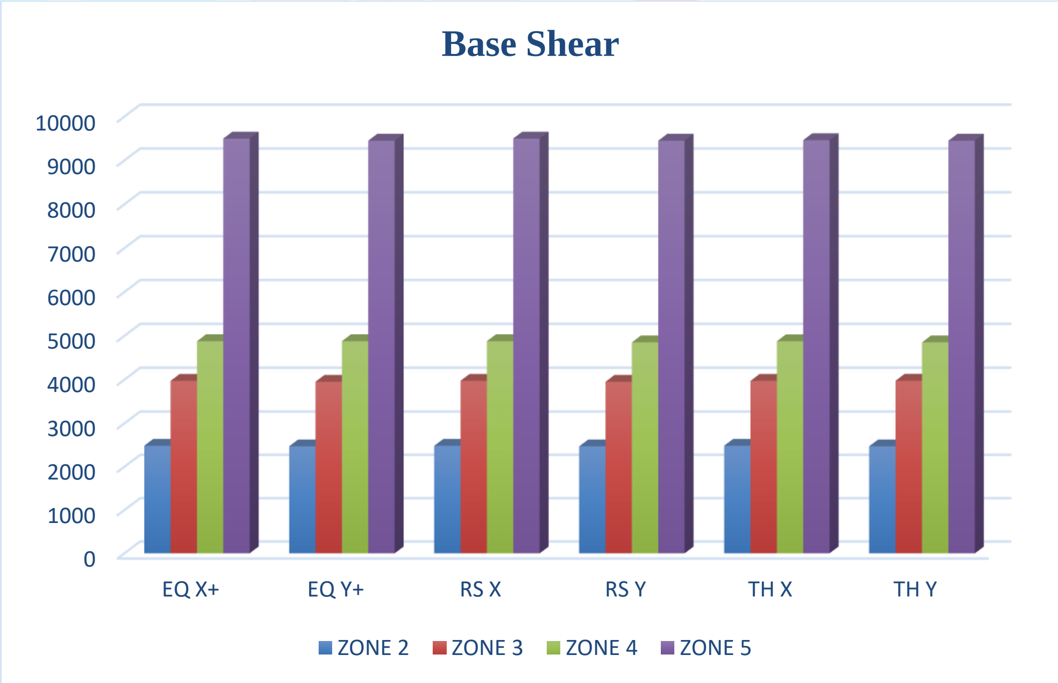

Fig.19. Comparison of Base Shear of H plan Concrete Structure in all zones.

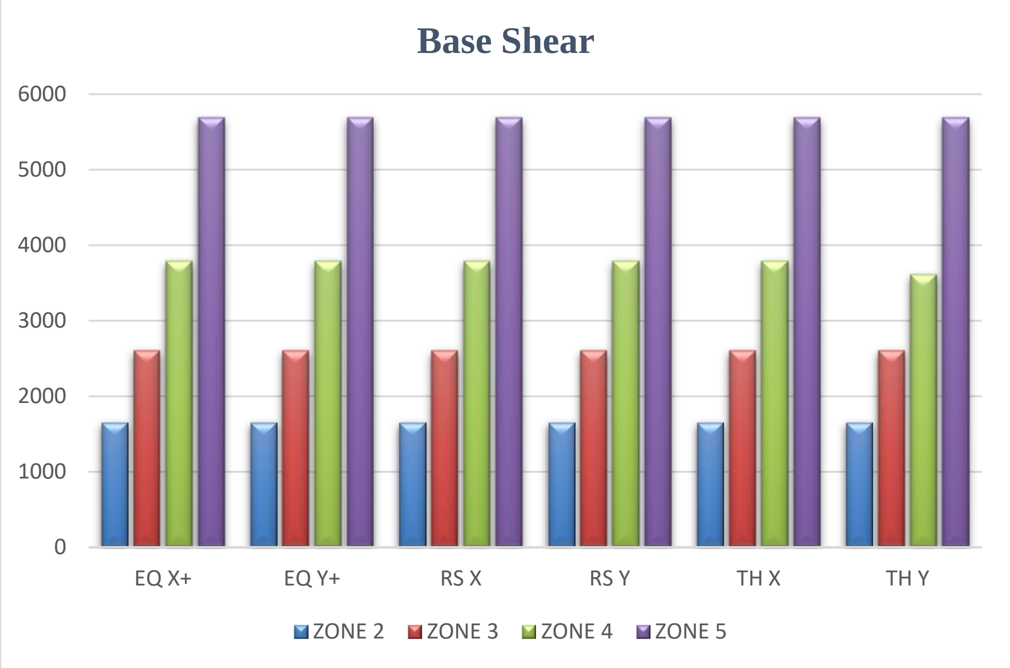

Fig.20. Comparison of Base Shear of H plan Composite Structure in all zones.

In Fig.17, Fig.18, Fig.19, and Fig.20 By studying we can see that the Base Shear values in C shaped Plan RCC structure are more compared to the values in C shaped Plan Composite structure in all the four seismic zones. RCC buildings are typically much heavier than buildings made from materials like steel or wood due to the high density of concrete. The weight of the building directly influences the base shear, as it is proportional to the building's mass. For Seismic calculation, since V_b is proportional to the weight of the building, a heavier structure (like an RCC building) will have a higher base shear compared to lighter buildings. For evaluating the Base shear values ETABS is used and three methods were followed Equivalent method, Response Spectrum method and Time History method. As Seismic Zones are increasing the Base Shear values are increasing because base shear is the total horizontal force that acts at the base of a structure due to lateral loads such as those induced by wind, earthquakes, or other dynamic forces. It is a crucial component in seismic and wind load analysis, as it helps in determining the overall stability of a building during these events. The above Tables and Graphs shows the Base shear values in both longitudinal direction(X) and transverse direction(Y). The maximum Base Shear value is 9498.786kN in C shaped plan in RCC structure and the maximum Base Shear value is 5692.422kN in C shaped plan in Composite structure and we can observe that the RCC structure has more base shear because mainly Base Shear depends on the mass (Seismic Weight) of the building.

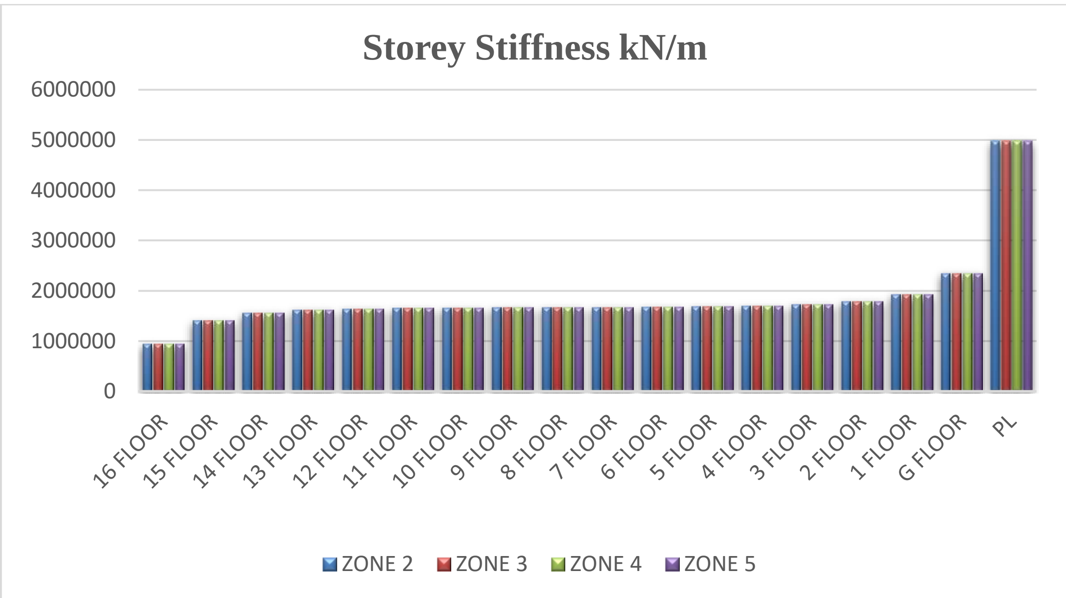

Fig.21. Comparison of Storey Stiffness values of C plan Concrete Structure in all zones.

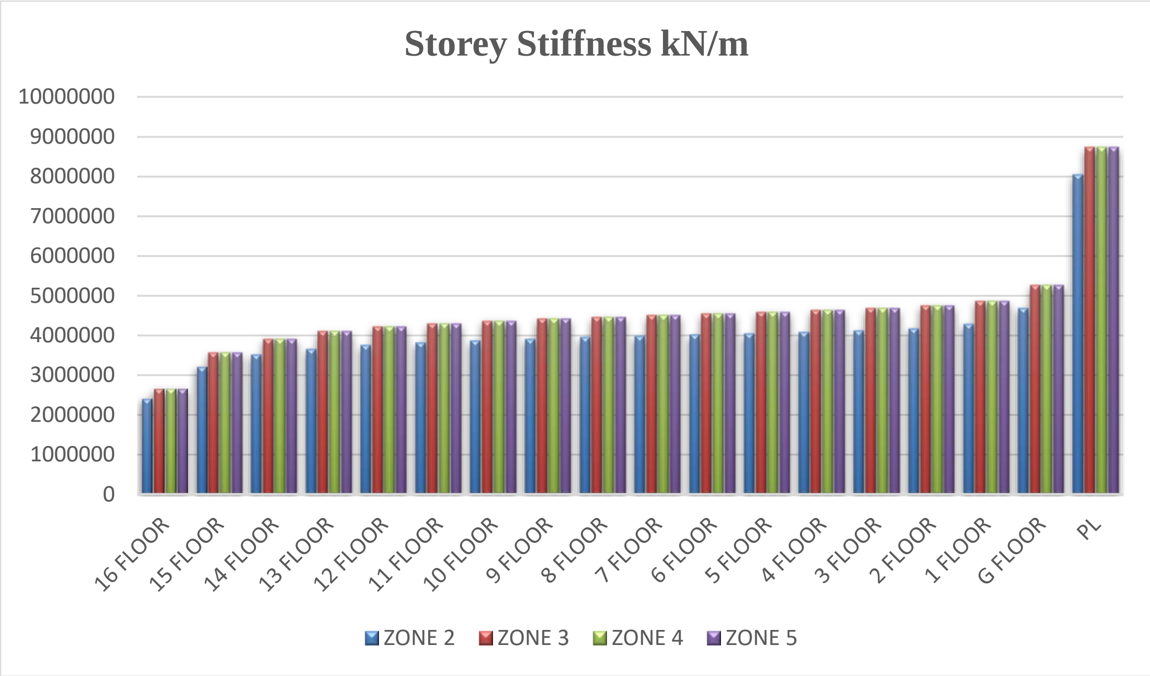

Fig.22. Comparison of Storey Stiffness values of C plan Composite Structure in all zones.

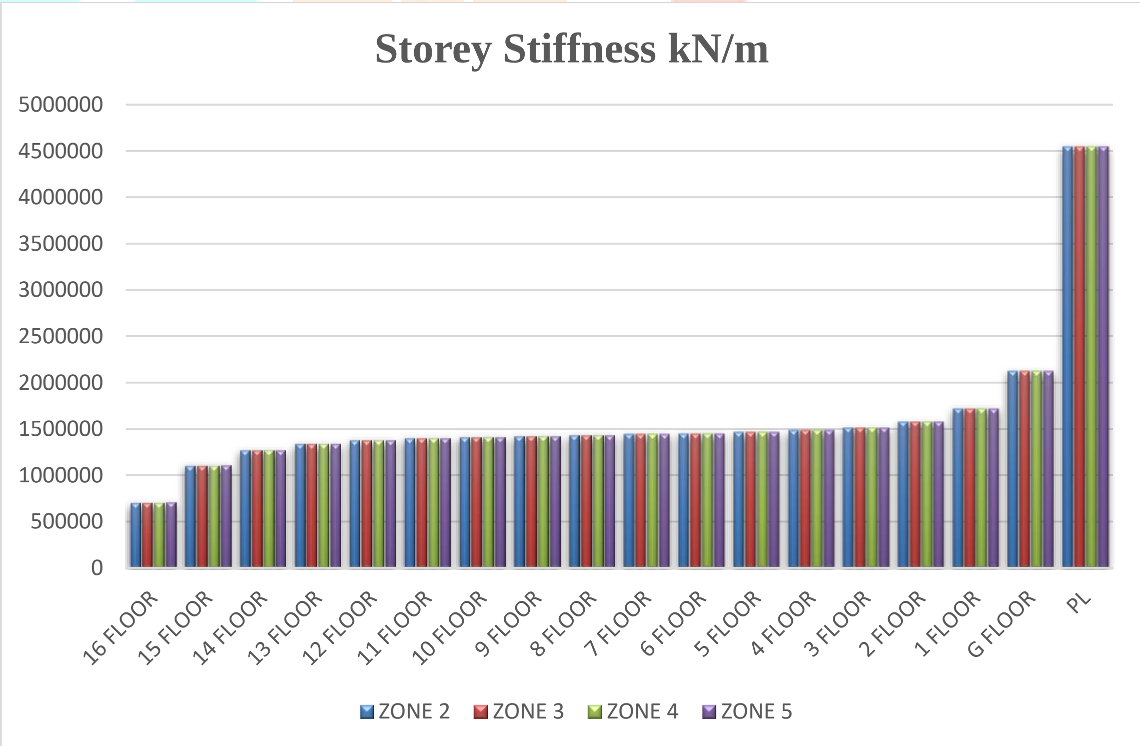

Fig.23. Comparison of Storey Stiffness values of H plan Concrete Structure in all zones.

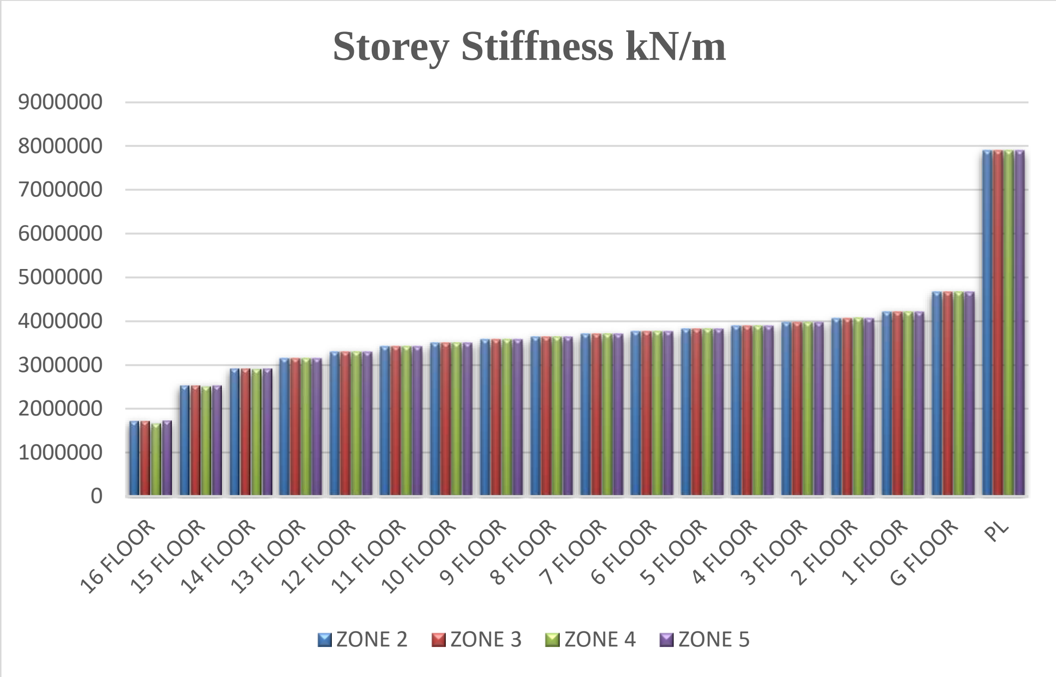

Fig.24. Comparison of Storey Stiffness values of H plan Composite Structure in all zones.

In Fig.21, Fig.22, Fig.23 and Fig.24, By studying we can observe that storey stiffness values are more for H shaped plan Composite structure than H shaped plan RCC structure. As we know the Stiffness indirectly proportional to the deflection of the structure, more the stiffness less the deflection. From above point we can understand that the Composite structure have more stiffness values then the RCC structure which says that the Composite structure is more resistant to forces than the RCC structure. One of the primary reasons for ensuring adequate stiffness in a structure is to control deflection (bending or displacement under load). Excessive deflection can affect the functionality, aesthetics, and safety of a building or structure. For instance, excessive bending in a beam or slab can cause cracks, misalignments of doors and windows, or operational issues in equipment. From above tables and figures we can conclude that the stiffness value in composite structure in all seismic zones is high compared to RCC structure. The maximum stiffness value for H shaped plan Composite structure in Zone II is 7897836 kN/m, Zone III is 7897836 kN/m, Zone IV is 7898395 kN/m and in Zone V is 7897777 kN/m. The maximum stiffness value for H shaped plan RCC structure in Zone II is 4546053 kN/m, Zone III is 4546049 kN/m, Zone IV is 4546049 kN/m and in Zone V is 4545985 kN/m.

5. CONCLUSIONS.

The following are the major conclusions drawn from the analysis of seismic behavior multistoried C-Shaped and H-Shaped RCC structure and Composite structure for all four Seismic Zones as per IS 1893: 2016.

1. Composite structures in H-Shaped configuration experience a 68% reduction in drift, with higher lateral stiffness than RCC structures, which have a 65% drift reduction.
2. Storey stiffness in composite structures with H-Shaped configuration is 59% higher, compared to a 56% increase in RCC structures with C-Shaped configuration.
3. Base shear in composite structures with H-Shaped configuration increases by 39%, while it increases by 32% in RCC structures, driven by the seismic weight of the structure.
4. By examining all the models and concluding H-Shaped composite structures show significantly reduced displacements compared to C-Shaped RCC structures due to symmetry along both axes.

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