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Comparative Study of the Seismic Performance of Multi-storey Buildings with Different Structural Systems

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Abstract: As per the previous records of earthquakes, there is an increase in the demand of earthquake resistance structures. So it is necessary to design and analyse the structure by considering seismic effect. To resist the seismic forces different structural systems are commonly used in multi-storey buildings. The aim to this work is to determine to most effective RC frame of 32-storyed and 64-storyed structure with lateral load resisting system such as Frame, Frame Tube, Braced Tube, Diagrid, Tube-in-tube, and Shear Wall-frame, Outrigger Structures. The behaviour of RC frame with different structural systems has been studied and conclusions are made by comparing Base shear, maximum storey drift, top storey displacement, top drift, time period as per IS1893-2016 (Part-1). The building is modelled and analysed using software ETABS 21.
Keywords: Frame, Frame Tube, Braced Tube, Diagrid, Tube-in-tube, Shear Wall-frame, Outrigger Structures, Dynamic Method (Response Spectrum Method and Time History Method), Story drift, Displacement, Etabs

I. INTRODUCTION

With the continuous increase in global population, there has been a significant rise in land usage. This phenomenon is referred to as urban expansion. Urban expansion poses several environmental challenges, such as increased air pollution and higher energy consumption. To accommodate the growing population while minimizing these adverse effects, the construction of high-rise or tall buildings becomes essential. To ensure the stability and safety of tall structures, especially under lateral forces, different structural systems are implemented. These include rigid frame structures, braced frame structures, shear wall systems, diagrid structures, outrigger systems, and tubular structures. One of the major concerns in the design of high-rise buildings is their performance during earthquakes. Earthquakes generate substantial horizontal forces that can severely damage structural components, potentially leading to collapse. To prevent such failures, it is crucial to incorporate lateral force-resisting systems into the design. These systems not only enhance the building's resistance to seismic and wind forces but also provide the necessary stiffness and strength to withstand both vertical and lateral loads. In this study investigate and compares the Base shear, maximum storey drift, top storey displacement, top drift, time period of RC frame of 32-storyed and 64-storyed structure with lateral load resisting system such as Frame, Frame Tube, Braced Tube, Diagrid, Tube-in-tube, and Shear Wall-frame, Outrigger Structures. The building is modelled and analysed using software ETABS 21. Non-linear Dynamic Analysis (Time History Analysis) is carried out for different structural systems and Base shear, maximum storey drift, top storey displacement, top drift, time period is calculated and compared.

II. STRUCTURAL MODELING

A. Geometrical Properties of Building

Table-1 Geometrical Properties of Building

S.No.	Particular	Dimensions
1	Building Plan Area	900 square meter
2	Typical Storey Height	3 metre
3	Column Cross Section Size	1000x1000mm
4	Beam Cross Section Size	300x600mm
5	Diagrid Cross Section Size	600x600mm
6	Bracing Cross Section Size	600x600mm
7	Shear Wall Thickness	300mm
8	Slab Thickness	200mm
9	Beam-Column Joint	Rigid
10	Beam –Diagrid Joint	Pinned
9	Foundation	Fixed at ground level

B. Material Properties of Buildings

Table-2 Geometrical Properties of Building		
S.No.	Material	Grade
1	Concrete(beam, bracing, column, diagrid)	M30
2	Concrete(shear wall)	M30
3	Concrete(slab)	M30
4	Reinforcement(rebar)	HYSD-500

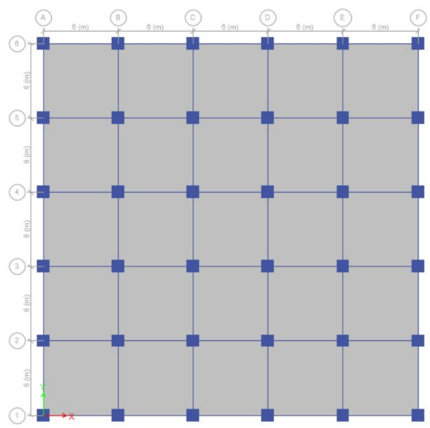

Fig-1 Typical Braced Frame plan/ Conventional Frame plan

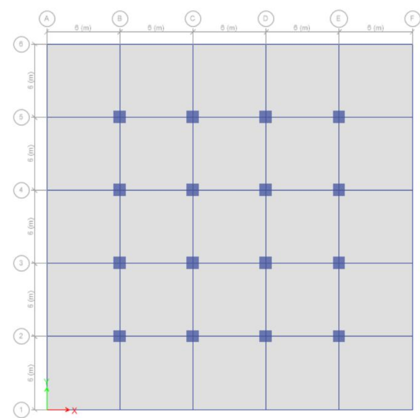

Fig-2 Typical Diagrid Frame plan

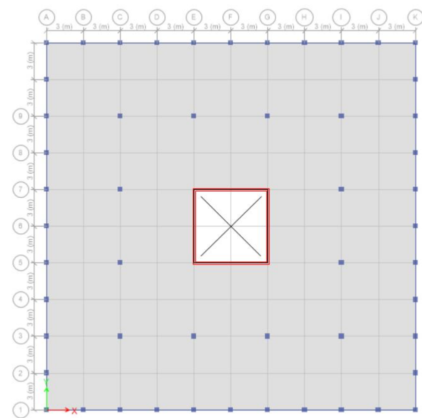

Fig-3 Typical Frame Tube plan

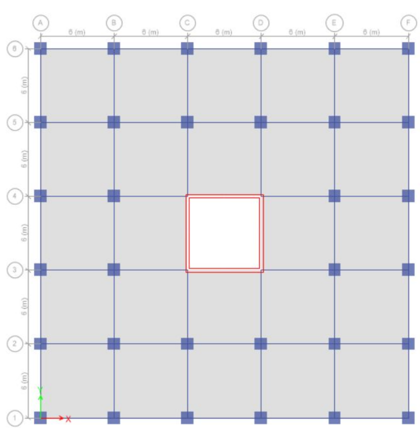

Fig-4 Typical Outrigger plan/ Typical Shear wall Frame plan

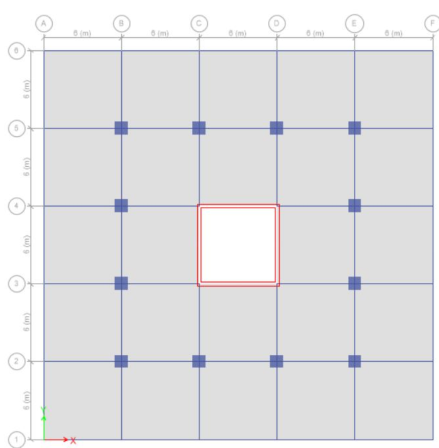

Fig-5 Typical Tube in Tube Frame plan

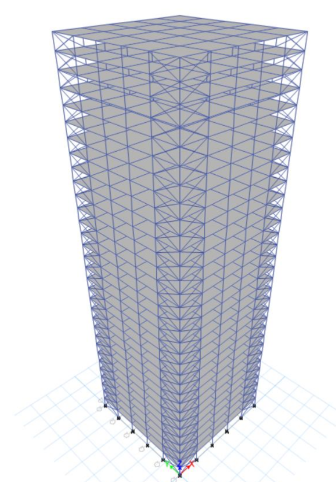

Fig-6 32-Stoery Braced Frame 3D view

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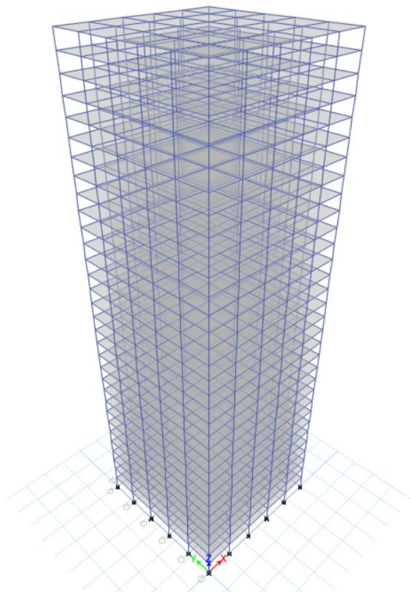

Fig-7 32-Stoery Conventional Frame 3D

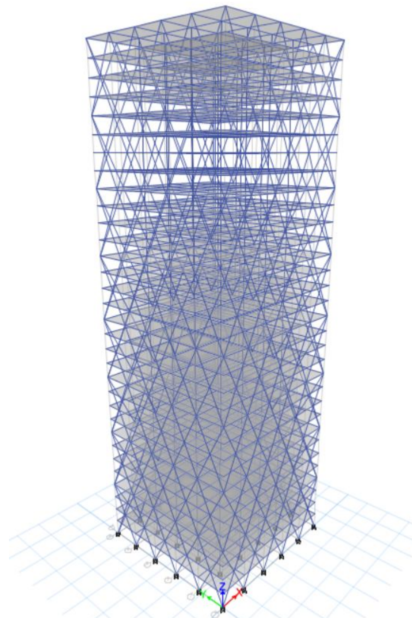

Fig-8 32-Stoery Diagrid Frame 3D view

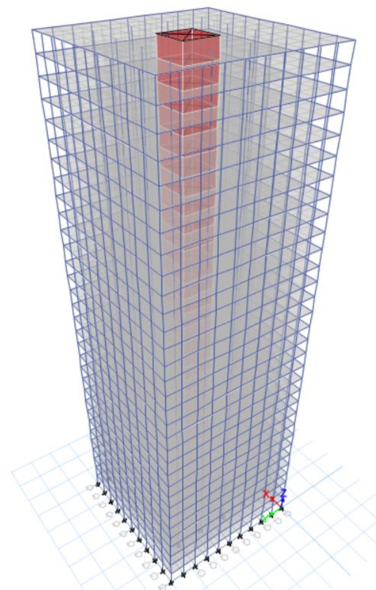

Fig-9 32-Stoery Frame Tube 3D view

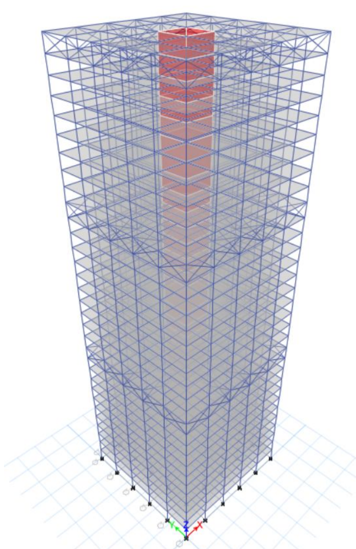

Fig-10 32-Stoery Outrigger 3D view

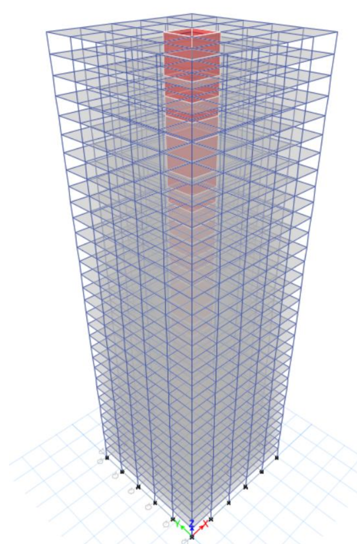

Fig-11 32-Stoery Shear wall Frame 3D view

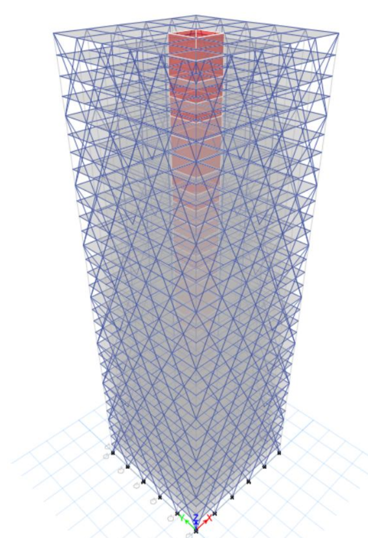

Fig-12 32-Stoery Tube in Tube Frame 3D

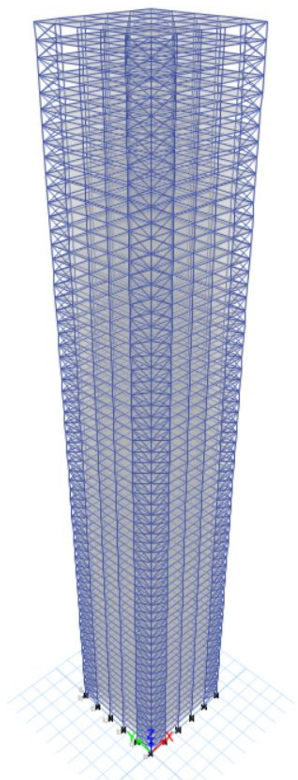

Fig-13 64-Stoery Braced Fame 3D view

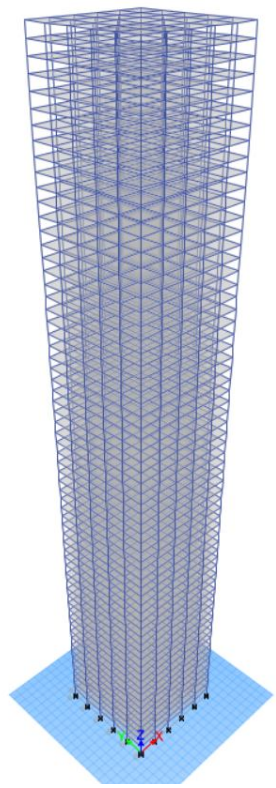

Fig-14 64-Stoery Conventional Fame 3D view

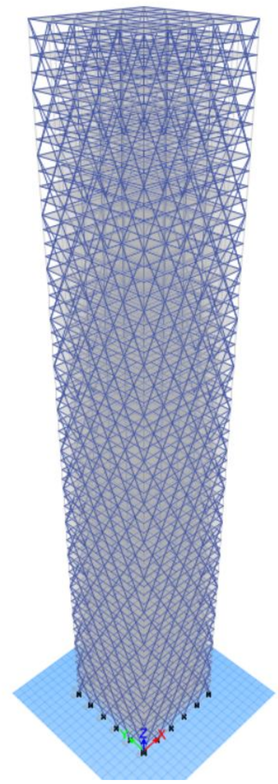

Fig-15 64-Stoery Diagrid Fame 3D view

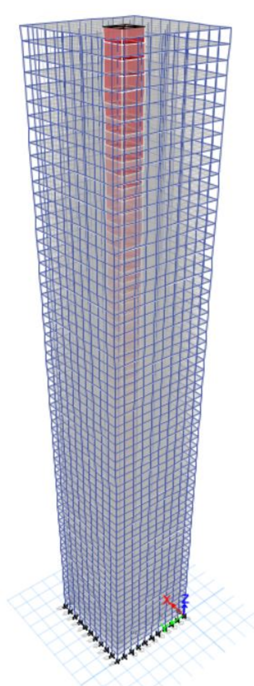

Fig-16 64-Stoery Frame Tube 3D view

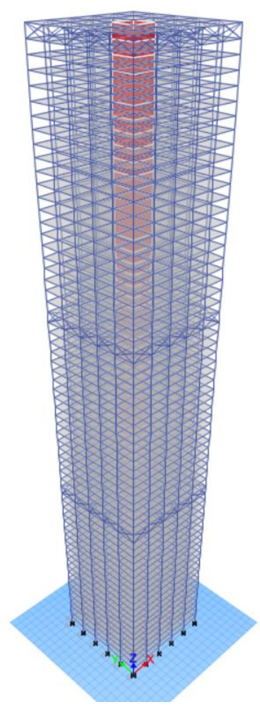

Fig-17 64-Stoery Outrigger 3D view

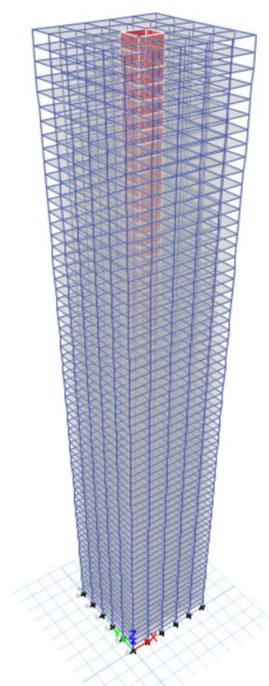

Fig-18 64-Stoery Shear wall Frame 3D view

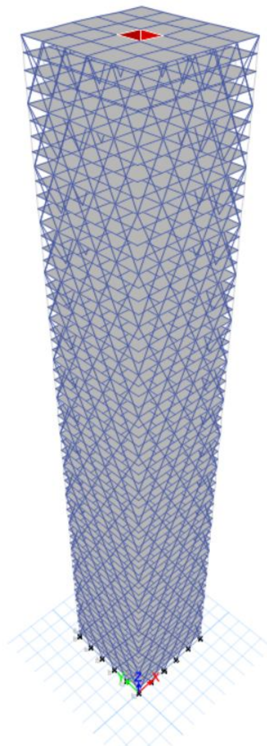

Fig-19 64-Stoery Tube in Tube Frame 3D

III. TIME HISTORY ANALYSIS ETABS

1) Time History Analysis: It is an analysis of dynamic response of the structure at each instant of time, when its base is subjected to a specific ground motion time history.
2) Loads: All loads action on the building except wind load were considered. These are-
   - Dead load (member self-weight)
   - Live load (as per IS 875 part-2-1987)
   - Lateral load due to earthquake (as per IS 1893 part-1-2016)
3) Member loading:
   a. Self-weight (software calculated)
   b. Live load: 3KN/m^2
   c. Earthquake load in X and Y direction. Table 3 shows the seismic data.

Table-3 Seismic data		
1	Earthquake zone	2
2	Importance factor	1
3	Type of soil	Soft
4	Response reduction factor	5
5	Time period	Program calculated
6	Damping ratio	5%
7	Time history data	Bhuj india

IV. ANALYSIS RESULTS

The analysis of all the models has been done and results are shown below the parameter which were studied are on the behavior of the building during seismic excitation are Base shear, maximum storey drift, top storey displacement, top drift, time period.

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A. Base Shear

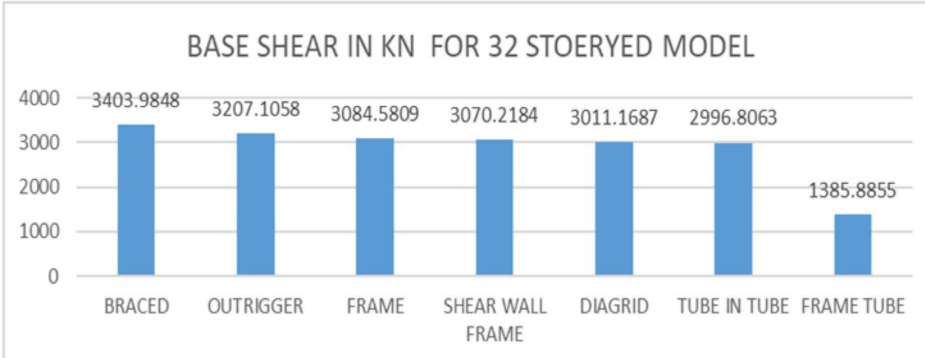

Fig-20 32-Stoery Base Shear.

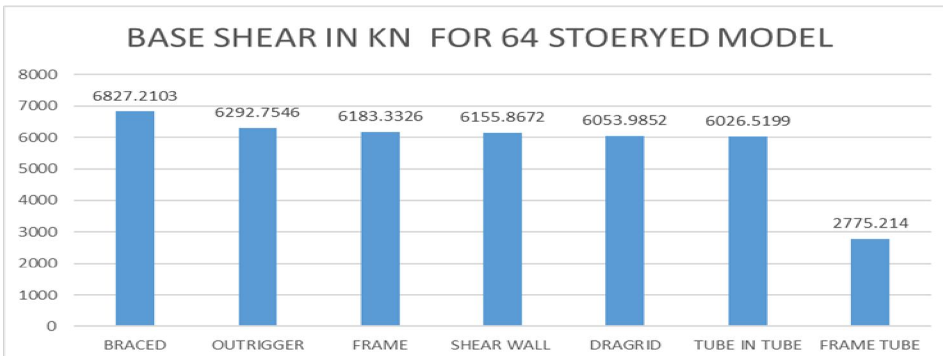

Fig-21 64-Stoery Base Shear.

B. Maximum Storey Drift

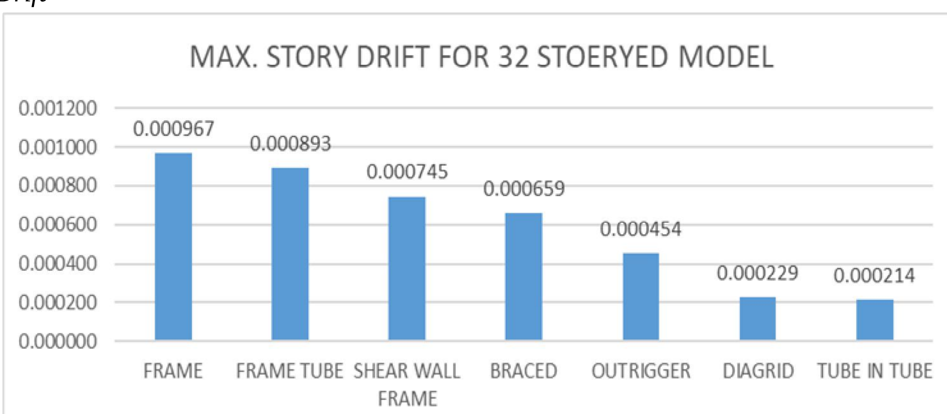

Fig-22 32-Stoery maximum story drift.

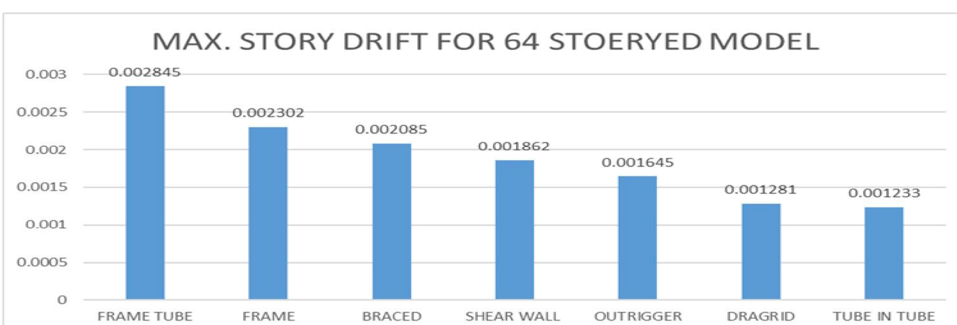

Fig-23 64-Stoery maximum story drift.

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C. Top Stoery Displacement

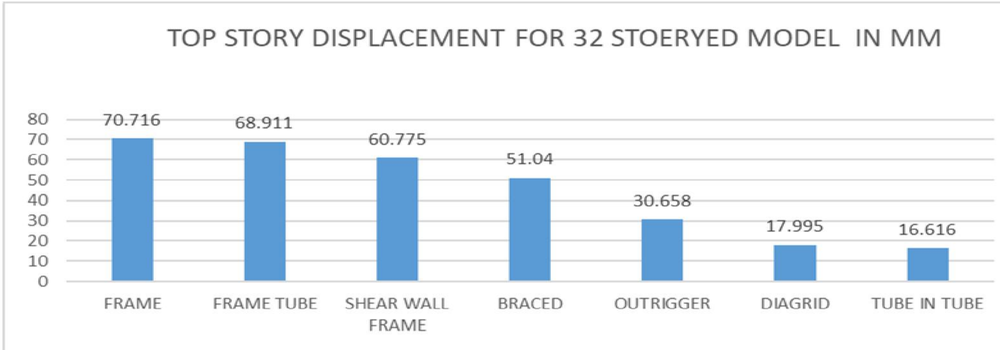

Fig-24 32-Stoery top story drift.

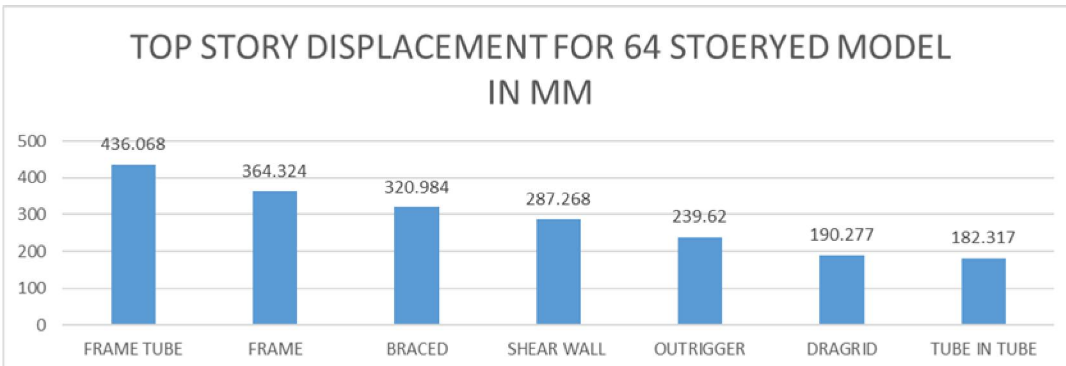

Fig-25 64-Stoery top story drift.

D. Top Drift

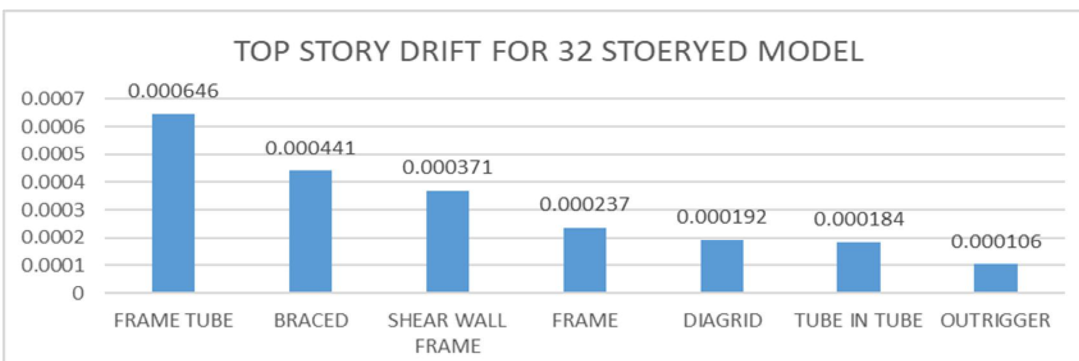

Fig-26 32-Stoery top story drift.

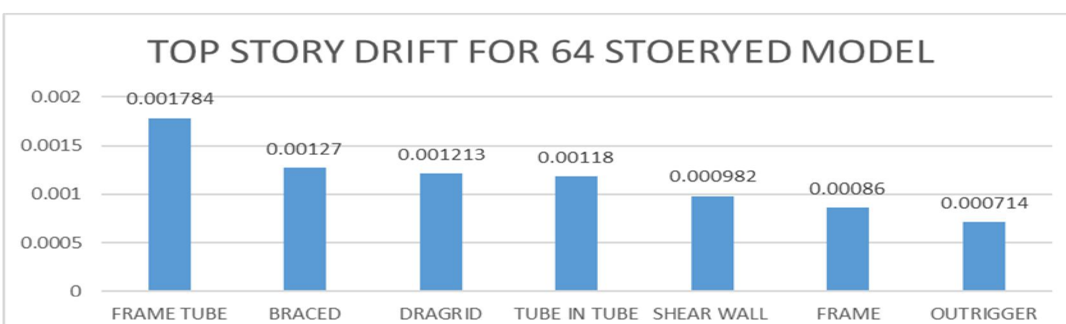

Fig-27 64-Stoery top story drift.

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E. Time Period

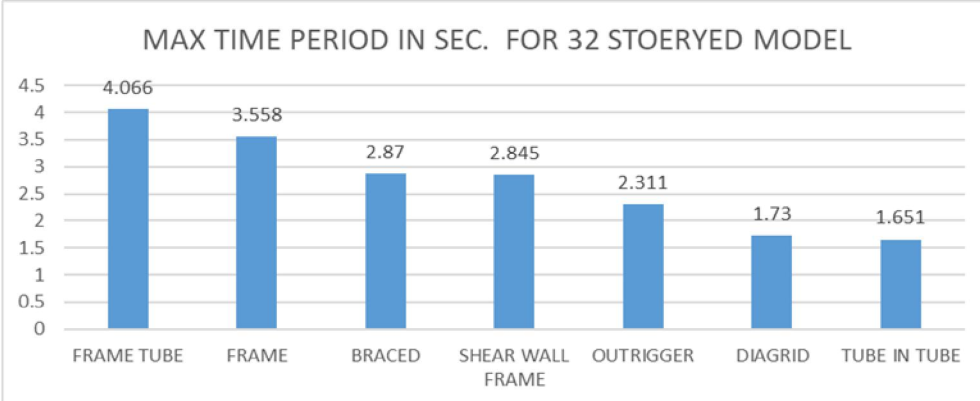

Fig-28 32-Stoery time period

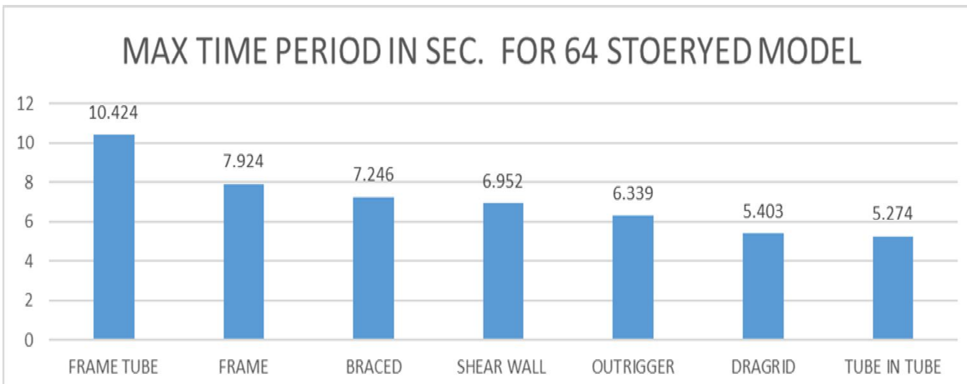

Fig-29 64-Stoery time period

V. CONCLUSIONS

1) Outrigger and Braced Systems exhibit very high flexibility in some cases, which might not be ideal unless well-controlled through damping or other seismic measures. They are effective in limiting drift but may need careful detailing to avoid excessive displacements or resonances.
2) Diagrid and Tube-in-Tube Systems show shorter time periods, suggesting high stiffness and better control over lateral displacements-suitable for tall buildings in high seismic zones.
3) Shear Wall Frame and Frame Tube Systems provide a balanced seismic response, making them reliable for medium- to high-rise buildings with moderate-to-high seismic demand.
4) The presence of multiple entries with widely varying time periods for the same system indicates that design variations (geometry, material properties, damping ratios) significantly influence seismic behavior.

While in comparision with 64 storey models-
a) Braced, Frame, and Outrigger systems show the highest increase in time periods, suggesting these are most impacted by height and may need additional seismic damping or energy dissipation systems in taller configurations.
b) Tube in Tube and Frame Tube systems maintain relatively lower time periods, indicating higher stiffness and potential for better seismic performance in controlling drift and reducing base shear.
c) Systems like Shear Wall and Diagrid (or Diagrid) are known for stiffness and lateral strength, and their performance in tall structures reinforces their value in seismic design.

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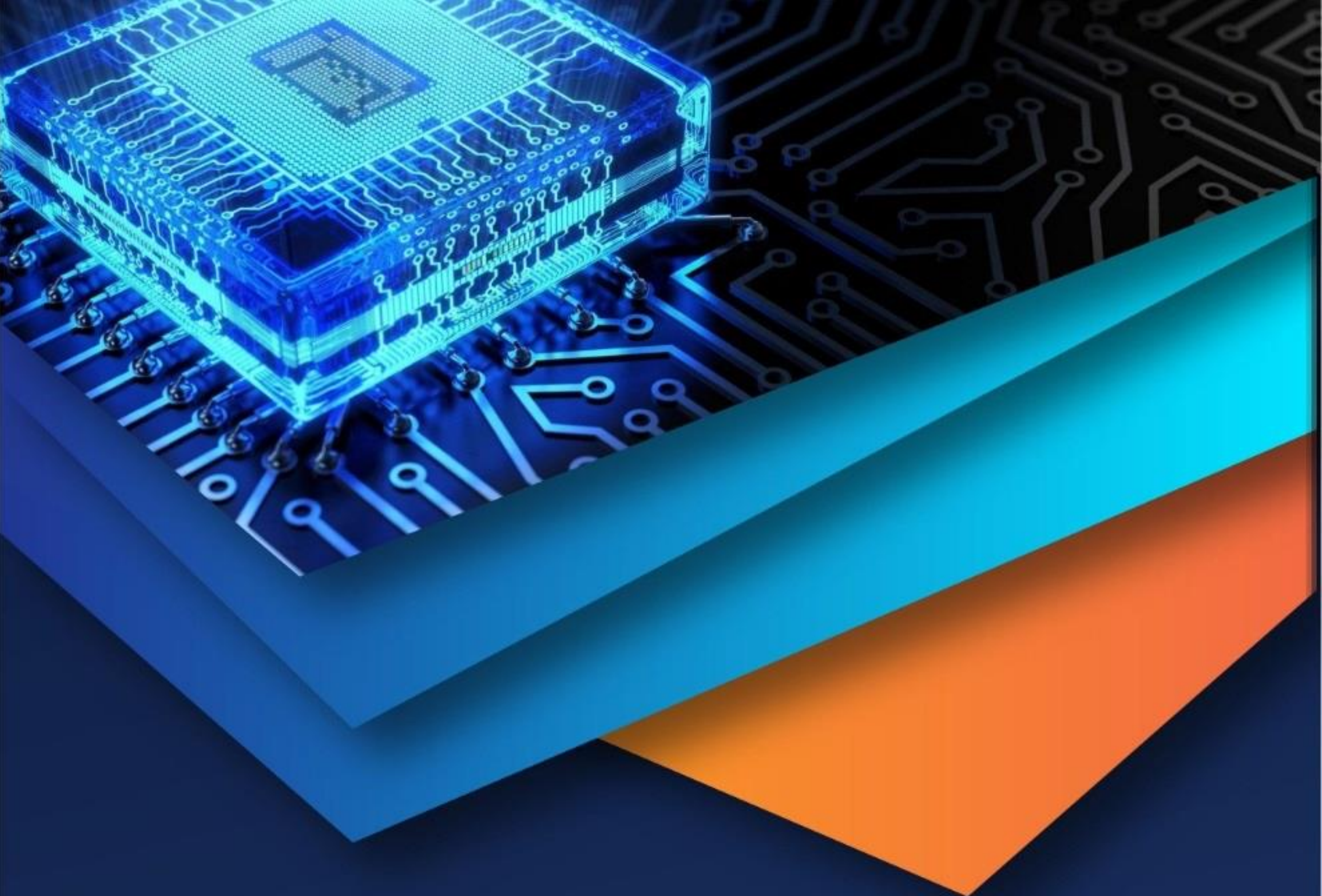

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