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An Analytical Study of Flat Slab and Convention Slab with Framed Tube System by Performing Time History Analysis

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Abstract: ***To study seismic demand for regular reinforced concrete frame of flat slab with drop and conventional slab structure by using framed tube structural system by performing time history analysis. The performance of these slabs on 30 storey building will be studied for the analysis, seismic zone (v) will be considered. It is a type of linear dynamic analysis, in which the strength of the structure is tested within the elastic limit of the structure. In this project, high rise building of 30 of area 1296sq.m along with framed tube subjected to earthquake loading are analysed by time history analysis using ETABS software. The dynamic parameters such as base shear, story displacements, and story drift and time period of flat slab building with framed tube is being studied and compared to conventional slab.***
Keywords: High-rise building, Framed tube, Time history analysis.

I. INTRODUCTION

Previously, buildings were only intended to withstand gravity stresses and could not withstand lateral loads. There has been a significant growth in the number of high-rise buildings during the previous two decades, and the present trend is towards high-rise constructions. With the rise in height of tall buildings, lateral loads become more important. The most frequent loads that occur from gravity's action are dead load, living load, and snow load. Wind and earthquakes produce lateral loads on buildings. High stresses emerge as a result of lateral loads, resulting in sway movement or vibrations. To resist lateral load in reinforced concrete buildings, structural components such as columns, beams, and slabs are sometimes changed. However, slabs are a bigger worry in this project. There are many different types of slabs, but this article will focus on two of them: flat slabs and conventional slabs. Flat slabs are used to prevent beam-column blockage and are very cost effective. Flat slabs distribute loads directly to columns without the use of beams

A. Conventional Slab

A conventional slab or regular slab is one that is supported by beams and columns. The slab thickness is minimal in these types, while the beam depth is considerable, and it is transmitted to the load-bearing beams and subsequently to the columns. The thickness of a standard slab is 4″ or 10 cm, and 5″ to 6″ is ideal. Conventional concrete slabs cannot be more than 9m in high structures, these type of slabs may not be a success if the dimensions are more than 9m. On a standard slab, reinforcement is given by horizontally placed bars known as main (primary) reinforcement bars and vertically arranged bars known as distribution bars. The bars provided are cranked at 45 degree angle to maintain the shear developed at the corners. Convention slabs may be of two types i.e. there is just one way slab for example a two-way slab depending on the dimensions when it comes to slab.

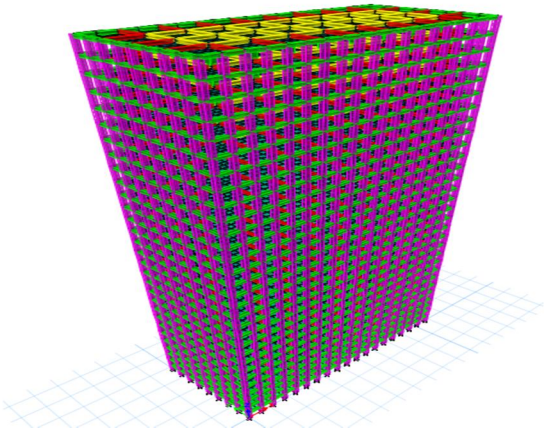

Figure 1: 3D view of structural with conventional slab

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B. Flat Slab

There are several possibilities for construction components in a multi-storey building, such as a beam-column frame structure or a flat slab. A flat slab can be utilised in a multi-storey structure for cost savings. To ensure safety, all multi-storey structures should be designed for lateral loads. Drop panel and column head are key flat slab add-on members. A drop panel is provided on the slab's bottom face. The effective gap between columns in each direction determines the size of the drop panel. The column head or column capital is located at the intersection of the slab and the column. Plate slab construction is significantly simpler than R.C.C. slab construction.

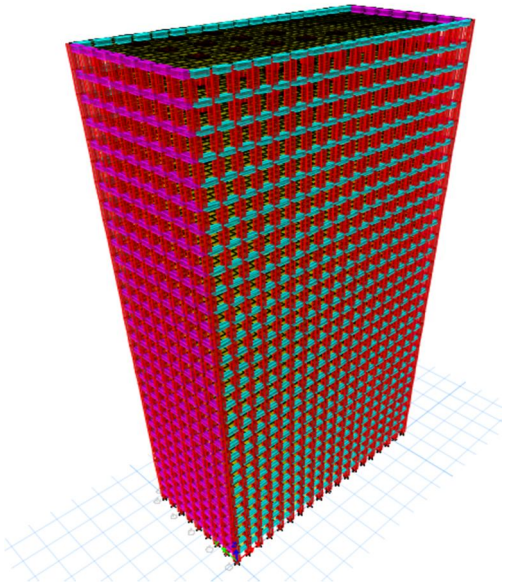

Figure 2: 3D view of structure with flat slab

C. Framed tube Structural System

Maximum lateral strength and stiffness efficiency of the entire structure can only be obtained by connecting all column parts in such a way that the entire building behaves as a hollow tube or stiff box cantilevering out of the earth. This type of equipment is known as a Framed Tube System. The tube structure is made up of tightly spaced columns, 2-4m apart, connected by deep girders
Overturning resistance and overturning stresses in the columns in this arrangement would be direct tension or compression with no bending High-stiffness moment-resistant frames construct a "tube" around the building's perimeter to provide lateral resistance.

II. MODELLING

This project models and analyses a 30-story RCC structure. Various IS codes were used during the analysis, including IS 456:2000 for concrete design, IS 875:2015 for loads, and IS 1893:2016 for seismic design.

A. Building plan and its geometry:

The analysis is based on the structural system like Framed tube used on reinforced concrete moment resisting frames, and the building plan geometry that we will be using here are 54m x 24m. Here we will be analysing a regular structure with rectangular shape with a 1296sqm area.

B. Material Properties

M-40grade of concrete for columns, beams and slabs, Fe-550 grade steel are used for all the models in this study.

C. Framed Tube Structure With Conventional Slab

A conventional slab with framed tube structural system provided in such a way that the entire building acts as a hollow tube or rigid box cantilevering out of the ground and distance between each column is 6m in x and y direction respectively around the perimeter of the 30-story structure and it has been modelled with a uniform bay width of 6m in the x and y directions. Time history functions are defined by using representative earthquake data, load cases are defined as linear time histories by using load type as acceleration in both the x and y directions, and the analysis is run.

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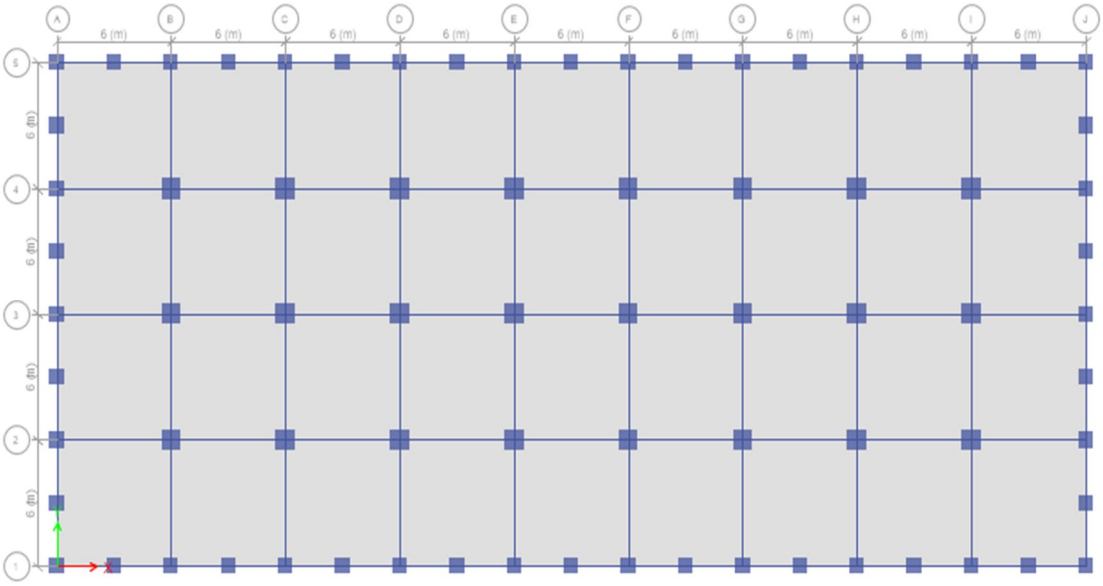

Figure 3: Plan view of RC normal frame

D. Framed Tube Structure with Flat Slab

A flat slab with framed tube structural system provided in such a way that the entire building acts as a hollow tube or rigid box cantilevering out of the ground and it has been modelled with dimensions of 762mm x 762mm, 990.6mm x 990.6mm for columns and 381mm x 609.6mm, 304.8mm x 609.6mm for beams are taking into considerations. Material and section properties are defined as mentioned in 3.2.2 and 3.2.3. Application of loads on beams and slabs is mentioned in 3.4.

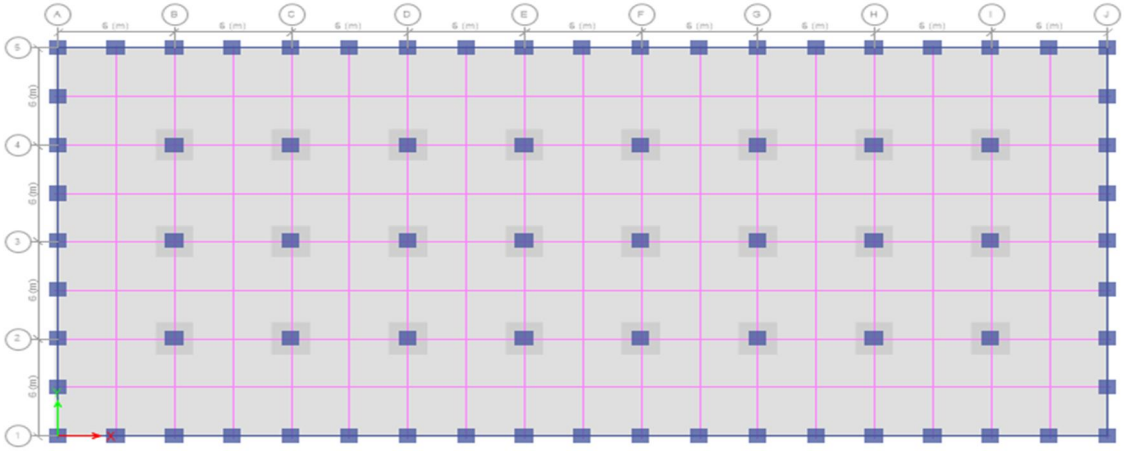

Figure 4: Plan view of RC frame with framed tube

E. Loads Applied

The loads acting on RCC building are divided into two types:

1) Loads due to gravity (Dead load and Live load).
2) Lateral loads.

Lateral load due to wind as per IS 875 (part 3): 2015 [11]

a) Wind speed – 50m/s
b) Terrain category – 2
c) Risk coefficient, K1 – 1
d) Topofigurey factor, K3 – 1
e) Windward coefficient, Cp – 0.8
f) Leeward coefficient, Cp – 0.5

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➢ *Functions*

- *Time History Function:* Linear dynamic analysis is required to investigate the seismic behaviour of structures exposed to ground motions. So, time history functions are defined by taking a representative earthquake data as the acceleration time histories from records of past historical earthquakes occurred, from which time history data (acceleration) of ALTADENA-EATON CANYON PARK is considered in ETABS V17 software for all three reinforced concrete frames
- *Response Spectrum Function:* The response spectrum function is defined for different parameters such as Zone factor – 0.1, seismic zone V. Response reduction factor - 5. Soil Type - II, (Medium soil). Importance factor - 1.5 and Minimum eccentricity - 0.05 (Damping) i.e., 5 percent are considered accordingly
- *Matched to Response Spectrum Function:* In linear dynamic analysis, the response of the building to ground motion is computed in the frequency domain while preserving all phase information. Time history matched to response spectrum is defined as a function that matches the acceleration time history (ALTADENA) with a response spectrum function in the x and y directions, and is denoted by MTHX and MTHY.

III. RESULTS AND DISCUSSIONS

The results obtained from the time history analysis of both models with framed tube structural system has been compared. Storey displacement, storey drift, base shear, and time history are some of the parameters.

A. Comparison of Conventional Slab And Flat Slab With Framed Tube System

1) Comparison of Story Displacements: The results which are obtained for comparison between conventional slab and flat slab with framed tube system in X and Y direction are shown in below table 5.13 and plotted as shown in graph 5.4 and 5.5.

Table 1: Values of story displacement

Storey	Conventional slab with framed tube system		Flat slab with framed tube system	
	X	Y	X	Y
30	85.29	120.97	93.53	127.86
27	82.4	116.41	91.13	121.46
24	78.58	109.79	87.06	113.31
21	72.99	100.86	81.26	103.29
18	67.06	89.77	73.73	91.45
15	59.7	76.83	64.46	77.92
12	49.37	62.2	54.07	62.92
9	37.25	45.71	41	46.7
6	23.21	27.38	26.94	29.62
3	8.95	9.94	12.04	12.35
Base	0	0	0	0

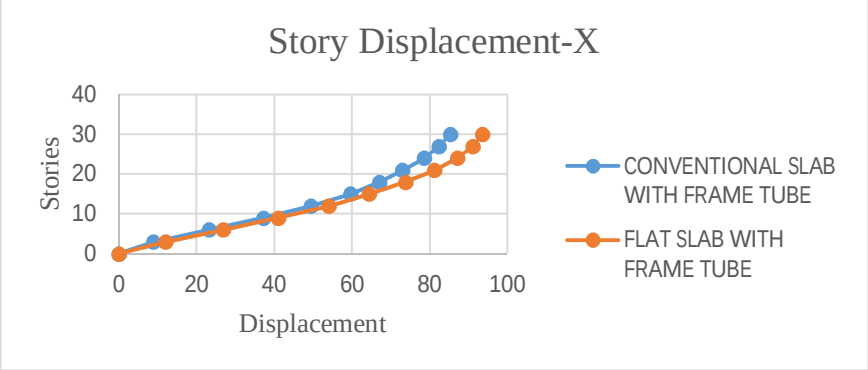

Figure 5: Represents comparison of storey displacement between conventional slab and flat slab with framed tube system in X-direction.

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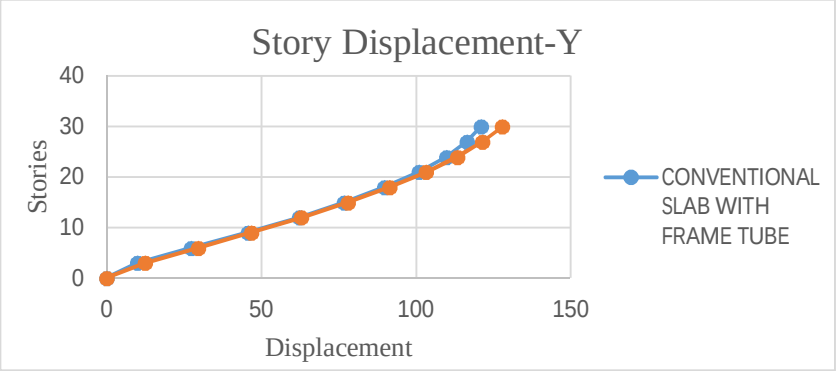

Figure 6: Represents comparison of storey displacement between conventional slab and flat slab with framed tube system in Y-direction.

2) *Comparison of Time Period:* The values of time period (sec) and mass participation factor in x and y directions are obtained and comparison of reinforced concrete normal frame with reinforced concrete frame with framed tube system are shown in below table 5.14 and plotted as shown in graph 5.6,5.7 and 5.8.

Table 2: Values of time period (sec) and mass participation factor

Modes	Conventional slab with framed tube system			Flat slab with framed tube system		
	Time period (sec)	Mass Participation X (%)	Mass Participation Y (%)	Time period (sec)	Mass Participation X (%)	Mass Participation Y (%)
1	3.25	0	0.7595	3.576	0	0.7584
2	2.553	0.7751	0	2.625	0.7918	0
3	2.26	0	0	1.929	0	0
4	1.047	0	0.1127	1.126	0	0.1252
5	0.838	0.1023	0	0.862	0.1014	0
6	0.746	0	0	0.634	0	0
7	0.582	0	0.0431	0.608	0	0.0422
8	0.479	0.0426	0	0.491	0.039	0
9	0.432	0	0	0.364	0	0
10	0.306	0	0.0526	0.318	0	0.046
11	0.254	0.0518	0	0.259	0.0436	0
12	0.23	0	0	0.193	0	0

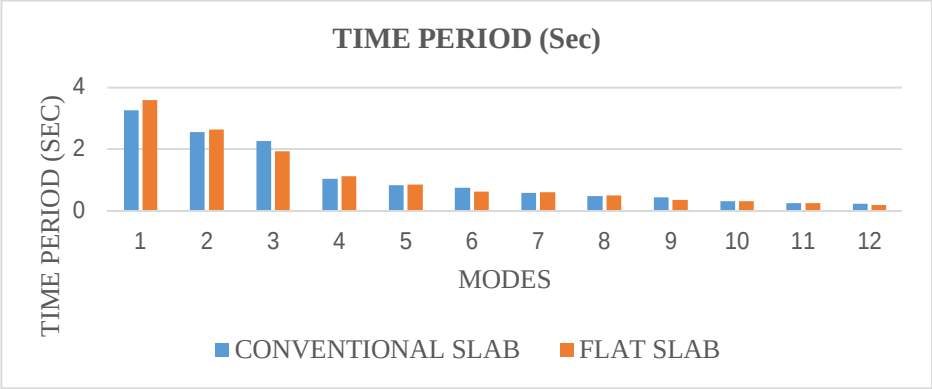

Figure 7: - Represents comparison of time period between conventional slab and flat slab with framed tube system.

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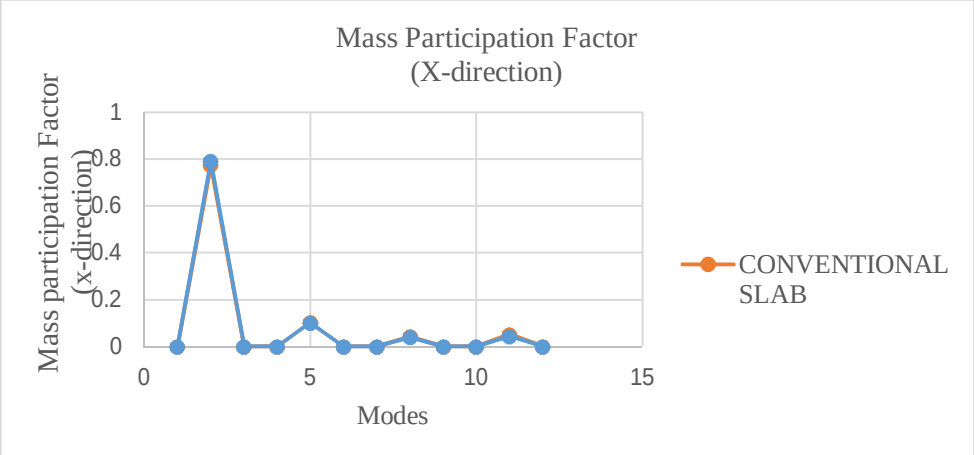

Figure 8: - Represents comparison of mass participation factor in x-direction between conventional slab and flat slab with framed tube system.

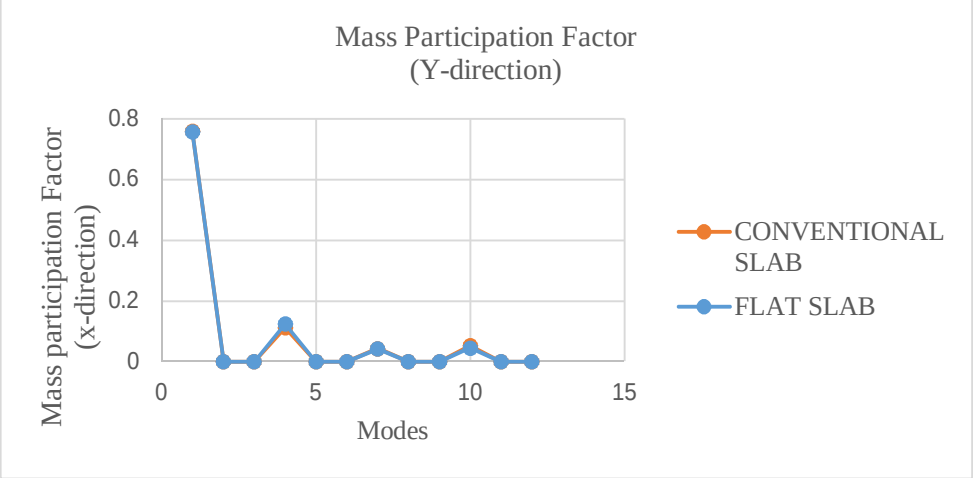

Figure 9: - Represents comparison of mass participation factor in y-direction between conventional slab and flat slab with framed tube system.

3) *Comparison of Story Drift:* The storey drift results obtained for comparing a conventional slab and flat slab with framed tube system are provided in table 5.15 and plotted in graph 5.9.

Table 3: Values of Story drift

Storey	Conventional slab with framed tube system	Flat slab with framed tube system
30	0.000276	0.000282
27	0.00059	0.00058
24	0.000841	0.000825
21	0.000979	0.00095
18	0.001089	0.00103
15	0.001143	0.00107
12	0.001245	0.00121
9	0.001432	0.0014
6	0.001461	0.00145
3	0.001282	0.0007
Base	0	0

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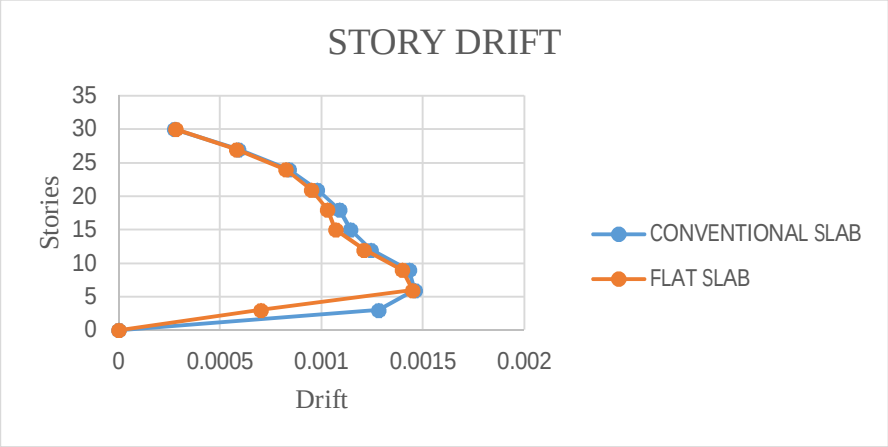

Figure 10: Represents comparison of story drift between conventional slab with framed tube system and flat slab with framed tube system.

The maximum drift in conventional slab with framed tube system was found to be 0.001461, and it was decreased to 0.00145, in a framed tube structure with flat slab.

4) *Comparison of Base Shear:* In the x and y directions, the maximum base shear for conventional slab and flat slab with framed tube system are compared in table 5.16 and plotted in graph 5.10.

Table 4: Values of base shear

Conventional Slab		Flat slab	
Fx (kN)	Fy (kN)	Fx (kN)	Fy (kN)
17006.071	13360.157	26131.6	19187.91

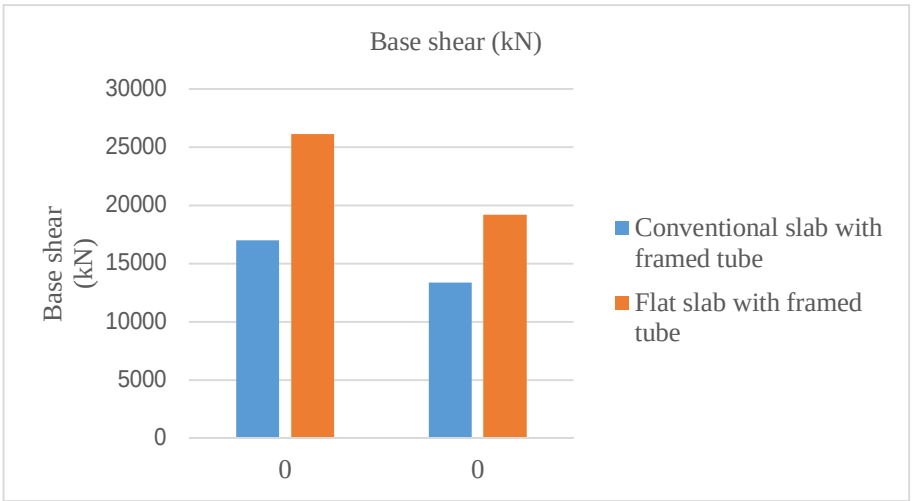

Figure 11: - Represents comparison of base shears in x and y direction between conventional slab with framed tube system and flat slab with framed tube system.

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IV. CONCLUSION

According to the data analysis, following conclusions were made

A. It was found that, the maximum story displacement obtained for framed tube structure with flat slab is 93.53mm in x-direction, which is reduced to 85.29mm in framed tube structure with conventional slab, where as in Y-direction, the maximum story displacement obtained for framed tube structure with flat slab is 127.86mm which is reduced to 120.97mm in framed tube structure with conventional slab.

B. Story drift appears to be 0.00146 at 21 meters above foundation level in framed tube structure with conventional slab, but it is decreased to 0.00145 in framed tube structure with flat slab.

C. The maximum base shear was found in framed tube structure with flat slab, which is 26131.6 KN in x-direction when compared to framed tube structure with conventional slab.

D. By observing both the models, the maximum base shear is considerably more in framed tube structure with flat slab than the framed tube structure with conventional slab.

E. Time period for framed tube structure with conventional slab is least when compared to framed tube structure with flat slab. After modal analysis, first two modes in both the x and y - axis, there are more mass participation concerns.

F. The framed tube structure with conventional slab can sustain more load compare to framed tube structure with flat slab.

G. The framed tube structure with conventional slab is effective at controlling displacements.

H. The framed tube structure with conventional slab gives better results as compared to framed tube structure with flat slab when time history analysis is performed.

I. Time history analysis was conducted on a 25 storied structure providing framed tube around the perimeter of the building was found superior in terms of story drift, displacement and time period.

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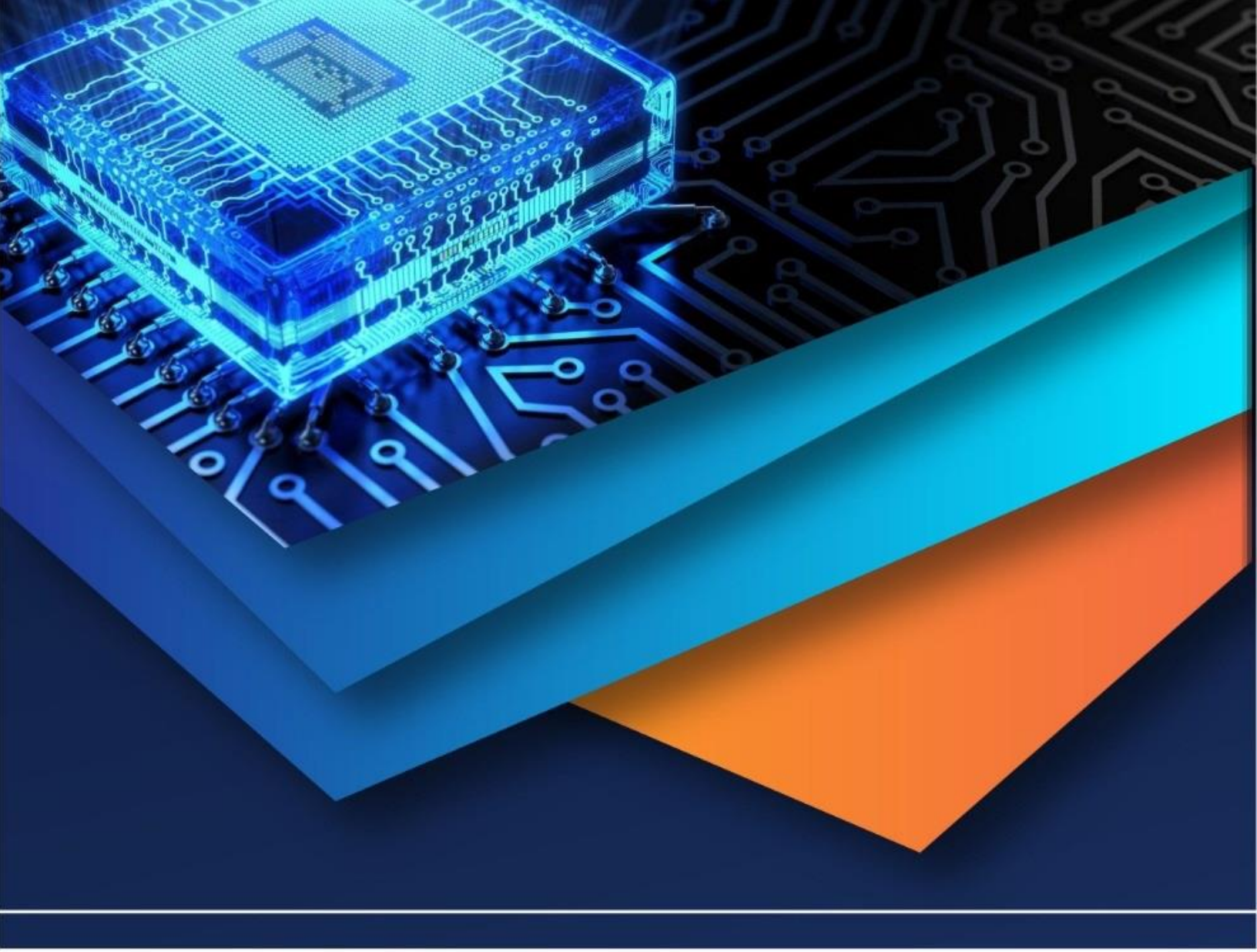

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