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A Comparative Study Of Lateral Load Resisting Systems In Tall Buildings

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Abstract –
Tall buildings are highly vulnerable to lateral forces such as earthquake and wind loads due to their increased height and flexibility. To improve structural stability and reduce lateral displacement, efficient lateral load resisting systems are required in high-rise structures. In this study, a comparative analysis of different structural systems including Moment Resisting Frame (MRF), Shear Wall System, Framed Tube System, and Bundled Tube System was carried out using ETABS 22.5 software. A G+40 reinforced concrete building having a plan dimension of 30 m × 30 m and storey height of 3 m was modelled and analysed according to IS 1893:2016 provisions. The performance of each structural system was evaluated based on parameters such as modal time period, maximum storey displacement, storey drift, and base shear. The analysis results indicated that the Framed Tube System provided better overall lateral stiffness and displacement control among the considered systems. The study highlights the importance of selecting suitable lateral load resisting systems for improving the seismic performance of tall buildings.

Keywords- *Tall Buildings, Lateral Load Resisting Systems, ETABS, Seismic Analysis, Framed Tube System, Bundled Tube System, Storey Drift, Base Shear.*

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I. Introduction

Throughout history, human beings have built tall monumental structures such as temples, pyramids and cathedrals to honour their gods. Human beings have always been struggling to push the limits of nature in their age-old quest for height, from the legendary Tower of Babel in antiquity, purportedly designed with the aim of reaching heaven, to today's tallest building. Today's skyscrapers are monumental buildings too, and are built as symbols of power, wealth and prestige. [1-4] At the beginning of the twentieth century, tall buildings were generally designed as offices, and achieved an important position as a "distinguished space" in the history. These buildings emerged as a response to the rapidly growing urban population, with the aim of meeting the demand for office units to be positioned as closely as possible to one another. Architects' creative approaches in their designs for tall buildings, the shortage and high cost of urban land, the desire to prevent disorderly urban expansion, the effort to create a skyline concept, and factors such as concerns for a cultural identity and for prestige have driven the increase in the height of buildings. [5-8]

Today it is almost impossible to imagine a major city without tall buildings. As the most important symbols of today's cities, tall buildings have become a source of faith in technology and national pride, and have changed the concept of the modern city along with its scale and appearance. Despite the fact that tall buildings have moved city life away from the human scale, in general it is accepted that these buildings are an inevitable feature of urban development. In the past, the forms used in design were restricted but currently freedom in the design of tall buildings has significantly increased, along with a contemporary widening of the form spectrum in design. [9-10] Tall buildings today, designed with the aid of advanced computer technologies, are built with exceedingly daring architectural and structural designs that are almost never found in their predecessors. The most important factors enabling the construction of tall buildings are developments and innovations in the following areas: materials, construction techniques, operating (mechanical) systems, structural systems and analysis, but at the same time, the increase in the height of buildings makes them vulnerable to wind and earthquake induced lateral loads. Essentially, in tall building design, which aims to respond to the needs of the occupants, in addition to structural safety, standards of occupancy comfort (serviceability) are also among the foremost design inputs. Excessive building sway due to wind can cause damage to non-structural elements, the breakage of windows, the shortening of fatigue life, the malfunction of elevators and other mechanical equipment, and damage to, or even the failure of, a structural system. In this regard, wind induced building sway affects both the structural safety and the serviceability of a building, and is thus a critical variable in the design of tall buildings.[11-13] As a result, building sway becomes a serious problem for designers as much as for occupants, and during windstorms it is necessary to keep it within acceptable limits, especially to reduce the discomfort felt by occupants on the top floors to a minimum and to prevent the negative outcomes.[14-17]

Tall buildings are highly vulnerable to lateral forces such as earthquake and wind loads due to their increased height and flexibility. To improve structural stability and reduce lateral displacement, efficient lateral load resisting systems are required in high-rise structures. In this study, a comparative analysis of different structural systems including Moment Resisting Frame (MRF), Shear Wall System, Framed Tube System, and Bundled Tube System was carried out using ETABS 22.5 software. A G+40 reinforced concrete building having a plan dimension of 30 m × 30 m and storey height of 3 m was modelled and analysed according to IS 1893:2016 provisions. The performance of each structural system was evaluated based on parameters such as modal time period, maximum storey displacement, storey drift, and base shear. The analysis results indicated that the Framed Tube System provided better overall lateral stiffness and displacement control among the considered systems. The study highlights the importance of selecting suitable lateral load resisting systems for improving the seismic performance of tall buildings. [18-23]

II. Objectives

1. To analyse the seismic behaviour of a G+40 reinforced concrete tall building using ETABS 22.5 software.
2. To compare the performance of different lateral load resisting systems such as:
   - Moment Resisting Frame (MRF)
   - Shear Wall System
   - Framed Tube System
   - Bundled Tube System
3. To evaluate important structural response parameters including:
   - Fundamental time period
   - Maximum storey displacement
   - Storey drift
   - Base shear
4. To identify the most efficient structural system for improving lateral stiffness and controlling displacement in tall buildings.
5. To study the influence of structural stiffness on seismic response and overall building performance.

III. Methodology

The present study focuses on the comparative seismic analysis of different lateral load resisting systems used in tall reinforced concrete buildings. The analysis was carried out using ETABS 22.5 software. Four structural systems namely Moment Resisting Frame (MRF), Shear Wall System, Framed Tube System, and Bundled Tube System were modelled and analysed under seismic loading conditions according to IS 1893:2016 provisions. [24-28]

The structural performance of each system is compared based on important parameters such as:

- Fundamental Time Period
- Maximum Storey Displacement
- Storey Drift
- Base Shear

The methodology adopted in the study includes modelling, load definition, seismic analysis, result extraction, and comparative evaluation of all structural systems.

Flow Chart of Methodology

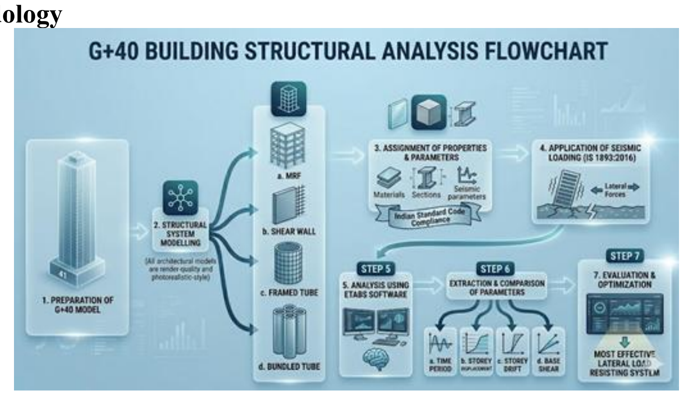

Fig.1 Flow Chart

Building Modelling

A G+40 reinforced concrete tall building having a regular and symmetrical plan configuration was considered for the present study. The plan dimension of the building was taken as 30 m × 30 m with a storey height of 3 m. The total height of the structure was 120 m.

The building model was created in ETABS 22.5 using a three-dimensional modelling approach. Beams and columns were modelled using frame elements, while slabs and shear walls were modelled using shell elements.

Deferent parameters which are used in building model are describe below in table number 1.

Table No.1 Building Parameters

Parameter	Value
Building Type	RCC Tall Building
Number of Storeys	G+40
Plan Dimension	30 m × 30 m
Storey Height	3 m
Total Height	120 m
Software Used	ETABS 22.5
Concrete Grade	M50
Steel Grade	Fe500

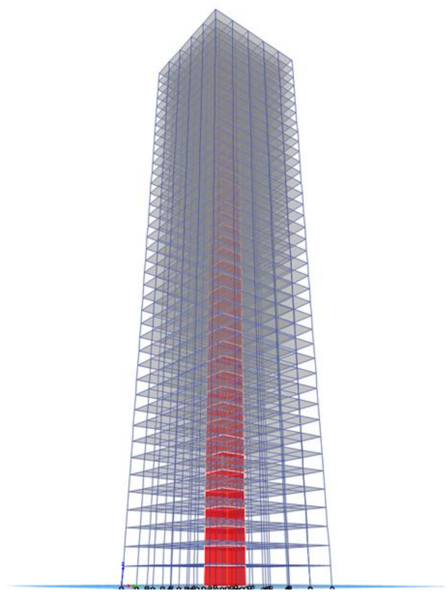

Fig.2 3D ETABS Model of Building with Shear Wall

Material Properties and Section Properties

The material properties used for the analysis were assigned according to Indian Standard provisions. Concrete grade M30 and reinforcement steel grade Fe500 were used for all structural models.

Different section properties were assigned for beams, columns, slabs, and shear walls. To achieve realistic structural behaviour, column sizes were reduced gradually with increase in height. Each of the section used in model mentioned below.

Table2. Section Properties

Structural Component	Size
Beam Size	300 mm × 600 mm
Lower Storey Column	900 mm × 900 mm
Middle Storey Column	700 mm × 700 mm
Upper Storey Column	500 mm × 500 mm
Slab Thickness	150 mm
Shear Wall Thickness	300 mm

Load Definition

The building was analyzed for seismic loading conditions. Dead load, live load, and seismic loads were assigned according to Indian Standard codes.

The self-weight of the structure was automatically considered by ETABS through dead load definition. A live load of 3 kN/m² was assigned to all floors.

Load Patterns Considered in all four models are same as u can see in figure 3 provided below.

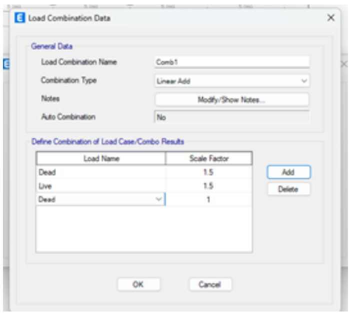

Fig.3 Load Pattern Definition

Seismic Parameters

The seismic analysis was carried out according to IS 1893:2016 provisions. The building was assumed to be located in Seismic Zone V with medium soil conditions.

The seismic load parameters used in the analysis are given below.

Table.3 Seismic Parameters

Parameter	Value
Seismic Zone	Zone V
Zone Factor (Z)	0.36
Importance Factor (I)	1
Response Reduction Factor (R)	5
Soil Type	Medium Soil
Damping Ratio	5%

Structural Systems Considered

Four different lateral load resisting systems were considered in the present study.

Moment Resisting Frame (MRF)

In the Moment Resisting Frame (MRF) system, lateral loads are resisted through beam-column moment action, and the structural behaviour mainly depends on the stiffness of the frame members. As shown in Figure 4, no additional lateral load resisting elements such as shear walls or tube systems were provided in this model. Therefore, the MRF structure acts as the basic reference model for comparison with other structural systems considered in the study.

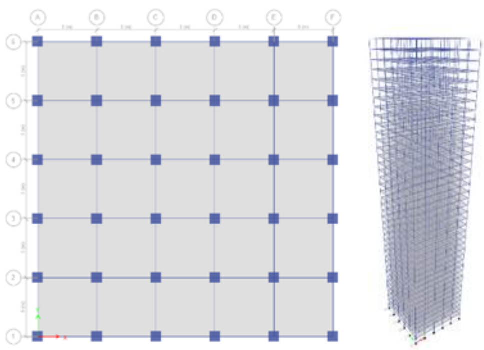

Fig.4 MRF Plan & 3D View From ETABS

Shear Wall System

In the Shear Wall System, reinforced concrete core walls were provided at the central region of the building to improve lateral stiffness and reduce displacement. As shown in Fig 5, the core wall system enhances the overall lateral load resisting capacity of the structure.

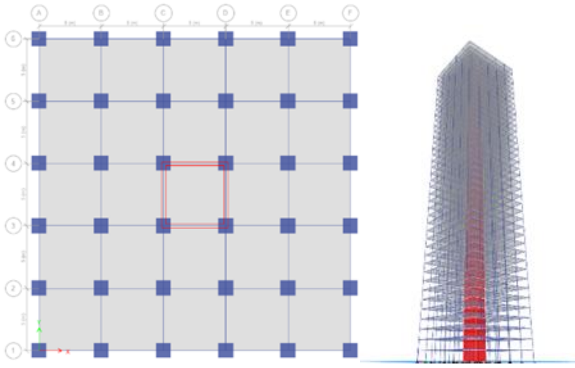

Fig.5 Shear Wall Plan & 3D View From ETABS

Framed Tube System

In the framed tube system, the perimeter columns and beams were strengthened to create a stiff exterior tube capable of resisting lateral forces effectively.

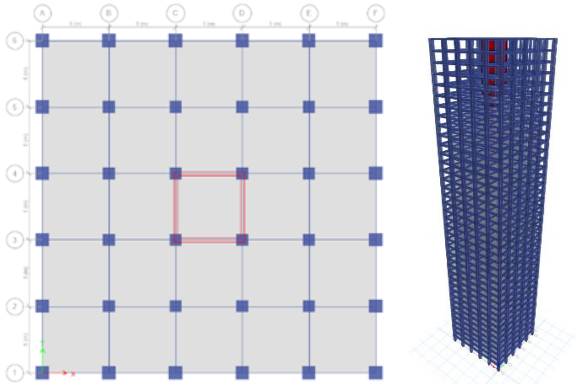

Fig.6 Frame Tube Plan & 3D View From ETABS

Bundled Tube System

In the bundled tube system, additional internal stiffened frames were introduced along selected grid lines to simulate the behaviour of interconnected tube systems.

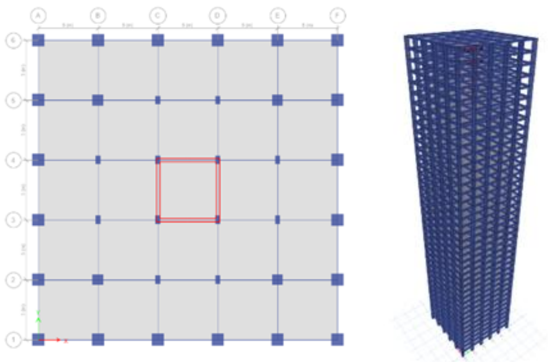

Fig.7 Bundled Tube Plan & 3D View From ETABS

IV. Analysis Procedure

After completion of modelling and load assignment, all structural systems were analysed using ETABS 22.5 software. Fixed supports were assigned at the base level of the structure.

The analysis was performed using equivalent static seismic analysis. The structural response was evaluated based on:

- Fundamental Time Period
- Maximum Storey Displacement
- Storey Drift
- Base Shear

The analysis of all structural models was carried out using equivalent static seismic analysis in ETABS 22.5. The supports at the base were assumed to be fixed. The slab was considered as rigid diaphragm for lateral load transfer. The comparison of structural behaviour was made based on the response parameters obtained from ETABS analysis.

V. Results

The seismic performance of the four structural systems was evaluated using ETABS 22.5 software. The comparison was carried out based on important structural response parameters such as fundamental time period, maximum storey displacement, storey drift, and base shear. As shown in the Figure 8 storey displacement and storey drift graph extracted from E-Tabs models.

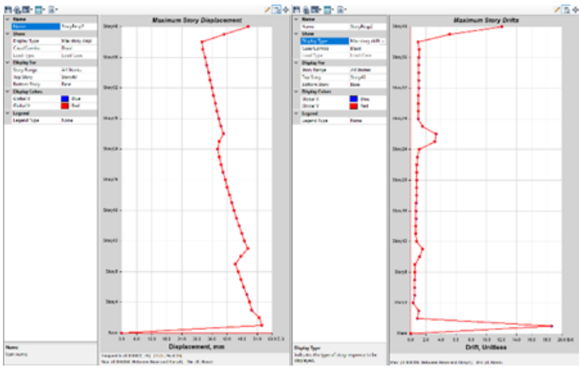

Fig.8 Displacement and Drift Graph of Shear wall from ETABS

The obtained results for all structural systems are summarized below.

Time Period Comparison

The fundamental time period decreased progressively with the increase in structural stiffness. The Moment Resisting Frame system showed the highest time period of 5.16 seconds due to its comparatively flexible behaviour. The addition of shear walls reduced the time period significantly because of increased lateral stiffness.

The Framed Tube System further reduced the time period to 3.992 seconds by utilizing stiff perimeter framing action. The Bundled Tube System exhibited the minimum time period of 3.968 seconds, indicating the highest stiffness among all structural systems considered in the study.

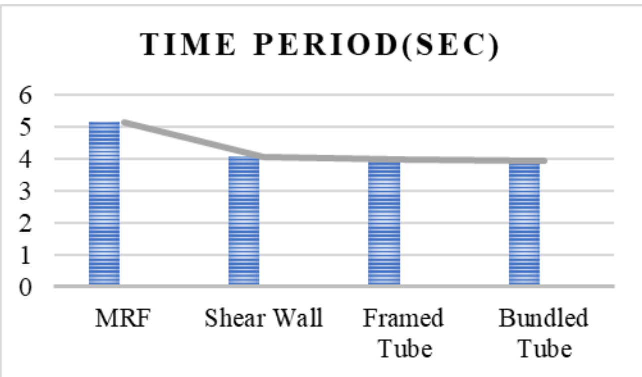

Fig.9 Comparison Graph of Time Period

Storey Displacement Comparison

The maximum storey displacement was highest in the MRF system with a value of 71.48 mm. This indicates higher lateral flexibility under seismic loading conditions. The Shear Wall System reduced the displacement considerably due to improved resistance against lateral forces.

The Framed Tube System showed the lowest displacement value of 54.96 mm, indicating efficient lateral load transfer through perimeter tube action. However, the Bundled Tube System showed increased displacement compared to the Framed Tube System. This may be attributed to simplified bundled tube configuration and stiffness distribution effects within the model.

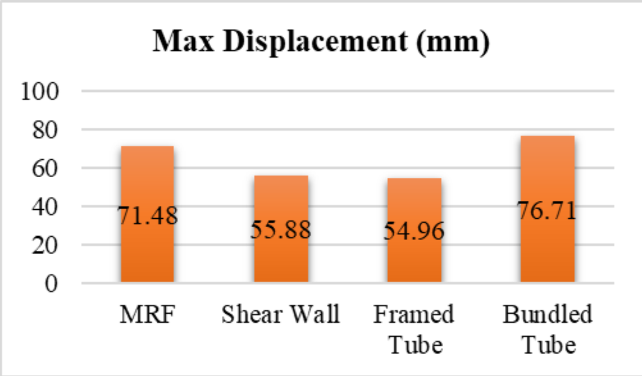

Fig.10 Comparison Graph of Max Displacement

Storey Drift Comparison

Storey drift is an important parameter in evaluating serviceability and lateral stability of tall buildings. The obtained drift values for all models were within permissible limits specified by IS 1893:2016.

The Framed Tube System and MRF model exhibited nearly similar drift values, while the Bundled Tube System showed slightly higher drift. The increased drift in the bundled tube configuration may be due to irregular stiffness interaction between internal and external tube elements.

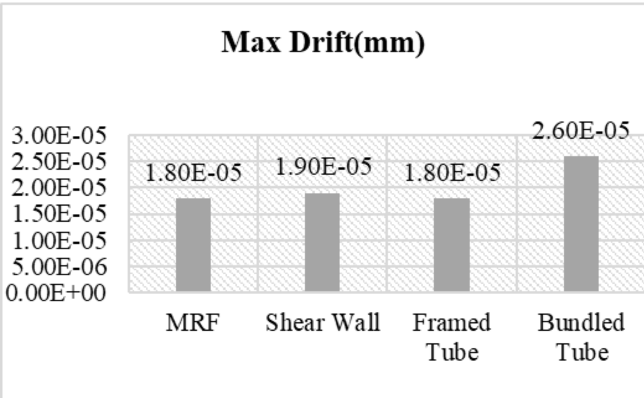

Fig.11 Comparison Graph of Max Drift

Base Shear Comparison

The base shear increased progressively from MRF to Bundled Tube System. The MRF system exhibited the lowest base shear due to lower structural stiffness. As the stiffness of the structure increased, the seismic force attraction also increased.

The Framed Tube and Bundled Tube Systems showed higher base shear values because stiff structures attract larger seismic forces. This behaviour is consistent with seismic structural response theory.

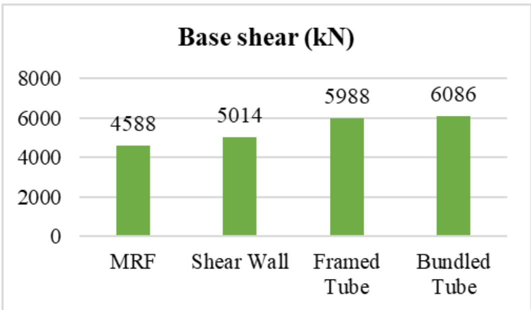

Fig.12 Comparison Graph of Base Shear

Table.4 Comparison of Structural Parameters

Structural System	Time Period (sec)	Max Displacement (mm)	Max Drift	Base Shear (kN)
MRF	5.16	71.48	0.000018	4588
ShearWall System	4.084	55.88	0.000019	5014
Framed Tube System	3.992	54.96	0.000018	5988
Bundled Tube System	3.968	76.71	0.000026	6086

VI. Discussions

From the comparative analysis, it is observed that the structural stiffness increased significantly with the introduction of shear walls and tube systems. The Framed Tube System demonstrated better overall seismic performance by effectively reducing displacement while maintaining controlled drift behaviour.

Although the Bundled Tube System exhibited higher stiffness and base shear capacity, the simplified modelling configuration resulted in comparatively larger displacement and drift values. Therefore, proper stiffness distribution and tube interaction play an important role in achieving optimum performance in bundled tube structures.

The study indicates that framed tube systems are highly effective for tall buildings subjected to seismic lateral loads due to their superior stiffness and displacement control characteristics.

VII. Conclusion

Based on the comparative seismic analysis carried out using ETABS 22.5 software, the following conclusions are drawn:

1. The structural behaviour of tall buildings is significantly influenced by the type of lateral load resisting system used.
2. The Moment Resisting Frame (MRF) system exhibited the highest time period and maximum displacement, indicating greater flexibility under seismic loading.
3. The introduction of shear walls improved the overall stiffness of the structure and considerably reduced lateral displacement.
4. The Framed Tube System showed better overall performance among all considered structural systems by providing:

- Lower Time Period,
- Reduced Displacement,
- Controlled Drift,
- and improved lateral stiffness.

5. The Bundled Tube System exhibited the highest stiffness and base shear values. However, due to simplified tube interaction and stiffness distribution effects, the displacement and drift values were comparatively higher than the Framed Tube System.
6. The study confirms that tube structural systems are highly efficient for resisting lateral seismic loads in tall buildings.
7. Proper selection of lateral load resisting systems plays a major role in improving the stability, safety, and serviceability of high-rise structures.
8. The use of ETABS software proved effective for modelling and comparative analysis of tall building structural systems under seismic loading conditions.

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