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Structural Performance Comparison of Structural Systems Using LIRA and ETABS

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Abstract. This paper investigates a comparison of structural systems of high rise (96m of 30 stories) buildings subjected to gravity load and wind load of speed 90mph. Three structural systems, Moment frame system, Shear wall system, and Tube-in-Tube system of identical base area and loadings are structurally designed, in ETABS and LIRA software. Linear wind response analysis was carried out as per ASCE 7-05. Parameters like fundamental time period, Maximum story displacement, Maximum column axial load and Vertical floor displacement are considered in this study. As per the findings, the maximum story displacement is found to be within the allowable limiting value. Tube-in-Tube system shows a better performance from the other systems for minimizing the story displacement. The modal time period, vertical displacement and Maximum column axial load values are also minimum in Tube -in-tube system.

Key words: Tube-in-tube system, Shear wall system, Moment frame system, story displacement

1 Introduction

Nowadays construction of taller buildings is becoming more important. This is influenced by several factors such as increment in the price of land, decrease in the availability of free land, spreading of urban areas widely and so on. For such structures design based on stiffness is the controlling approach rather than design based on strength [1- 3].

One of the most critical lateral loads, for tall buildings, is wind load which varies with time and height [4, 5]. The extreme vibration due to wind load is a main hindrance in designing and constructing high rise buildings [6, 7]. Other effects of this load are inter-story drifting and lateral deflection., Movement of buildings caused by wind generates uncomfortable state to humans owing to their sensitive behavior of vibration. Accordingly, the drift index is limited within the range of 1/600 to 1/400 [8].

To minimize such effects a stable and rigid structure is needed. Therefore, as the height of a building is increasing it becomes crucial to choose a suitable structural system. The term structural system represents to a system of a structure that resists lateral loads from either earthquake or wind [9]. In this paper three structural systems namely the Moment frame system, Shear wall system, and Tube-in-Tube systems are selected for comparison.

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1.1 Moment frame system

This system is designed by rigid connection of vertical column and horizontal beam members where, Load is resisted by flexural stiffness of these members [10]. In this system, size of columns progressively becomes larger towards the base and this size is controlled by the gravity load that also increases downwards the base. Lateral forces are resisted by the rigid action of the frame with bending moment and shear force development at the joints [1, 11,12].

1.2 Shear wall system

Shear wall system is one of the most feasible and popular systems that resist lateral loads with its shear walls [13-15]. Shear walls, in walls of separate plane form, act as a cantilever which is vertical and fixed at the base. Similarly, the shear walls can also act as connected walls which are non-planar assemblages around an elevator [16]. The strength and plane stiffness of shear wall system are higher when compared to moment frame systems [1][12]. A higher stiffness could be obtained when beams are set in between to join the shear walls. By this action the individual cantilever action of the walls will be restrained for acting as a single unit [17].

1.3 Tube-in-Tube system

Tube- in – tube system is a form created by an inner core within an outer framed tube where, portion of the lateral load is resisted by the core [12, 18]. The combined action of the core and framed tube aids in resisting the gravity and lateral loads [19-21]. A floor diaphragm that connects the core and framed tube helps in transferring the lateral loads to both systems. For a malicious attack with missiles or airplanes more tubes could be provided inside the outer tube giving extra purpose as an extra defense line [1]

2 Purpose of Study

The main objective of this study is to find the response of the systems in terms of modal time period, maximum story displacement, Maximum column axial force and Vertical story displacement. And the analysis is structured as:

- To get the most effective structural system against the lateral wind load.
- To compare the above-mentioned parameters both in LIRA and ETABS software.

3 Methodology

The following procedure was followed to carry the investigation:

- Three structural systems Moment frame system, Tube-in-Tube system and Shear wall system were selected.
- Models considering reinforced cement concrete were created for 30 stories tall building for these three systems.
- Gravity and wind loads were taken as per ASCE 7-05.
- Manual design of the frame members and software design of the whole structure. Investigation of analysis results in terms of time period, maximum story displacement, maximum column axial force and story vertical displacement to understand the response of the different systems.

4 Design Codes and Loadings

Limit state design philosophy and ACI code were adopted [22, 23]. While, loadings as per ASCE 7-05 [8] were taken as:

Dead load on roof 10.6 KN/m^2
Dead load on mechanical floor 15.7 KN/m
Dead load on office floor 1.375t/m^2
Facade load on perimeter beams 1.0 KN/m
Importance factor 1
Live load on roof 0.6 KN/m^2
Live load on mechanical floor 11.9 KN/m^2
Live load on office floor 2.5 KN/m^2
Wind speed 90mph
Exposure condition B

The 29th floor is mechanical floor while others are office floors

5 Building description and Models

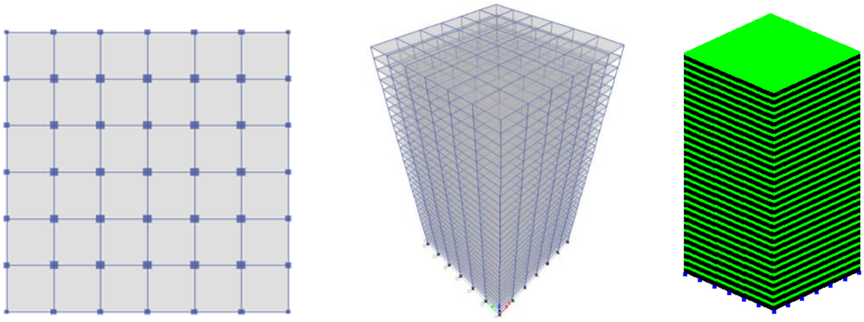
5.1 Building Description

Plan dimension 48m*48m
Story height 3.2
Structure Utility office
Mechanical floor slab thickness 350mm
Drop panel size 1.33m*1.33m
Shear wall of (1-5 floors) 500mm
Shear walls of (11-15 floors) 400mm
Shear walls of (21-25 floors) 300mm
Number of Stories 30
Total height of the building 96m
Office floor slab thickness 250mm
Roof slab thickness 150mm
Drop panel thickness 0.4m
Shear walls of (6-10 floors) 450mm
Shear walls of (16-20 floors) 350mm
Shear walls of (21-25 floors) 250mm

Frame spacing 8m but, in case of shear wall and Tube-in-tube systems outer frame spacing is taken to be 4m. Type of slab is flat slab in shear wall and Tube-in-tube systems. Shear wall thicknesses is considered the same in Tube-in-tube and Shear wall systems

5.2 Building Models

5.2.1 Moment frame system



(a) (b) (c)

Fig. 1. Plan view (a), 3D view of moment frame system in (b) ETABS, (c) LIRA

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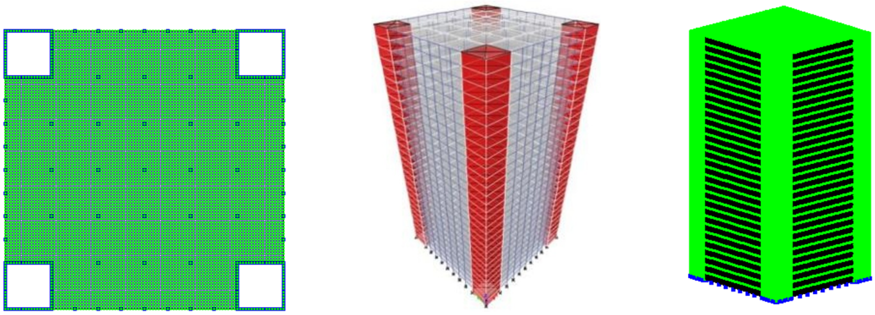
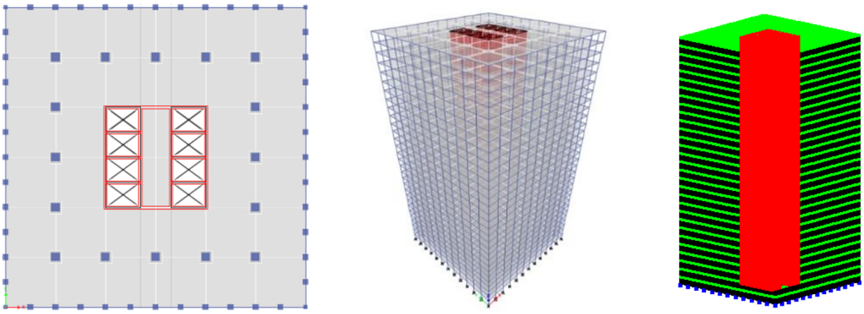
5.2.2 Shear wall system



(a) (b) (c)

Fig 2. Plan view (a), 3D view of shear wall system in ETABS (b) and LIRA (c)

5.2.3 Tube-in-Tube system



(a) (b) (c)

Fig 3. Plan view (a), 3D view of Tube-in-tube system in ETABS (b) and LIRA (c)

6 Results and discussion

6.1 Manually designed frame sections

The following are beam and column sections designed manually according to ACI code, they are then applied in the software for the three systems.

Table 1. Column section sizes

	Column sections(m^2)		
Columns	**Typical**	**Edge**	**Corner**
Roof columns	0.3*0.3	0.3*0.3	0.3*0.3
Mechanical floor col.	0.45*0.45	0.3*0.3	0.3*0.3
(26-28 floor) col.	0.75*0.75	0.45*0.45	0.35*0.35
(21-25floors) col.	1*1	0.65*0.65	0.45*0.45
(16-20floors) col.	1.2*1.2	0.8*0.8	0.55*0.55
(11-15 floors) col.	1.35*1.35	0.95*0.95	0.7*0.7
(6-10 floors) col.	1.35*1.35	0.95*0.95	0.7*0.7
(1-5 floors) col.	1.5*1.5	1.1*1.1	0.7*0.7

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Table 2. Beam section sizes

Floor	**m^2**
Roof	0.55*0.35
Mech. Floor	0.7*0.45
Office floor	0.65*0.4

6.2 Modal Time Period

The modal time period of Moment frame is higher compared to the other structural systems. In contrast, Tube in Tube and shear wall systems have almost the same time periods.

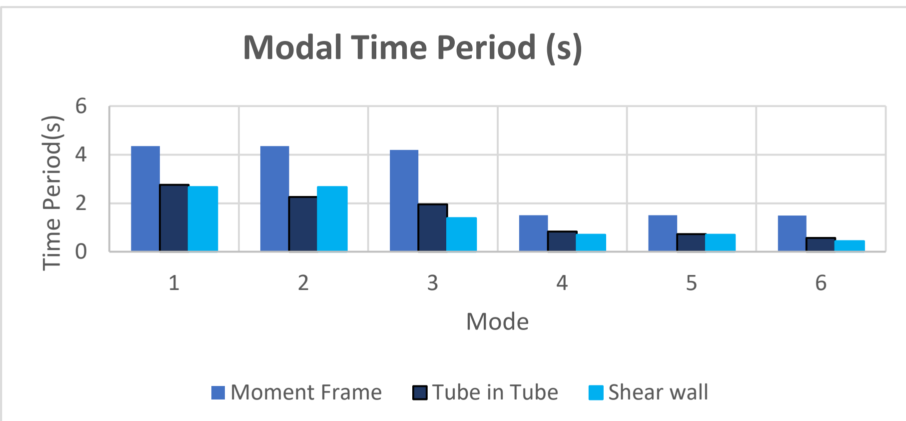

Fig 4. Modal time period from LIRA

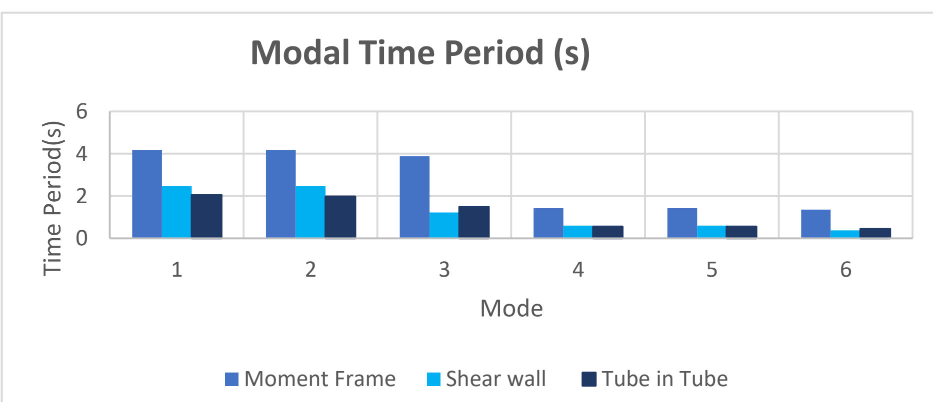

Fig 5. Modal time period from ETABS

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6.3 Maximum story displacement in mm

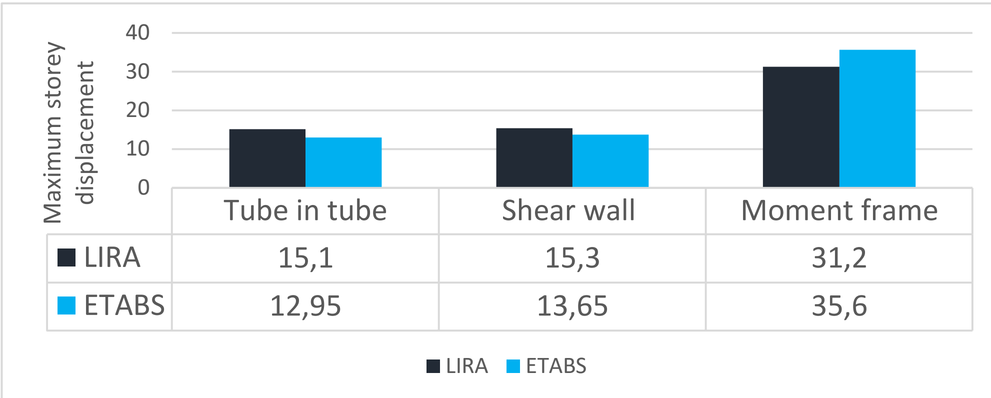

Fig 6. Maximum story displacement in mm

The maximum story displacement of Moment frame in the global X direction is 2.06 times of tube-in-tube and 2.04 times of shear wall system (LIRA results).

6.4 Maximum column axial load at the base in Tons

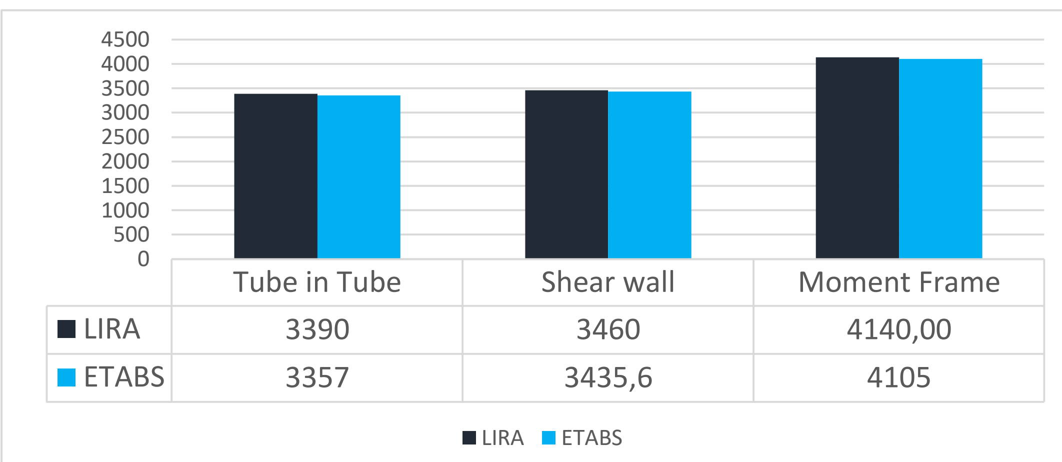

Fig. 7. Maximum column axial load at the base in tons

The maximum typical column axial load at the base of shear wall and moment frame systems are greater by 2% and 18.11% respectively comparing to tube-in-tube system (LIRA results).

6.5 Maximum vertical Displacement of floors in mm

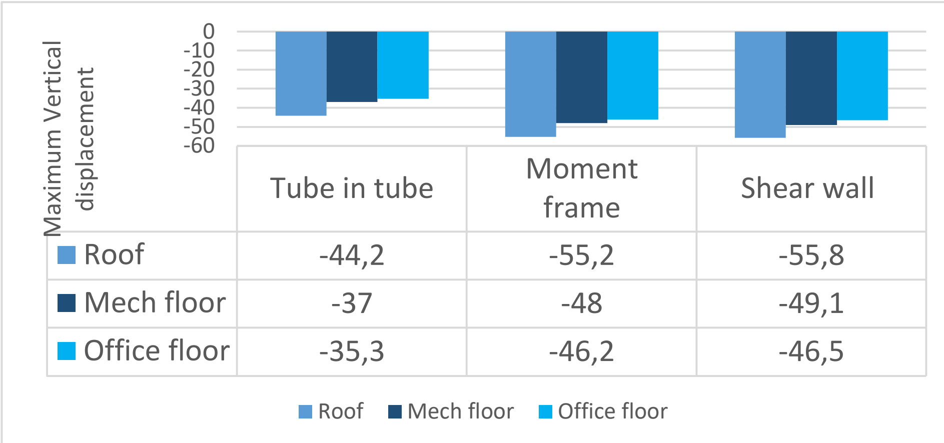

Fig 8. Maximum floors' vertical displacement in mm

The floors' vertical displacement of Tube-in-tube system is found to be smaller in comparison to the other two systems. The roof's' vertical displacement of moment frame and shear wall is 1.25 times greater than of tube-in-tube system (LIRA results).

7 Conclusion

The preliminary manually designed beam and column section sizes were used in the software design and no member was found to fail. Unlike Moment frame and Shear wall systems, Tube-in-tube system has different time periods in the global X and Y axes as a result of its geometrical asymmetry. Having minimum lateral drift, tube-in-tube system is found to be most effective structural system for lateral wind load resistance. The results in the maximum story displacement of the two software is almost similar, the bit difference might be caused from application of the wind load where in ETABS it was applied from the software directly. The paper recommends further study to be conducted considering earthquake loads.

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