COMPARATIVE ANALYSIS OF TUBE(S)-IN-TUBE TYPE AND BUNDLE TUBE TYPE TALL BUILDING WITH AND WITHOUT OUTRIGGERS WITH DIFFERENT ASPECT RATIO

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Abstract - *In last decades, tubular systems employed for tall buildings were efficient structural systems. However, increasing the height of a building leads to an increase in structural systems corresponding to the loads imposed by lateral loads. Based on this approach, new hybrid structural systems are emerging to provide strength and stiffness. This research consists of comparative analytical study of Tube(s)-in-tube type structural system (with 1,2 & 3 internal tubes) and Bundle tube type structural system for tall buildings with and without outrigger system to identify different structural parameters for specific sets of building. In this study different plan aspect ratio (length/width) ranging from 2 to 6 has been used to do comparative analysis of three different systems for tall building. This study largely analyses structural aspects for a building like maximum displacement, storey drift, time period, and load carried by peripheral system. Furthermore, this thesis also focuses on multifaceted analysis like Dynamic Wind load analysis and Response Spectrum Analysis. The modelling and analysis of models are carried out by computer software ETABS 18.*

Key Words: **Tall Building, Aspect Ratio, Tube(s) in Tube, Bundle Tube, Outriggers**

1.INTRODUCTION

High-rise building also refers as Tall Buildings. Tall building has many different functions in modern days. The mixed used tall building consists of levels of wise functions like; at ground level there can be retail and food and beverage, the first level can be used for commercial & offices and the second level may be residential. A tall building is not only taller, but has many different functions, but also very specific purposes. There is no proper definition for Tall building, because it has subjective definition. Tallness of a structure depends on various parameters like proportion of the building, height and technology used in buildings which is relevant to tall buildings. As per Council on Tall Buildings and Urban Habitat (CTBUH), based on height the building it can be classified into ‘Tall building' (<300m height), ‘Super Tall building' (>300m but <600m), ‘Mega Tall building' (>600m).

1.1 Tube(s) in Tube Type Structure

The system, in its elementary form, consists of perimeter columns spaced closely together with deep beams at each floor level, forming the tubular shape, thus creating the effect of a hollow tube pierced with openings for windows. The total loads acting on the structures to be collectively shared between the inner and outer tubes.

Tube(s) in Tube structures or Framed tube structures with multiple internal tubes are widely used due to their high stiffness in resisting lateral loads. The use of more than one internal tube decreases the effect of shear lag in tubes, allowing more active involvement of inner columns in resisting lateral forces.

1.2 Bundle Tube Type Structure

The Bundled-Tube System can provide more stiffer lateral force resisting system than the Tube-in-Tube system, which fall short to manage the lateral deformation of the buildings with huge plan area. In place of a tube, the bundled tube type system contains a multi-cell tube formed by interconnection of many separate tubes, which jointly work to withstand overturning moments and lateral loads of the structure.

Hence the growth in the stiffness of the structure is evident, this type of system permits the greatest height and the greatest floor space. And this system is also economically efficient. In bundled tube systems, the columns are more evenly stressed and give a high lateral stiffness to the building.

1.3 Outriggers and Belt Wall/Truss System

The structural arrangement for this system comprises of a main concrete core connected to exterior columns by relatively stiff horizontal members such as a one or two storey deep walls, commonly referred to as outriggers.

The combination of the exterior and interior systems by outriggers and belt-truss increases the effective depth of the structure when it deflects as a cantilever and makes them act together against lateral loads (unite their deformed shapes), leading to more efficient use of these systems.

2. AIM, OBJECTIVE AND SCOPE OF WORK

2.1 Aim of Work

"COMPARATIVE ANALYSIS OF TUBE(S)-IN-TUBE TYPE AND BUNDLE TUBE TYPE TALL BUILDING WITH AND WITHOUT OUTRIGGERS WITH DIFFERENT ASPECT RATIO"

2.2 Objective of Work

The objective of present work is as follows:

- To observe the structural behaviour of tall tube(s)-in-tube and bundle tube type structure with conventional outrigger system building.
- To study the effect of aspect ratio on tube(s)-in-tube and bundle tube type structure with conventional outrigger system in tall building.
- To compare the analysis in terms of displacement, storey drift, time period, Load Carried by Peripheral system of different models.

2.3 Scope of Work

- Modelling and Analysis of tube(s) in tube and bundle tube type system with and without outriggers system.
- Total 32 building models will be analyzed.
- Providing analytical comparison for various parameters like; Displacement, Storey Drift, Time Period.
- Analyzing and Comparing the results of different aspect ratio ranging from 2:1 to 5:1.
- Height of each model will be 150 m i.e., 50 Storey
- Plan dimensions are considered from 21 x 42 m to 21 x 105 m with the respective aspect ratio of 2:1 to 5:1
- Outrigger system applied at 12th, 26th, 34th, and 42nd stories for 50 storey building.
- For analysis IS 16700:2017, IS 1893 (PART 1):2016, IS 875 (PART 3) codes are used.

3. ANALYTICAL MODELS CONSIDERED OF ANALYSIS

Table -1: Data Considered for Models of Aspect Ratio 2 to

Details About Analytical Models		Aspect Ratio				
		2	3	4	5	6
Building Length	L	21 m	21 m	21 m	21 m	21 m
Building width	B	42m	63 m	84m	105m	126m
Building Height	H	150 m	150 m	150 m	150 m	150 m
Number of Storey	n	50	50	50	50	50
Floor Height	h	3 m	3m	3m	3m	3m
Bundle Tube Structure		M2.1	M3.1	M4.1	M5.1	M6.1
Bundle Tube Structure with Outriggers System		M2.2	M3.2	M4.2	M5.2	M6.2
Tube(s) in Tube Structure	1 Internal Tube	M2.3	M3.3	M4.3	M5.3	M6.3
	2 Internal Tube	M2.4	M3.4	M4.4	M5.4	M6.4
	3 Internal Tube	M2.5	M3.5	M4.5	M5.5	M6.5
Tube(s) in Tube Structure with Outriggers System	1 Internal Tube	M2.6	M3.6	M4.6	M5.6	M6.6
	2 Internal Tube	M2.7	M3.7	M4.7	M5.7	M6.7
	3 Internal Tube	M2.8	M3.8	M4.8	M5.8	M6.8

4. LOADING DATA

Table -2: Loading Data Considered

Seismic Parameters	Seismic Zone		Zone - III	
	Soil type		Type II	
	Importance factor		1	
	Response reduction factor		5	
Wind Parameters	Wind Speed		39	m/s
	Terrain Category		3	
	Importance factor		1	
	Gust Factor	Aspect Ratio	GF	
		2	2.0862	
		3	2.0463	
		4	1.9692	
		5	1.9447	
		6	1.9141	
Loading Data	Live load at floor		2.5	KN/m^2
	Floor Finish load at floor		1.5	KN/m^2
	Wall load		3.1	KN/m

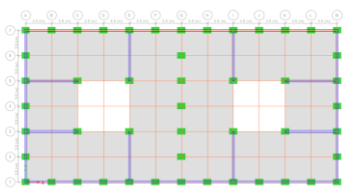
5. MATERIAL AND MEMBER PROPERTIES

Table -3: Material and Member Properties Considered

Material Property	Concrete Grade	M40	
	Steel Grade	Fe500	
Member Property	Beam Size	450 X 750	mm
	Column Size	900 X 1100	mm
	Slab thickness	150	mm
	Outrigger Wall size	250	mm

6. MODELLING

The structural modelling has been carried out in ETABS 18. Response spectrum analysis is done as per clause 7.8.1 of IS 1893:2002 for height greater than 90 m for zone III. Gust factor method for wind load is considered as per clause 7.1 of IS:875 (part III). As there is no option to calculate and analyze structure by gust factor method in ETABS, manually wind load is calculated and applied at each storey level in the form of user defined load on the Diaphragm.



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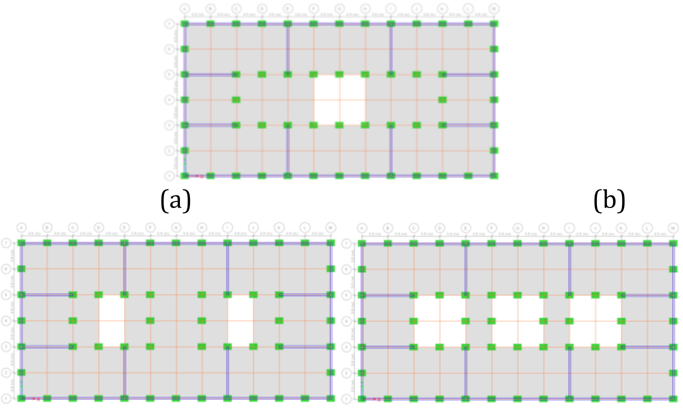

Fig -1: Plan of; (a) Bundle tube Type system, (b) 1 Internal tube Type system, (c) 2 Internal tube Type system and (d) 3 Internal tube Type system with Outriggers for Aspect Ratio 2

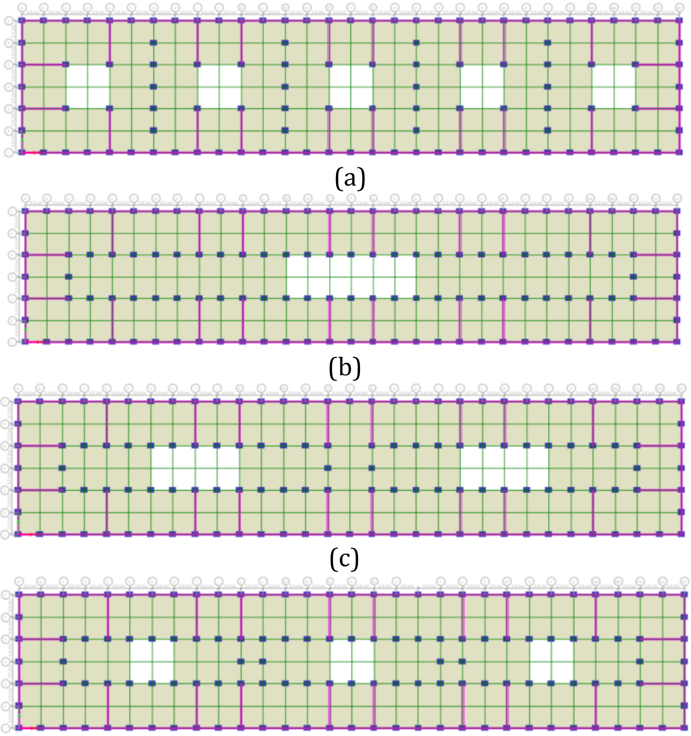

Fig -2: Plan of; (a) Bundle tube Type system, (b) 1 Internal tube Type system, (c) 2 Internal tube Type system and (d) 3 Internal tube Type system with Outriggers for Aspect Ratio 5

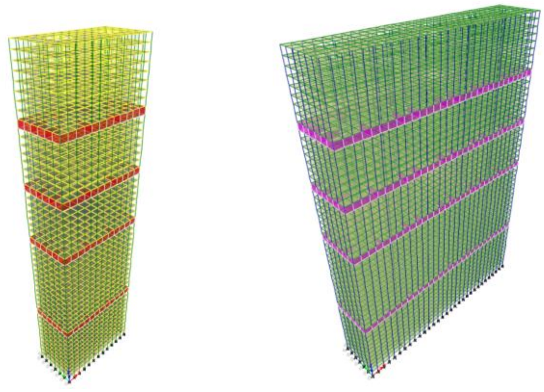

Fig -3: 3D View of; (a) Aspect ratio 2 model and (b) Aspect ratio 5 model

7. RESULTS AND DISCUSSION

7.1 Maximum Displacement

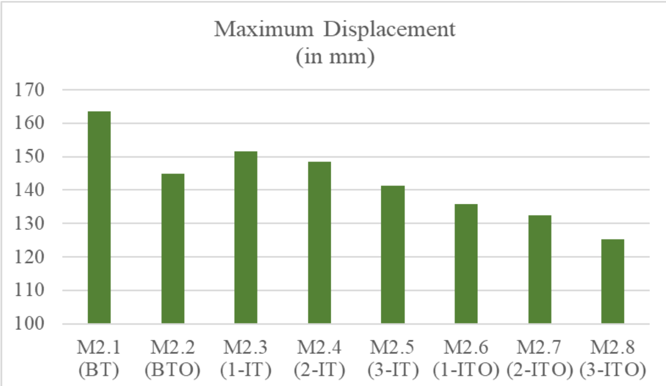

Chart -1: Comparison of Maximum Displacement for Aspect Ratio 2 Models

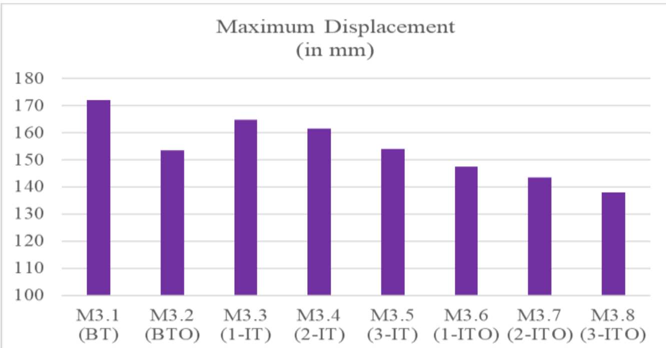

Chart -2: Comparison of Maximum Displacement for Aspect Ratio 3 Models

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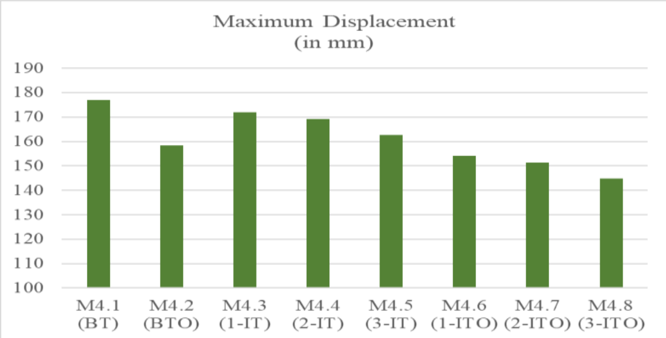

Chart -3: Comparison of Maximum Displacement for Aspect Ratio 4 Models

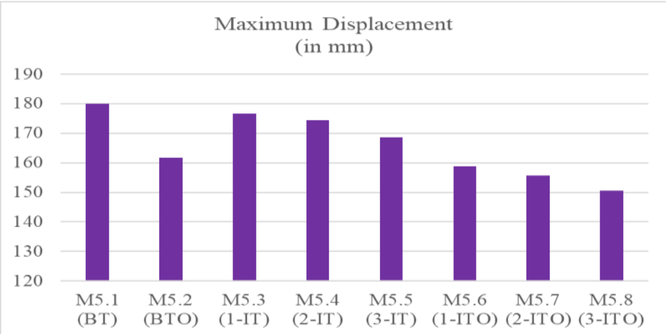

Chart -4: Comparison of Maximum Displacement for Aspect Ratio 5 Models

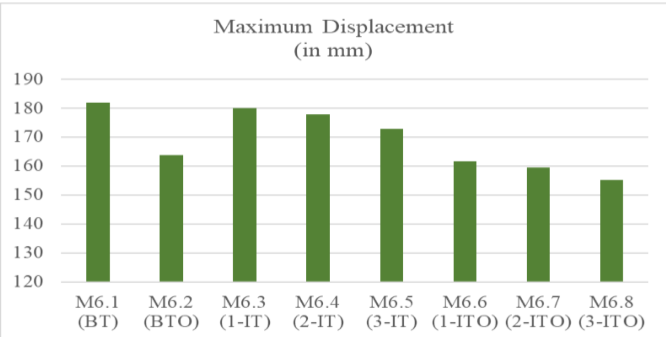

Chart -5: Comparison of Maximum Displacement for Aspect Ratio 6 Models

7.2 Storey Drift

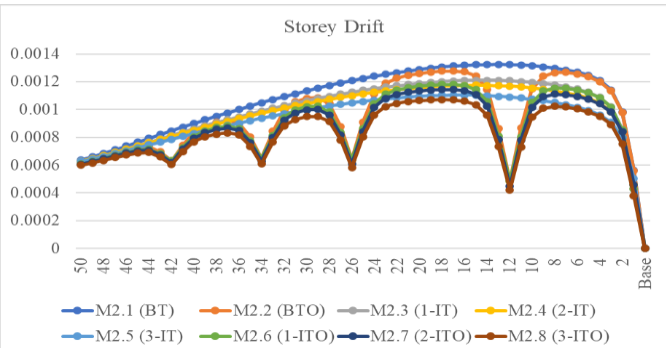

Chart -6: Comparison of Maximum Storey Drift for Aspect Ratio 2 Models

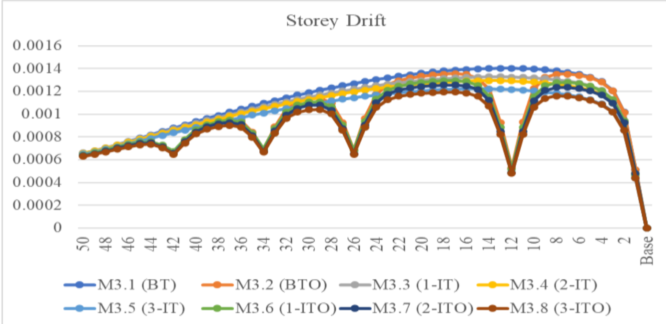

Chart -7: Comparison of Maximum Storey Drift for Aspect Ratio 3 Models

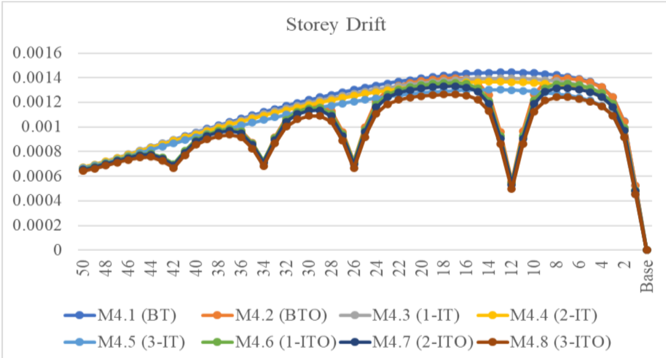

Chart -8: Comparison of Maximum Storey Drift for Aspect Ratio 4 Models

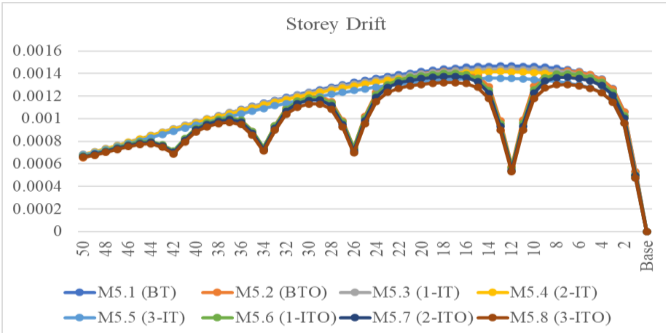

Chart -9: Comparison of Maximum Storey Drift for Aspect Ratio 5 Models

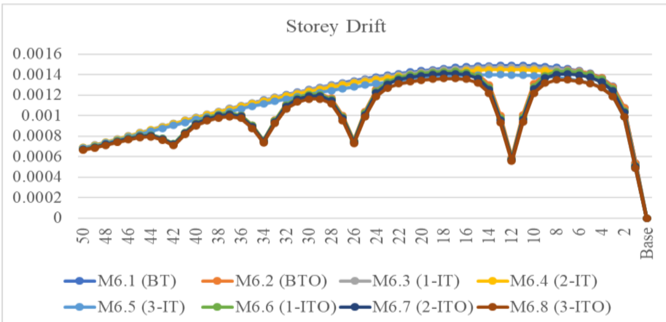

Chart -10: Comparison of Maximum Storey Drift for Aspect Ratio 6 Models

7.3 Load Carried by Peripheral System

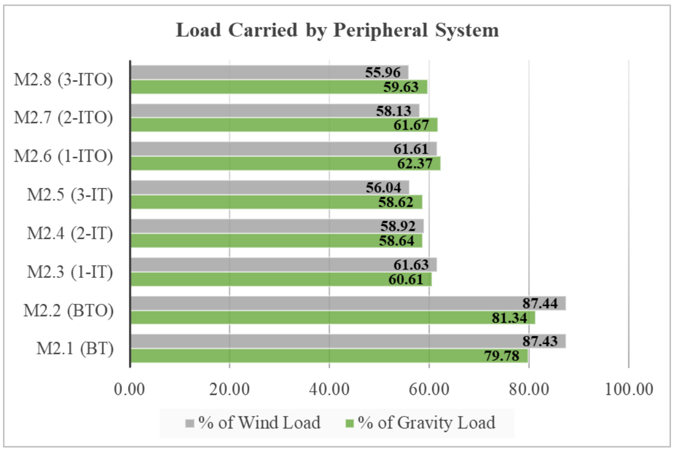

Chart -11: Comparison of Load Carried by Peripheral System for Aspect Ratio 2 Models

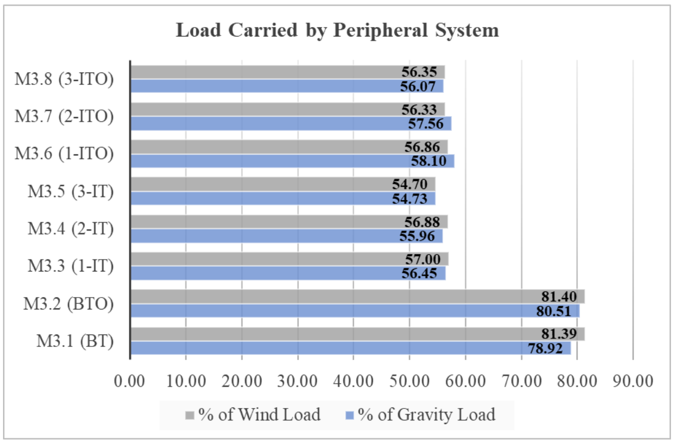

Chart -12: Comparison of Load Carried by Peripheral System for Aspect Ratio 3 Models

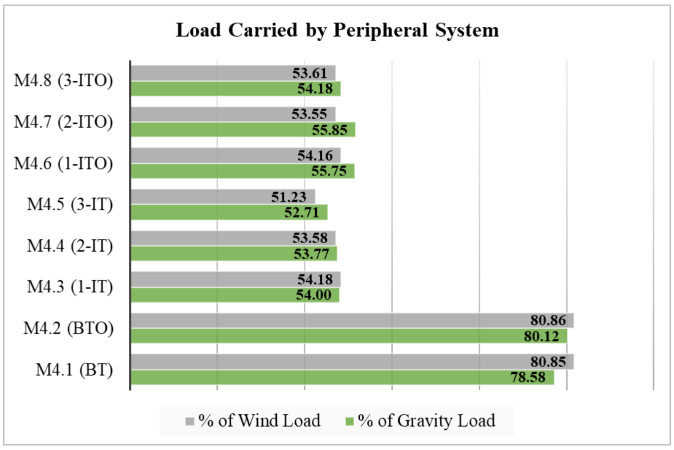

Chart -13: Comparison of Load Carried by Peripheral System for Aspect Ratio 4 Models

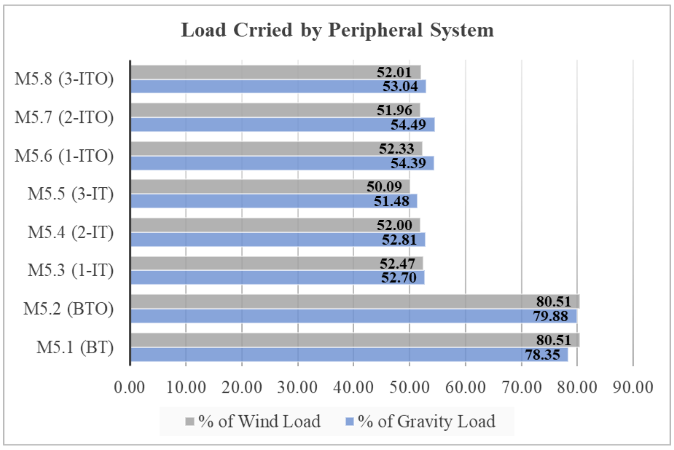

Chart -14: Comparison of Load Carried by Peripheral System for Aspect Ratio 5 Models

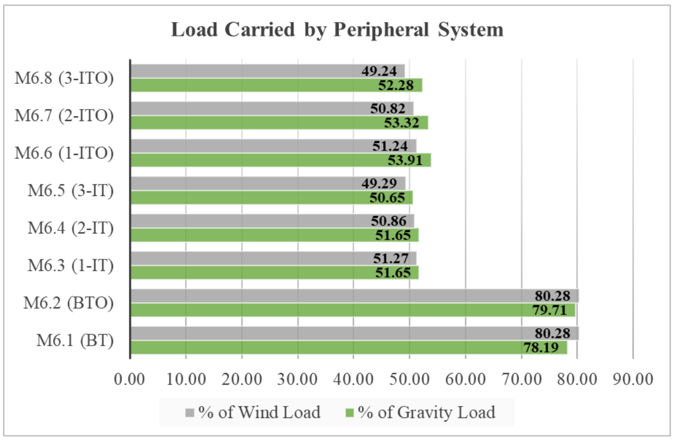

Chart -15: Comparison of Load Carried by Peripheral System for Aspect Ratio 6 Models

7.3 First Mode Time Period

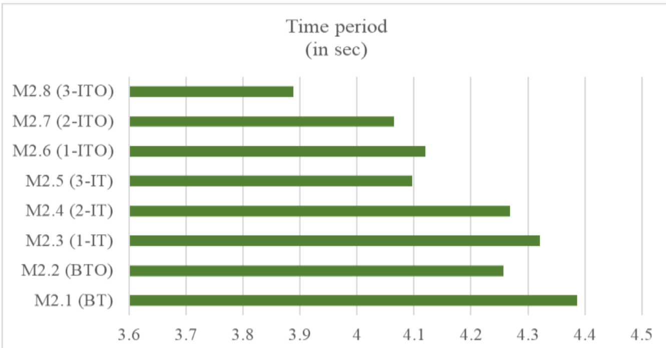

Chart -16: Comparison of First Mode Time Period for Aspect Ratio 2 Models

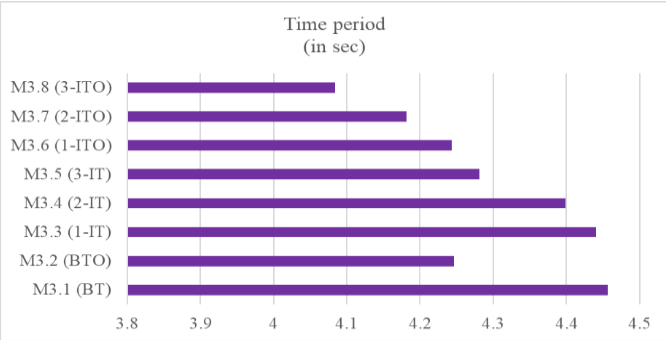

Chart -17: Comparison of First Mode Time Period for Aspect Ratio 3 Models

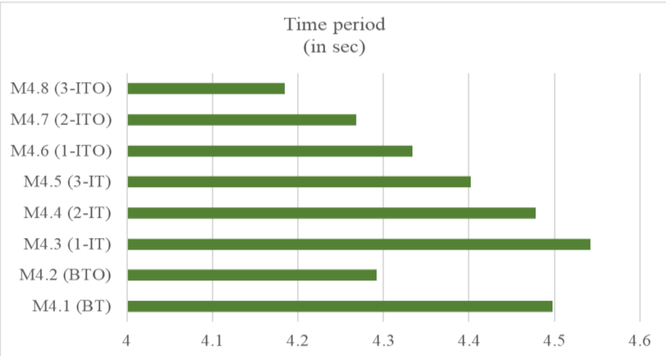

Chart -18: Comparison of First Mode Time Period for Aspect Ratio 4 Models

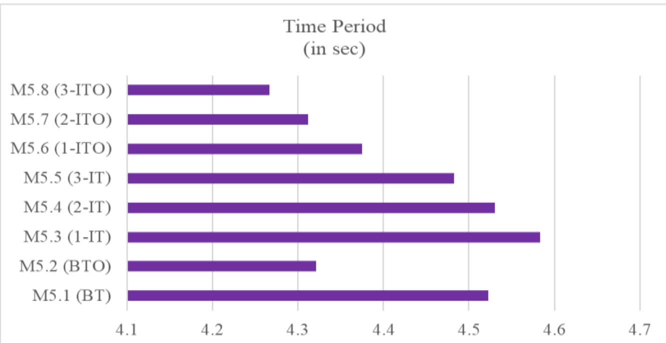

Chart -19: Comparison of First Mode Time Period for Aspect Ratio 5 Models

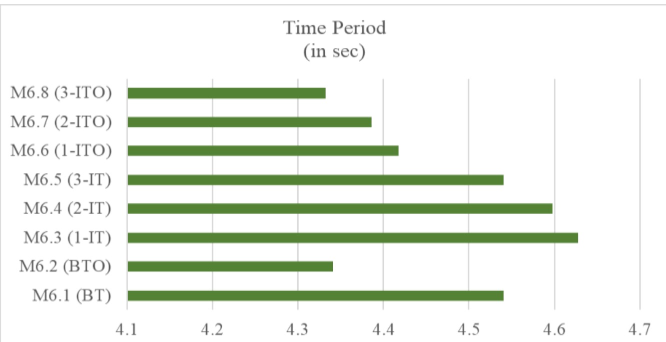

Chart -20: Comparison of First Mode Time Period for Aspect Ratio 6 Models

8. CONCLUSIONS

Maximum Displacement:

- Bundle Tube type structural system observed maximum displacement values for aspect ratios 2 to 6.
- For aspect ratio 2, Maximum 23.45 percentage of reduction in value of maximum displacement is observed in the 3 internal tube with outriggers system as compare to bundle tube type system.
- For aspect ratios 2 to 6, the percentage of reduction in displacement is noted maximum for 3 internal tube type system with outriggers as compared to bundle tube type system, respectively varying from 23.45% to 14.77%.
- In case of percentage reduction for all models, aspect ratio 6 models are noted with minimum values of it. Furthermore 1 and 2 internal tube type systems observed with lowest values for percentage reduction of 1% and 2% respectively for the same aspect ratio.

Storey Drift:

- For aspect ratios 2 to 6, the values of storey drift are detected maximum for Bundle Tube type structural system.
- Minimum percentage reduction of less than 10% is observed in all models of aspect ratio 6 compare to other aspect ratios.
- For aspect ratios 2 to 6, the percentage of reduction in displacement is noted maximum for 3 internal tube type system with outriggers as compared to bundle tube type system, respectively varying from 19.17% to 8.84%.
- For aspect ratio 2, Maximum 19.17% of reduction in value of maximum displacement is observed in the 3 internal tube with outriggers system as compare to bundle tube type system.

Load Carried by Peripheral System:

- Load Carried by peripheral system is maximum in bundle tube type system, which respectively varies from 79.78% to 78.19% in gravity load and 87.43% to 80.28% in wind load.
- As the number of internal tubes increases the load carried by peripheral system decreases, that shows effective and efficient involvement of the internal tubes in resistance of loads.
- In tube(s) in tube type system for aspect ratio 2, percentage of load carried by peripheral system is maximum and as the aspect ratio increases the values of load carried by peripheral system decreases. For aspect ratio > 4, the values are nearly at 50%, which means that there is almost equal contribution of internal and external tubes in the system.

Time Period:

- Minimum time period is observed in 3 internal tube with outriggers system for aspect ratio 2 as compared to any other system or aspect ratio.

- Maximum time period is observed in bundle tube type system for aspect ratios 2 & 3. Moreover, time period values for 1 internal tube type system slightly increases for aspect ratio 4, 5 & 6. Time period value for 2 internal tube type system also slightly increase for aspect ratio 6 as compared to bundle tube type system.

Summary:

- As per the comparative analysis done in chapter 7, values of parameter of study i.e., Maximum displacement, storey drift, and time period increases with increase of plan aspect ratio from 2 to 6.
- Use of Outriggers in structural systems can reduce displacements, storey drift and time period as compare to structural systems without outriggers.
- As per the study, the structural system with 3 internal tubes with outriggers has proven most effective as compared to other systems.
- The comparative analysis of all structural systems for plan aspect ratio 2 to 6, we can conclude that all structural systems i.e., bundle tube type, internal tube type and systems with outriggers, works more efficiently for aspect ratio 2 of plan.

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