International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 07 Issue: 06 | June 2020 www.irjet.net p-ISSN: 2395-0072

Comparative Study on Tube in Tube Structure with Different Peripheral Systems & Tube in Tube System with the Conventional Outrigger System for the Tall Structures.

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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 material corresponding to the loads imposed by lateral loads. Based on this approach, new structural systems are emerging to provide strength and stiffness with the minimum premium for height. This research consists the comparative study of the Tube in Tube structures with different peripheral systems such as Framed Tube, Braced Tube and Diagrid systems. As well as the Conventional Outrigger system is introduced along with the above mentioned system to improve the lateral load resistance capacity of the structure. Building with two different geometries, square and rectangular is considered which have 35m x 35m and 35m x 70m dimensions of plans. The study is carried out for two different heights i.e. 45 stories (171m) and 54 stories (205.2m). The storey height of each storey of the building is 3.8m.The building is located at Bhuj. In models with outrigger system the outriggers are applied at 12th, 23rd, 30th and 38th stories for 45 storey building and at 14th, 28th, 38th and 46th stories for 54 storey building. The modeling and analysis of models are carried out by computer software ETABS17.*

***Key Words*: Tall building, Framed Tube, Braced Tube, Diagrid, Conventional Outrigger**

1. INTRODUCTION

The anxiety to construct high is nothing new for civilization and the competition for building bigger and taller is as archaic as civilization. Development of new technology occurs founded upon demand, and the technology progresses towards enhanced efficiency. Subsequently at current-day higher and effective structures are evolved to exploit land uses more economically. Advancement in structural engineering, technology improvements in construction techniques, have greatly enlarged the height limit.

Construction of tall structures using tubular structural system started from the percept that lateral stiffness is the governing design criterion, and the strength essentiality is automatically satisfied. Meeting the stiffness requirements causes the structural engineering to appeal the efficient structural system with consideration of material saving design. Recent studies prove that the design criterion in high rise buildings depends on the skeleton of the structural system and in some structural systems (diagrid structures); it may be changed to strength requirement. Thus, providing both stiffness and strength requirements concurrently leads to the optimal design of a tall building. Over the last decades, for design optimization of tall structures, a combination of two or more structural systems to push the limit height of the buildings has developed.

1.1 Tube in tube Structure with different peripheral configuration

a) **Framed tube structure**
b) **Braced tube structure**
c) **Diagrid structure**

a) **Framed tube structure:** Frames consists of closely spaced columns, 2 to 4 m between centers, with deep girders connecting them. The ideology is to develop a tube like structure which acts like a continuous perforated chimney or stack. The lateral resistance of this structure is provided by stiff moment resisting frames which form a tube throughout the periphery of the building.

b) **Braced tube structure:** The tubular structure is further modified and can be done by cross bracing the frame with X-bracings wholly the entire building. As the braced tube diagonals are connected to the column at each and every intersection, they virtually erase the shear lag effects in flange and web frames together.

c) **Diagrid Structure:** Diagrid means "Diagonal Grid". One of the expressive structural design solutions for tall buildings is recently incorporated by the diagrid structural system. Diagrid, with a perimeter structural configuration described by a narrow grid of diagonal members involved both in gravity and in lateral load resistance, utilizes less structural steel than a conventional steel frame. Diagrid provides for a more defendable structure and has emerged as a new design trend for tall-shaped complex structures due to aesthetics and structural performance.

1.2 Outrigger structural system

Outriggers are rigid horizontal structures designed to recover the building overturning stiffness and strength by connecting the building core wall to the External column. Outrigger system for tall buildings has been used for narrow and tall buildings to provide resistance to lateral loads. As the outrigger is connected between core and the exterior column, this commutes the overturning moment and efficiently reduces resulting lateral displacement at top floors. When Horizontal loading acts on the building, the column restrained outriggers resist the rotation of the core, causing the lateral deflections and moments in the core to be smaller than if the free standing core alone resisted the loading. The result is to increase the effective depth of the structure when it bends as a vertical cantilever, by inducing tension in the windward columns and Compression in the leeward columns. It should be noted that while the outrigger system is very effective in increasing the structure's flexural stiffness, it doesn't increase its resistance to shear, which has to be carried mainly by the core.

2. AIM, OBJECTIVE & SCOPE OF WORK

2.1 Aim of Work

The aim of my work is "Comparative Study on Tube in Tube Structure with different peripheral systems & Tube in Tube System with the conventional Outrigger system for the Tall Structures."

2.2 Objective of Work

The main objective of present work is as follows:

➢ To study the various effects on performance of tall tube structure with different peripheral system like framed tube, braced tube and diagrid system having square and rectangular plan.
➢ To observe the structural behaviour of tall tube structure with conventional outrigger system for various heights.
➢ To compare the analysis in terms of time period, displacement and inter storey drift of the different models.

2.3 Scope of Work

➢ Study of various available literatures on tall tube structure and outrigger system.
➢ Building with 35m x 35m and 35m x 70m plans having 45 stories and 54 stories is considered.
➢ Bhuj city is considered as per location of the building.
➢ Outrigger system applied at 12th, 23rd, 30th and 38th stories for 45 storey building and at 14th, 28th, 38th and 46th stories for 54 storey building.
➢ Response spectrum analysis method is applied for analysis of the structure.
➢ Modeling and analysis are carried out by computer software ETABS 17.
➢ For analysis IS 16700:2017, IS 1893 (PART 1):2016, IS 875 (PART 3) codes are used.

3. BUILDING CONFIGURATION

Table -1: Building Configuration

BUILDING CONFIGURATION			Height-1 / Plan-1	Height-1 / Plan-2
Building Length	L	m	35	35
Building Width	B	m	35	70
Building height	H	m	205.2	205.2
Numbers of floor	n	m	54	54
Floor height	h	m	3.8	3.8
Tube in tube structure	Framed System		M1	M7
	Braced System		M2	M8
	Diagrid System		M3	M9
Tube in tube structure with outrigger system	Framed System		M4	M10
	Braced System		M5	M11
	Diagrid System		M6	M12

BUILDING CONFIGURATION			Height-2 / Plan-1	Height-2 / Plan-2
Building Length	L	m	35	35
Building Width	B	m	35	70
Building height	H	m	171	171
Numbers of floor	n	m	45	45
Floor height	h	m	3.8	3.8
Tube in tube structure	Framed System		M13	M19
	Braced System		M14	M20
	Diagrid System		M15	M21
Tube in tube structure with outrigger system	Framed System		M16	M22
	Braced System		M17	M23
	Diagrid System		M18	M24

4. LOAD DATA

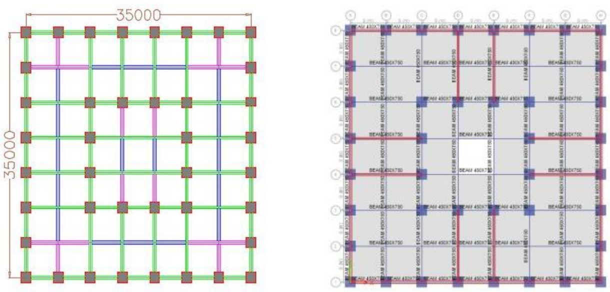
Referring to IS 456:200 and IS 875 (PART 1 & 2) specifies the various loads and forces that have to be considered while performing the design of R.C.C. structures. The design dead load and live loads on floor slab are 1.5 kN/m2 and 2.0

kN/m2 respectively. The wall load is 2.53 kN/m considered. For lateral load calculation Bhuj location is selected. The dynamic wind loading is computed based on the basic wind speed of 50 m/sec and terrain category II as per IS:875 (III)-2002(Gust factor method). The design earthquake load is computed based on the zone V, medium soil, importance factor of 1 and response reduction factor of 5.

5. MATERIAL & MEMBER PROPERTIES

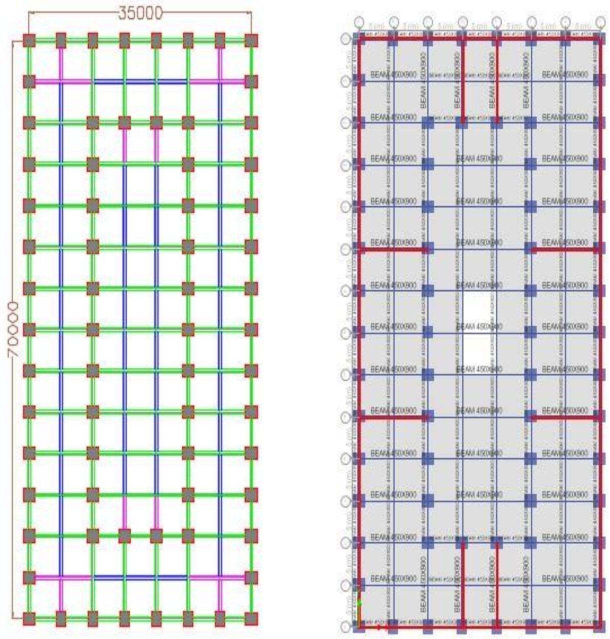
Table -2: Material & Member properties

Description	Height-1 / Plan-1	Height-1 / Plan-2	Height-2 / Plan-1	Height-2 / Plan-2
Material Properties				
Concrete Grade	M40	M40	M40	M40
Steel Grade	Fe500	Fe500	Fe500	Fe500
Member Properties				
Beam Size	450 X 750	450 X 750	450 X 750	450 X 750
Column Size	1500 X 1500	1500 X 1800	1500 X 1500	1500 X 1800
Slab thickness	150 mm	150 mm	150 mm	150 mm
Bracing Size	450 X 450	450 X 450	450 X 450	450 X 450
Diagrid Size	900mm dia.	900mm dia.	900mm dia.	900mm dia.
Outrigger Wall size	300 mm	300 mm	300 mm	300 mm



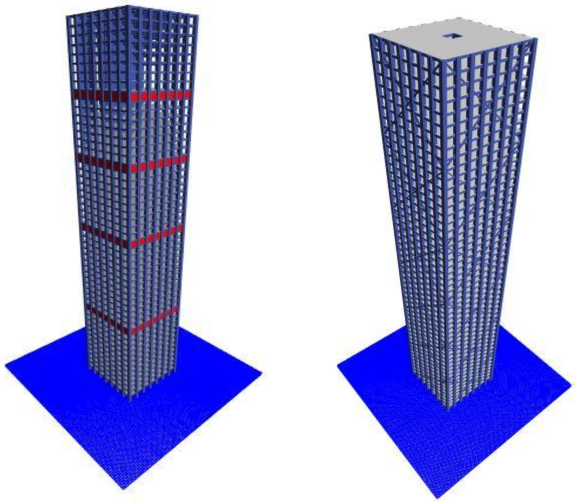
(a) (b)

Fig -1: Plan-1 (a) Column and beam layout (b) Outrigger and belt wall layout

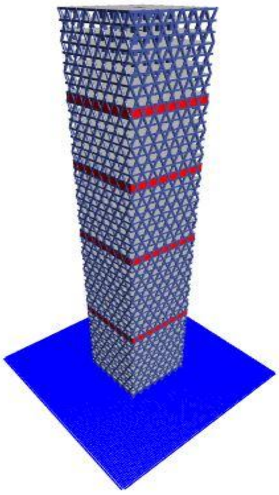


(a) (b)

Fig -2: Plan-2 (a) Column and beam layout (b) Outriggerand belt wall layout



(a) (b)



(c)

Fig -3: 3D view (a) Framed System (b) Braced System (c)Diagrid System

6. COMPARISION OF ANALYSIS RESULTS

6.1 Comparison of Maximum Lateral Displacement

Table -3: Maximum lateral displacement

No.	Max. Displace-ment (mm)	%	No.	Max. Displace-ment (mm)	%
Height-1 / Plan-1					
M1	384.855	100	M4	280.979	100
M2	222.838	57.90	M5	185.609	66.06
M3	180.086	46.79	M6	171.694	61.11
Height-1 / Plan-2					
M7	341.076	100	M10	260.679	100
M8	276.007	80.92	M11	211.388	81.09
M9	234.383	68.72	M12	220.818	84.71
Height-2 / Plan-1					
M13	208.568	100	M16	136.838	100
M14	116.485	55.85	M17	92.284	67.44
M15	84.384	40.46	M18	82.621	60.38
Height-2 / Plan-2					
M19	184.634	100	M22	128.736	100
M20	136.873	74.13	M23	105.229	81.74
M21	108.984	59.03	M24	101.123	78.55

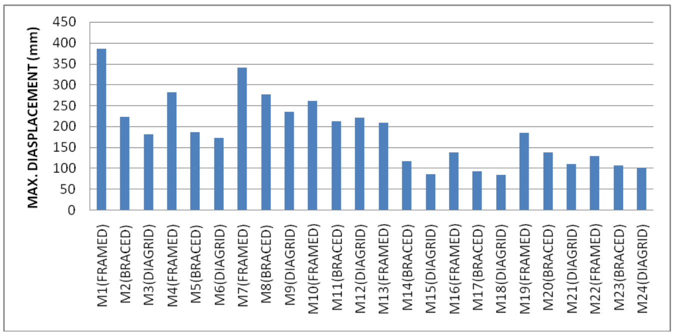


Chart -1: Comparison of max. Displacement

6.2 Comparison of Maximum storey Drift

Table -4: Maximum storey drift

No.	Max. Storey Drift	%	No.	Max. Storey Drift	%
Height-1 / Plan-1					
M1	0.002384	100	M4	0.002638	100
M2	0.001508	63.26	M5	0.001441	54.62
M3	0.001036	43.46	M6	0.000991	37.57
Height-1 / Plan-2					
M7	0.002427	100	M10	0.002256	100
M8	0.00184	75.81	M11	0.001665	73.80
M9	0.001315	54.18	M12	0.001253	55.54
Height-2 / Plan-1					
M13	0.001862	100	M16	0.001692	100
M14	0.000993	53.33	M17	0.000921	54.43
M15	0.000608	32.65	M18	0.0006	35.46
Height-2 / Plan-2					
M19	0.001633	100	M22	0.001462	100
M20	0.001178	72.14	M23	0.001079	73.80
M21	0.000733	44.89	M24	0.0007	47.88

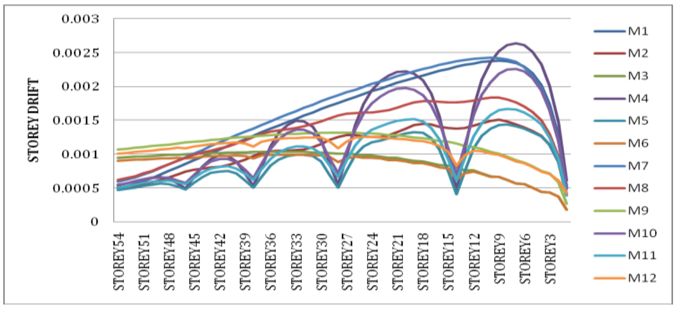


Chart -2: Comparison of storey drift at each storey (54 storey building)

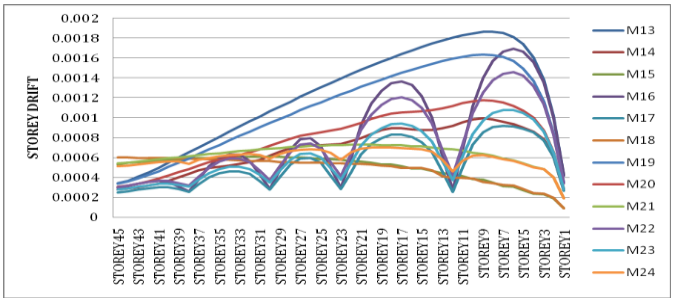


Chart -3: Comparison of storey drift at each storey (45 storey building)

6.3 Comparison of Time Period

Table -5: Time Period

No.	First Mode Time Period (Second)	%	No.	First Mode Time Period (Second)	%
Height-1 / Plan-1					
M1	6.467	100	M4	5.63	100
M2	4.877	75.41	M5	4.515	80.20
M3	3.893	60.20	M6	3.865	68.65
Height-1 / Plan-2					
M7	6.275	100	M10	5.541	100
M8	5.434	86.60	M11	4.967	89.64
M9	4.498	71.68	M12	4.413	79.64
Height-2 / Plan-1					
M13	5.235	100	M16	4.338	100
M14	3.89	74.31	M17	3.517	81.07
M15	2.847	54.38	M18	2.812	64.82
Height-2 / Plan-2					
M19	5.061	100	M22	4.274	100
M20	4.349	85.93	M23	3.85	90.08
M21	3.377	66.73	M24	3.285	76.86

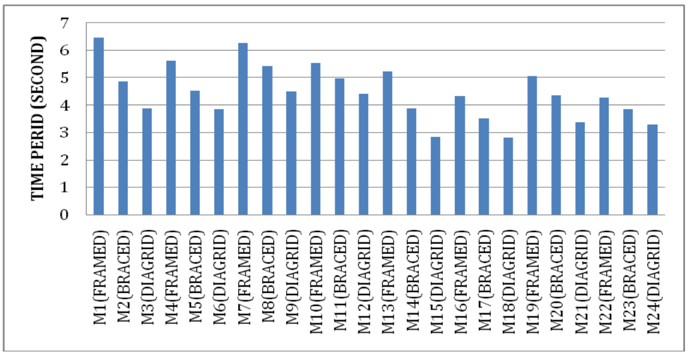


Chart -4: Comparison of time period

6.4 Comparison of Base Reaction

Table -6: Base Reaction

No.	Base Reaction (kN)	%	No.	Base Reaction (kN)	%
Height-1 / Plan-1					
M1	1220422.0	100	M4	1245494.6	100
M2	1232314.2	101	M5	1257386.8	101
M3	1120064.6	91.8	M6	1145137.2	91.9
Height-1 / Plan-2					
M7	4069134.2	100	M10	4335984.7	100
M8	2537669.8	62.4	M11	2570720.0	59.3
M9	2202094.6	54.1	M12	2235144.8	51.6
Height-2 / Plan-1					
M13	1017018.4	100	M16	1042090.9	100
M14	1026928.6	101	M17	1050567.0	100.8
M15	933387.2	91.8	M18	958459.8	92
Height-2 / Plan-2					
M19	2099858.4	100	M22	3623235.6	100
M20	2114724.8	100.7	M23	2147775.1	59.3
M21	1835078.8	87.4	M24	1865849.8	51.5

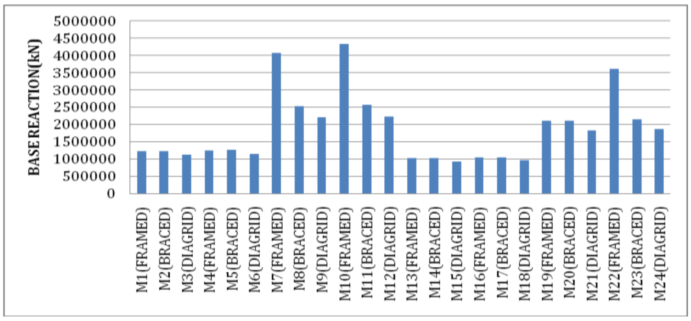


Chart -5: Comparison of base reaction

6.5 Load carried by Peripheral System

Table -7: Load carried by Peripheral system

No.	Total Load		Load Carried By Peripheral System			
	Gravity Load (kN)	Wind Load (kN)	Gravity Load (kN)	%	Wind Load (kN)	%
Height-1 / Plan-1						
M1	1220422.02	23684.45	769930.05	63.09	16309.51	68.86

M2	1232314.23	23684.46	782953.43	63.54	17844.41	75.34
M3	1120064.62	23684.45	586041.75	52.32	20654.93	87.21
M4	1245494.62	23684.45	836210.30	67.14	16308.00	68.86
M5	1257386.83	23684.45	847923.00	67.44	17389.69	73.42
M6	1145137.22	23684.45	590476.49	51.56	20641.28	87.15
Height-1 / Plan-2						
M7	2519830.14	46382.58	1370939.45	54.41	27668.25	59.65
M8	2537669.79	46382.57	1389915.85	54.77	29646.37	63.92
M9	2202094.61	46382.57	882418.65	40.07	32972.01	71.09
M10	2552880.37	46382.58	1467260.35	57.47	27668.75	59.65
M11	2570720.03	46382.57	1484991.31	57.77	29638.13	63.90
M12	2235144.85	46382.57	876076.26	39.20	30836.07	66.48
Height-2 / Plan-1						
M13	1017018.35	16355.57	633525.68	62.29	11263.72	68.87
M14	1026928.53	16355.57	644342.87	62.74	12295.40	75.18
M15	933387.18	16355.57	490531.56	52.55	14140.82	86.46
M16	1042090.95	16355.57	697354.19	66.92	11263.14	68.86
M17	1050567.05	16355.57	703513.04	66.97	12291.77	75.15
M18	958459.78	16355.57	495255.88	51.67	14130.57	86.40
Height-2 / Plan-2						
M19	2099858.45	29035.38	1122444.39	53.45	17322.45	59.66
M20	2114724.83	29035.38	1132081.42	53.53	18521.63	63.79
M21	1835078.84	29035.38	742223.20	40.45	20424.51	70.34
M22	2132908.68	29035.38	1216068.57	57.01	17323.12	59.66
M23	2147775.07	29035.38	1230890.97	57.31	18516.63	63.77
M24	1865849.75	29035.38	738855.42	39.60	20388.21	70.22

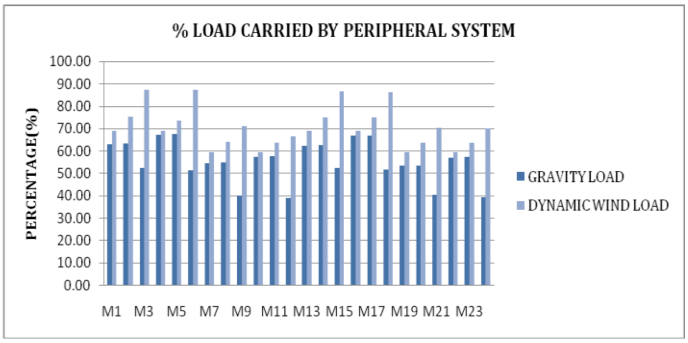


Chart -6: Comparison of % load carried by peripheral system

7. CONCLUSIONS

From the study, it is observed that for square and rectangular geometry, for both different heights, minimum lateral displacement observed in the tube in tube structure with outrigger system having a diagrid peripheral system. It is also remarked that the lateral displacement in the tube in tube structure with outrigger system is lesser than the structure without outrigger system. The storey drift is very much less in structures having square geometry and diagrid system as a peripheral system. The storey drift is invigilated minimum at the stories where the outrigger and belt wall is applied. The first mode time period is lesser in the structures having a rectangular geometry compared to square geometry. The first mode time period is highest in the structures having a framed system and lowest in structures having a diagrid system. The gravity load is resisted by both the peripheral and core system but the lateral load (earthquake or wind load) is mainly resisted by peripheral system i.e. exterior tube. There are two main loads which acted on the structure i.e. gravity load and lateral load (earthquake and wind load). Wind load is higher compared to earthquake load for 54 and 45 storey tube in tube structures, considered in this study. So, wind load is governing for the studied structures. In short, the tube in tube structure with outrigger system is more effective than without outrigger system. If talk about the peripheral systems, the diagrid system is most expedient and braced and framed system are successively less expedient than the previous one.

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