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Performance of Tubular Structure under Seismic Excitation

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Abstract*: Advancement in the building construction technology and structural analysis the tall structures have been significantly increased due to over growing population and for land mark of country. The tall structures are more prone to lateral load. In this study different forms of tubular structure are used to resist the Earthquake forces. Tubular structures are made based on the idea that building is design to act like a hollow cylinder cantilever perpendicular to the grounds. The aim of this paper is to present the seismic performance of tubular structure with and without central core. The Framed tube system, Tube in tube system, Bundled tube system, Braced tube system and Moment resisting Frame was analyzed to draw the comparison on the basis of base shear, storey drift, time period and storey shear satisfying the structural codes- IS 456-2000, IS 1893(Part 1):2016 in E-TABs software by Response spectrum method.

Keywords: Framed tube system, Tube in tube system, Bundled tube system, Braced tube system, Base shear, Storey drift, Time period and Storey shear, Response Spectrum method, E-TABs

I. INTRODUCTION

Tall structures are constructed rapidly due to advancement in the building construction technology and structural analysis due to overgrowing population, urbanization and to make the land marks of the country the structure are made to be taller. The structures are said to be tall, if it is higher than low - rise structure. The taller structure is more prone to earthquakes forces. For the stability of the structure to with stand the lateral forces the different structural forms has been designed over the last decades. The construction of tall structure is possible with tubular structure forms by the concepts the structure is design to act like a hollow cylinder cantilever perpendicular to the grounds. The concept of tubular system was developed by Dr. Fazlur Khan. Tubular system is economic, safe and serviceable for tall structure than conventional framed system in high- rise structure. Tubular structure can be constructed using steel, concrete and composite construction.

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In the tubular system closely spaced column is connected with deep spandrel beams that are tied together form a rigid frame that amount to dense and strong structural wall along the exterior of the building.

The exterior framing is designed sufficiently strong to resist all lateral loads on the building, thereby allowing the interior of the building to be simply framed to gravity load.

II. TYPES OF TUBULAR SYSTEM

A. Framed tube system

It is modification in the moment resisting frame where the exterior shell is made by closely spaced column of 1.5 - 4.5, which is connected by deep spandrel beam of 0.5 - 1.5 in the structure. In this system, the exterior shell is design to resist lateral load and interior beam and column is design to resist gravity load.

B. Tube in tube system

This structural system is advancement in the framed tube system in which outer tube around the exterior and the inner tube is formed at the inner core. The tubes are interconnected by the floor slab and works together to resist the lateral loads to provide stability and rigidity in the structure.

C. Bundled tube system

The Bundled tube system consist of multicellular tube interconnected with each other and they work together to resist lateral loads and overturning moment experienced by the structure. This system is economically efficient and versatile structure can be build.

D. Braced tube system

Frame tube system consists of additional bracing system in its exterior farming than it is said to be braced tube system. The interconnection of all the exterior columns forms rigid box to withstand lateral forces. In this system it is possible to have a lot of space for window due to abroad spacing of column.

III. RESPONSE SPECTRUM METHOD

In order to perform the seismic analysis and design of a structure to be built at particular location, the actual time history is record is required .However, it is not possible to have such records at location. Further, the seismic analysis of structure cannot be carried out simply based on the peak value of the ground acceleration as the response of structure depend upon the frequency content of ground motion and its own dynamic properties.

To get rid of the above difficulties, earthquake response is the most popular tool in the seismic analysis of structures. In response spectrum method, the calculation of maximum displacement and member force in each modes of vibration can be done with smooth design spectra which are average of earthquake motion.

IV. METHODOLOGY

1. For the present work, 40 storeys building having each floor height constant of 3 meter was considered.
2. Moment resisting frame was considered as reference model for the study.
3. Modelling of tubular structure such as framed tube, tube in tube, bundled tube and braced tube system with and without core was done in the reference of moment resisting frame.
4. All the models were analyzed according to IS 1893(part 1): 2016 in ETABs software to understand the behaviour of structure under lateral loads.
5. Tubular structure with and without core were compared on the basis of seismic parameter such as story drift, story shear, time period and storey displacement with the reference model.
6. Based on the result of comparison the most effective lateral load resisting has been obtained.

V. MODELING AND ANALYSIS

In present research work, 40 storied reinforced concrete structures with constant floor height of 3 meter and dimension of plan is 40m x 40m is considered. All together 9 models has used for the study. Different forms of tubular structures with and without core had been modeled taking base model as moment resisting frame. The core is placed at the centre and it is about 6.25% of total area space. The dimension of core is 10m x 10m. The spacing of column in the case of tubular structure is 2.5m centre to centre to form a tube where as in moment resisting frame is 5m Centre to Centre. The structures are located in zone 4, so the dynamic analysis according to IS 1893(part1): 2016 had been conducted. Modeling and analysis was done in ETABs 2017 software. The preliminary data required for the analysis of building are tabulated below.

Table-I: Preliminary data for buildings

S.N	Particulars	Dimension/size/value
1	Plan dimension	40m x 40m
2	No. of stories	40
3	Height of the floor	3m
4	No. of grids in X dir.	9
5	No. of grids in Y dir.	9
6	Spacing of grids in X dir.	5
7	Spacing of grids in Y dir.	5
8	Size of column (1 to 10 storey)	800mm x 800mm
9	Size of column (11 to 20 storey)	700mm x 700mm
10	Size of column (21 to 30 storey)	600mm x 600mm
11	Size of column (31 to 40 storey)	500mm x 500mm
12	Bay length of tube	2.5m
13	Primary beam	300mm x 600mm
14	Secondary beam	300mm x 500mm
15	Thickness of core wall	250mm
16	Thickness of slab	150mm
17	Grade of concrete	M30
18	Grade of rebar	HYSD 415
19	Live loads	4 kN/m²
20	Floor loads	1 kN/m²
21	Seismic zone	iv
22	Type of soil	2
23	Zone factor	0.24
24	Response reduction(R)	5
25	Important factor	1
26	Core dimension	10m x10m

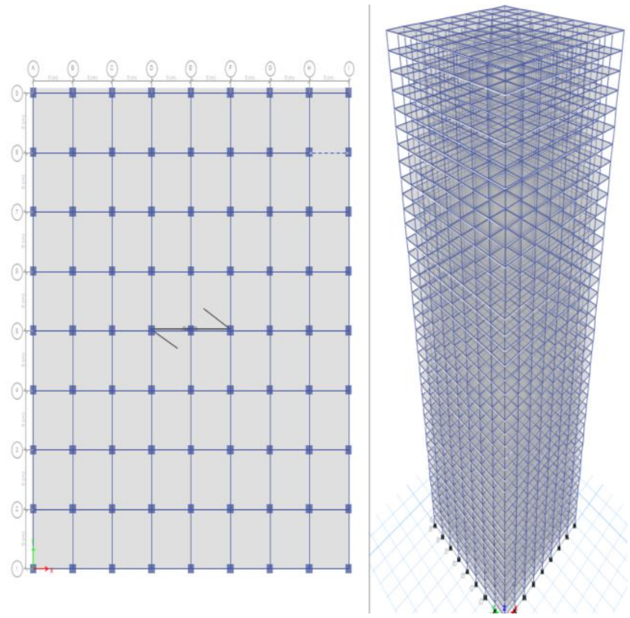

Fig 1: Plan & 3D View of Moment resisting frame model

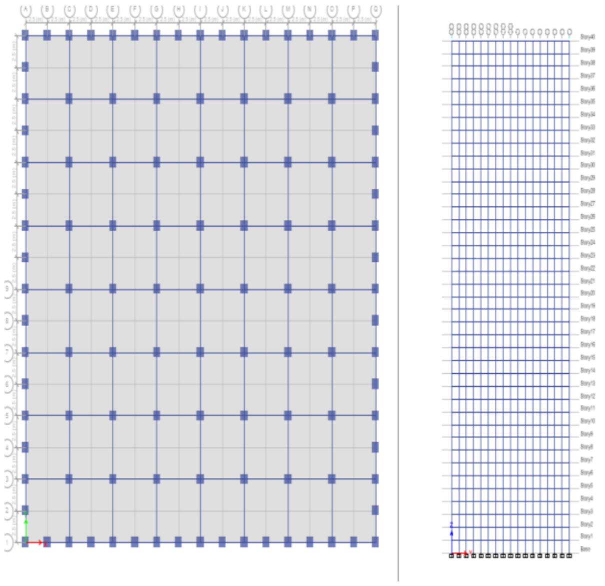

Fig 2: Plan & Elevation of Frame tube model

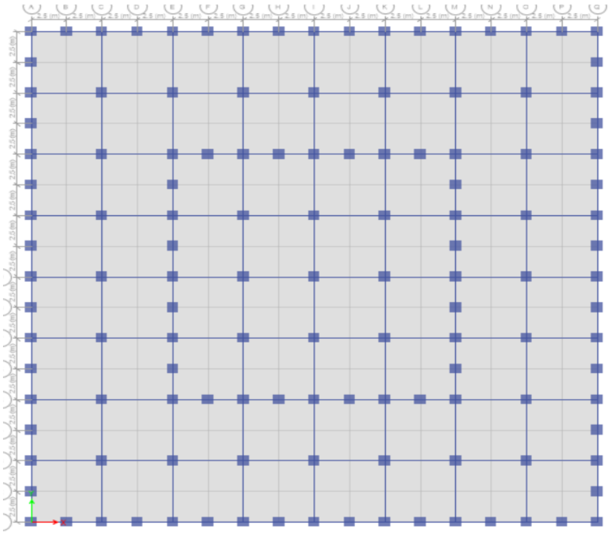

Fig 3: Plan of Tube in tube model

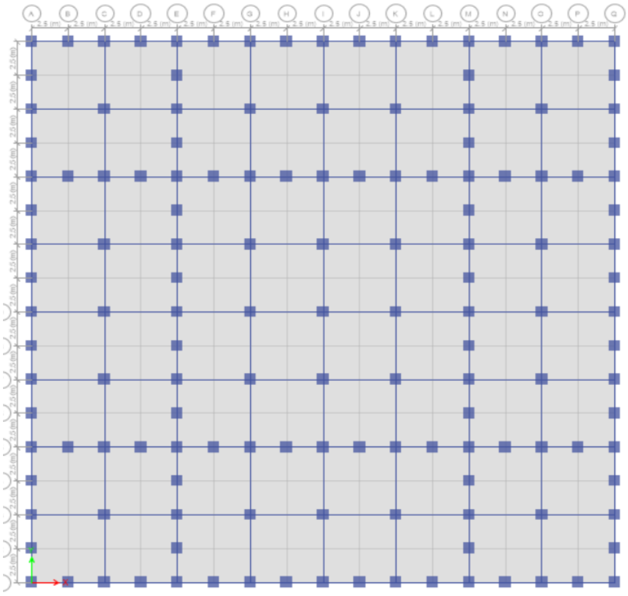

Fig 4: Plan of Bundled tube model

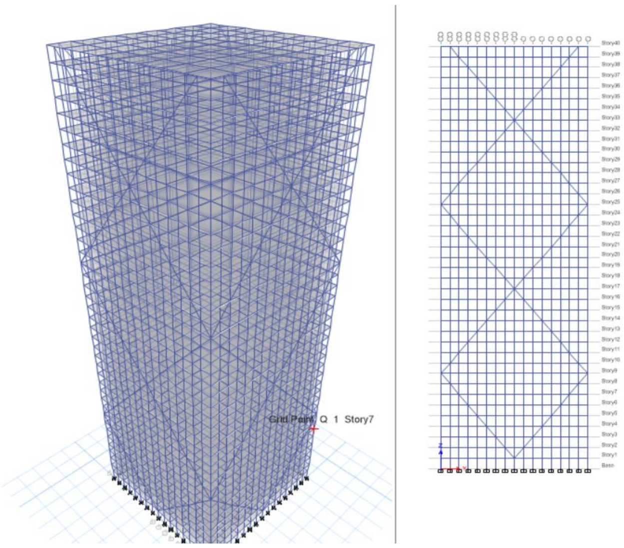

Fig 5: 3D View & Elevation of Braced tube model

VI. RESULT AND DISCUSSION

Response spectrum method is applied on the model to perform seismic analysis as per IS 1893(part1):2016 in zone 4. The effect of core in the tubular structure is evaluated based on the seismic parameter such as base shear, Storey displacement, storey shear and time period. All the results has been observed and tabulated below.

A. Storey displacement

It is the maximum horizontal displacement of storey with respect to its base. In the case of high rise structure the displacement is important parameter for the stability of structure against lateral load. According to high rise building code the lateral displacement shouldn't exceed H/500, where H is the total height of building. All the models are within permissible displacement. The storey displacement of different model in X and Y direction is as follows:

Table-II: Result of maximum displacement

S.N	Structural system	Displacement(in mm)	
		X- direction	Y- direction
1	Moment resisting frame	134.295	135.646
2	Framed tube system	95.825	95.825
3	Tube in tube system	90.641	90.641
4	Bundled tube system	86.942	86.929
5	Braced tube system	80.016	80.016
6	Framed tube system with Central core	85.401	85.401
7	Tube in tube system with Central core	81.329	81.52
8	Bundled tube system with Central core	78.128	78.041
9	Braced tube system with Central core	73.362	73.447

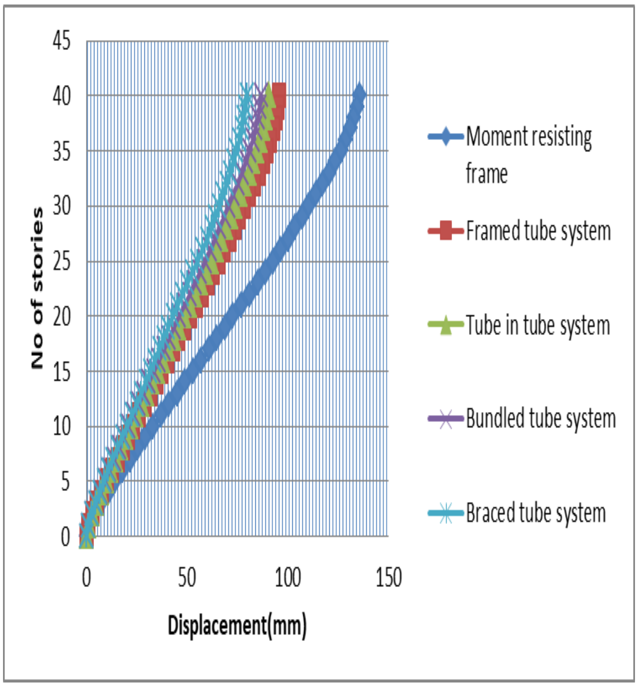

Fig 6: Comparison of displacement in X - direction

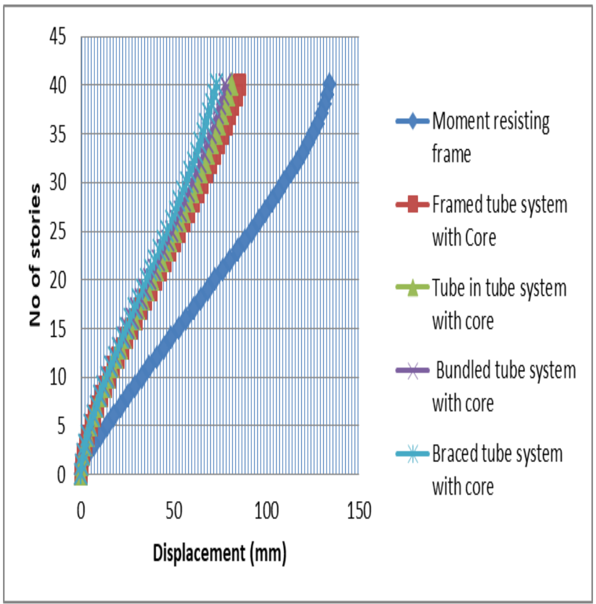

Fig 7: Comparison of displacement in X – direction

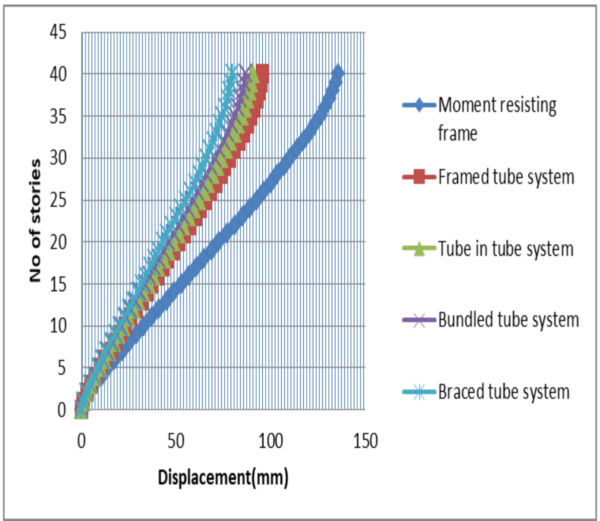

Fig 8: Comparison of displacement in Y – direction

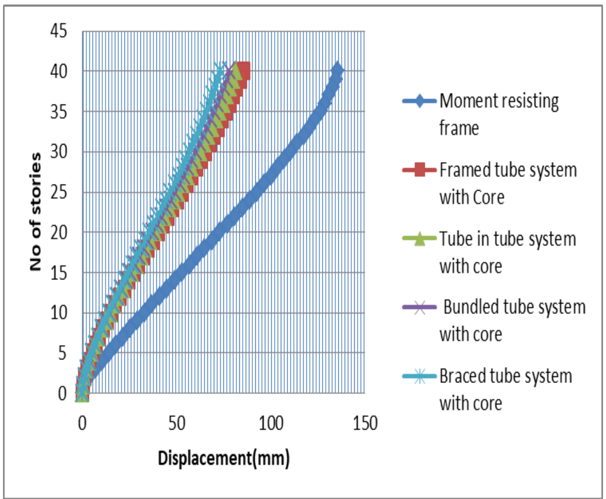

Fig 6: Comparison of displacement in Y – direction

From above graph and table, it can be observed that as height of building increase, the storey displacement is increased. Moment resisting frame has larger displacement in compare to tubular structure. The displacement of framed tube system, tube in tube system, bundled tube system and braced tube system is reduced to 28.5%, 32.5%, 35%, 40.22% in X- direction and 29.5%, 33.17%, 35.91%, 41% in Y-direction respectively in compare to moment resisting frame where as in addition with core in frame tube system, tube in tube system, bundled tube system and braced tube system is reduced to 36.40%, 39.44%, 41.82%, 45.37% in X – direction and 37.04, 39%, 42.46, 45 in Y - direction.

B. Storey drift

Story drifts is the difference in displacement of two successive stories divided by the height of that floor. The maximum storey drift in any storey of building due to lateral loads should not exceed 0.4% of storey height as per IS 875:2016(part3). In present work all the model are within permissible value. The storey drift of different model in X and Y direction is as follows:

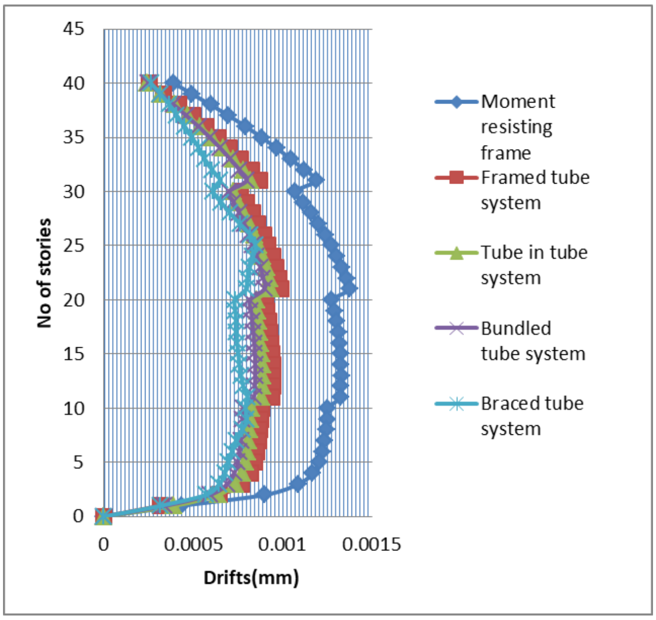

Fig 9: Comparison of storey drift in X – direction

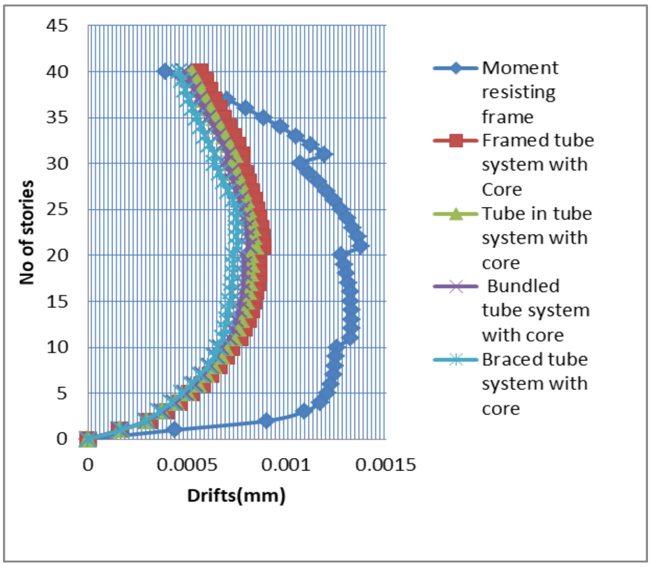

Fig 10: Comparison of storey drift in X – direction

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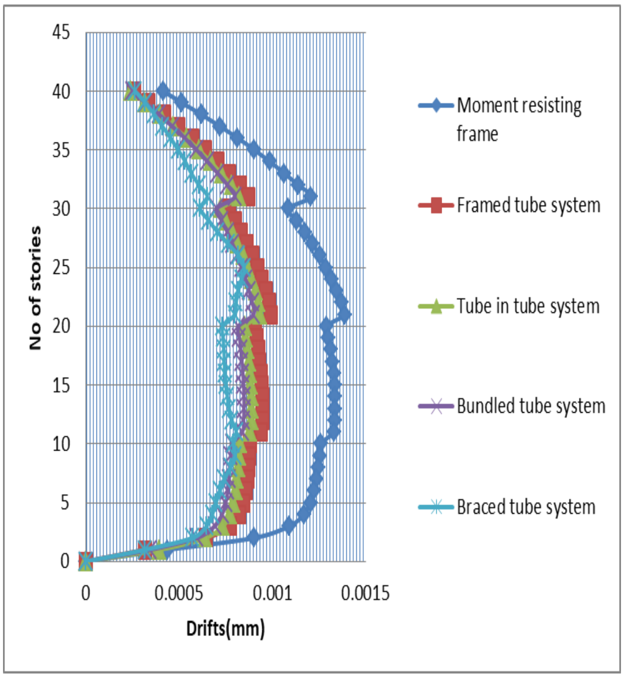

Fig11: Comparison of storey drift in Y – direction

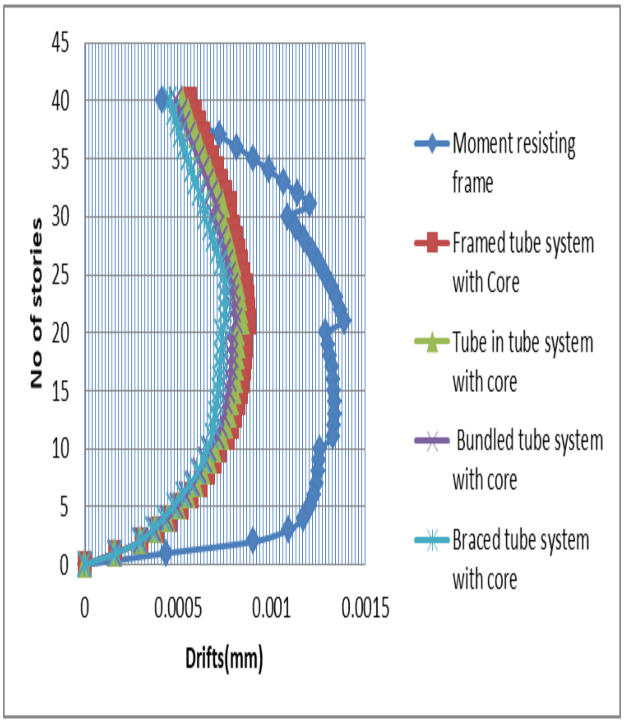

Fig 12: Comparison of storey drift in Y – direction

From above graph, it was observed that the moment resisting frame have greater storey drift than tubular structure. The storey drift is significantly decreased with the tubular structure. The entire models have the maximum storey drift at 21 storey. The storey drift is reduced to 18%, 22%, 31.1%, 26% in frame tube system, tube in tube system, bundled tube system, and braced tube system in compare to moment resisting frame. In addition of core in frame tube system, tube in tube system, bundled tube system and braced tube system the storey drift is decreased to 33.33%, 36.6%, 39.08% and 41% in compare to moment resisting frame.

C. Base shear

Base shear is the total horizontal forces act on the base of structure due to occurrence of earthquake motion. The base shear of different model are tabulated and presented in the graph as below:

Table III: Result of Base shear

S.N	Structural system	Base Shear(in kN)	
		X- direction	Y- direction
1	Moment resisting frame	7917.0319	7917.0319
2	Framed tube system	9118.5734	9111.925
3	Tube in tube system	9914.5044	9909.3827
4	Bundled tube system	10714.4388	10718.5627
5	Braced tube system	10946.8224	10944.7144
6	Framed tube system with Central core	11656.7144	11654.4698
7	Tube in tube system with Central core	12378.5868	12376.1454
8	Bundled tube system with Central core	13100.0101	13097.7297
9	Braced tube system with Central core	12958.4637	12955.8763

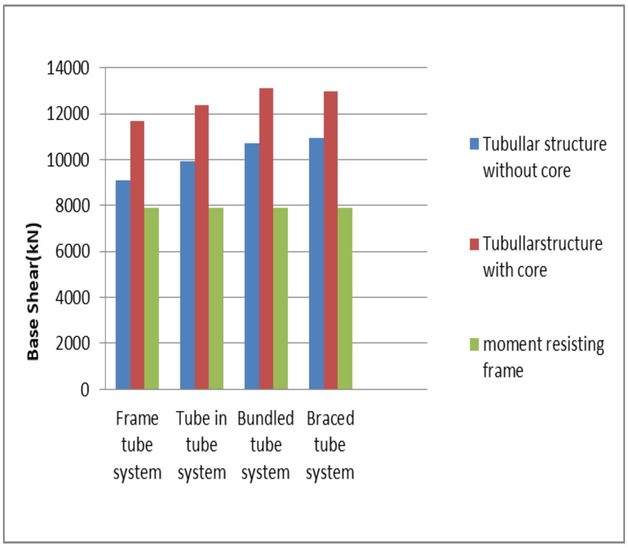

Fig 13: Comparison of base shear in X – direction

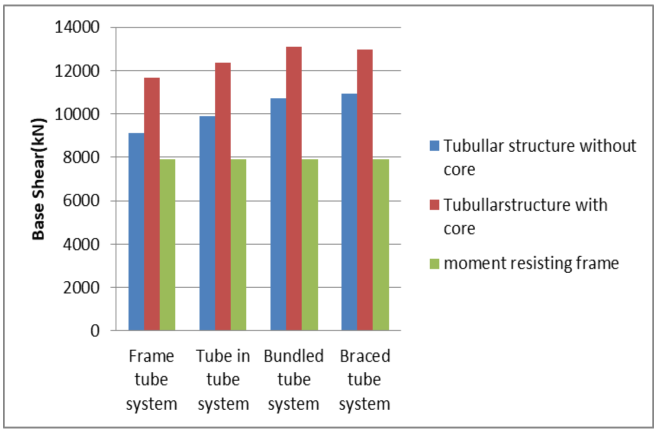

Fig 14: Comparison of base shear in Y – direction

From above bar graph and table, it can be observed that base shear is more in tubular structure than moment resisting frame.

In compare to moment resisting frame, base shear in frame tube system, tube in tube system, bundled tube system and braced tube system is increase to 15%, 25%, 35%,38% in both X and Y direction respectively and by addition of core the base shear has been increased to 47%, 56%, 65%, 63% in both X and Y direction.

D. Storey shear

The design lateral load acting on each floor level is called storey shear. The values of storey shear are maximum at the bottom and minimum at the top. The comparative maximum values of storey shear in X and Y direction is tabulated and presented in the bar graph below

Table IV: Result of Storey shear

S.N	Structural system	Story Shear(in kN)	
		X- direction	Y- direction
1	Moment resisting frame	8654.9218	8644.2981
2	Framed tube system	9536.4519	9529.9187
3	Tube in tube system	10326.2225	10321.1374
4	Bundled tube system	11112.3598	11116.24
5	Braced tube system	11308.2549	11306.0773
6	Framed tube system with Central core	11918.0633	11915.7684
7	Tube in tube system with Central core	12638.6567	12636.9077
8	Bundled tube system with Central core	13363.3092	13360.639
9	Braced tube system with Central core	13203.9352	13199.4472

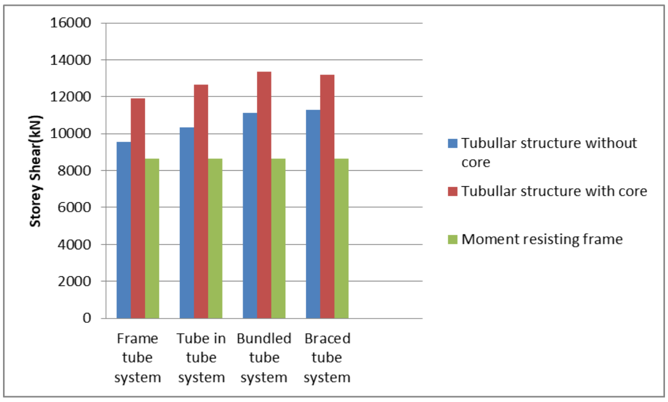

Fig 15: Comparison of storey shear in X – direction

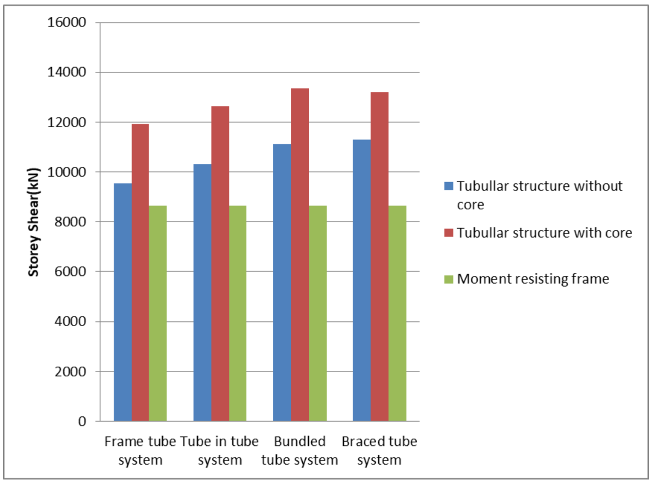

Fig 16: Comparison of storey shear in Y – direction

From above bar graph, it is observed the storey shear increase in tubular structure in compare to moment resisting frame. It is increased to 10.01%, 19.31%, 28.69%, 30.65% in framed tube system, tube in tube system, bundled tube system, braced tube system without core and with core it is increased to 37%, 46.08%, 54.40%, 52.55% respectively .

E. Time period

The time required to complete one oscillation of structure during earthquake is called time period. The time period of the entire model are tabulated and presented in graph as follows:

Table V: Result of time period

S.N	Structural system	Time Periods(in sec)
1	Moment resisting frame	4.59
2	Framed tube system	3.756
3	Tube in tube system	3.539
4	Bundled tube system	3.354
5	Braced tube system	3.158
6	Framed tube system with Central core	3.058
7	Tube in tube system with Central core	2.91
8	Bundled tube system with Central core	2.796
9	Braced tube system with Central core	2.672

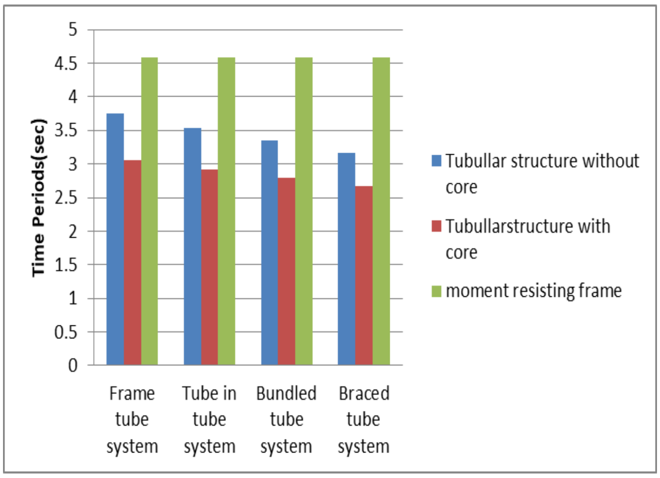

Fig 17: Comparison of time period

From above graph, it is observed that moment resisting frame have maximum time period than tubular structure. The time period is reduced to 18%, 22.8%, 26%, and 31.19% in the frame tube system, tube in tube system, bundled tube system and braced tube system respectively in comparison to moment resisting frame. In addition to central core in the frame tube system, tube in tube system, bundled tube system and braced tube system the time period is decreased to 33.33%, 36.6%, 39.08% and 41% respectively. The reduction in time period makes the structure stable during earthquake motion.

VII. CONCLUSION

From above results and discussion the conclusion have been drawn as follows:

1) The displacement value of all the tubular structure system shows the reduced displacement in both X and Y direction as comparing with moment resisting system. However the frame tube system shows the highest and braced tube system shows least displacement in compare to all the tubular system.
2) Storey drift of the entire all the structural system have low values of storey drift at the ground and maximum values at the middle of the structures. Moment resisting frame show more values of storey drift in compare to other structural system.
3) The comparative results of base shear shows that moment resisting frame has lesser base shear than the tubular structure. In addition of core at the centre of tubular structure increase the base shear of tubular structure in both X and Y direction respectively.
4) Storey shear of all the tubular structure is greater than moment resisting frame .The results shows that tubular structure with core has increased in storey shear than tubular structure without core.
5) Frame tube system and braced tube system has highest and least time period in compare to other tubular structures. It shows that addition of core at the centre of tubular structures decreased the time period more as compared to tubular structure without core.

Finally, we concluded that the tubular structures are very economical and better lateral load resisting system than moment resisting frame system. In addition of core in the tubular structure makes the structure more efficient and stable in resisting the earthquakes forces. It is seen that braced tube system with and without core had better performance to resist the lateral in comparison to other tubular structure.

REFERENCES

1. Ghasemi,"EVALUATION OF SEISMIC BEHAVIOUR OF IRREGULAR TUBE BUILDINGS IN TUBE SYSTEMS", Advance in Science and Technology Research Journal, Vol. 10,2016, pp. 46-51.
2. Eadukondalu and Reddy, " Study of Lateral Structural Systems in Tall Buildings", International Journal of Applied Engineering Research, Vol.13, 2018, pp.11738-11754.
3. Lu Xinzheng , Xie Linlin , Yu Cheng and Lu Xiao , "Development and application of a simplified model for the design of a super- tall mega tall- braced frame - core tube building", ELSEVIER,Vol.110 2016, pp. 116-126.
4. Patel and John, "Seismic analysis of frame tube structure", International journal of Scientific & Engineering Research, Vol.6, Issue12,2015,pp.2229-5518.
5. Brunesi,Nascimbene , Casagrande, " Seismic analysis of High –rise Mega- braced framer- core building", ELSEVIER, Vol. 115, 2016 pp.1-17.
6. Wadagule and Charantimath , "Comparative study of tube in tube structure and Frame tube structure", International Research journal of Engineering and Technology, Vol.6, Issue 7,july-2019,pp.1668-1673
7. Zhang, Lu, Z. Lu , Ye and Qian, " Collapse for a Super- Tall Mega –braced frame Core- tube building", 15th World Conference on Earthquake Engineering 2012.
8. L. Shruthi and Vijaya S., "seismic Analysis of Lattice Shell Tube RC Framed Building," International Journal of Engineering Research and Technology, Vol. 3, Issue 7, 2014, pp. 1201-1205.
9. Essam. , Ayyash and Ghoniem E.H , "Seismic Response of High- Rise Buildings with Different Structural System", International journal of Engineering and Innovative Technology, Vol. 8, Issue 9, November -2018,pp.42-51.
10. Tuna, Wallace, Yang and Moehl, " Seismic performance of reinforced concrete core wall building with and without moment resisting frame ", 15th World Conference on Earthquake Engineering 2012.
11. Shadulla and K M , "Analysis of tube in tube structure with different size of inner tube", International journal of Technical Innovation in Modern Engineering & Science, Vol. 4, Issue10, 2018,pp.75-83.

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