**International Journal of Advanced Research in Engineering and Technology (IJARET)**
Volume 11, Issue 6, June 2020, pp. 328-337, Article ID: IJARET_11_06_029
Available online athttp://www.iaeme.com/IJARET/issues.asp?JType=IJARET&VType=11&IType=6
ISSN Print: 0976-6480 and ISSN Online: 0976-6499
DOI: 10.34218/IJARET.11.6.2020.029



# SEISMIC PERFORMANCE OF BUNDLED TUBE STRUCTURES IN SEISMIC ZONE IV & ZONE V OF INDIA

**Patil. Kiran Kumar**
M.Tech Scholar, Department of Civil Engineering, GITAM - Gandhi Institute of Technology and Management, Visakhapatnam, Andhra Pradesh, India

**Chandan Kumar. Patnaikuni**
Assistant Professor, Department of Civil Engineering, GITAM - Gandhi Institute of Technology and Management, Visakhapatnam, Andhra Pradesh, India

**Balaji .K.V.G.D**
Professor, Department of Civil Engineering, GITAM - Gandhi Institute of Technology and Management, Visakhapatnam, Andhra Pradesh, India.

**B. Santhosh Kumar**
PhD Scholar, Department of Civil Engineering, GITAM - Gandhi Institute of Technology and Management, Visakhapatnam, Andhra Pradesh, India. &
Deputy Executive Engineer, W.R. Department, GOAP, India

**ABSTRACT**

*Seismic performance of the 150m tall rectangular plan Bundle tube and framed tube structures have been performed with the CQC method in Response spectrum method in Seismic zone 4 and Zone 5 of IS 1893-2016 code provisions. With the high flexibility to terminate the tubes at required heights of the structure, the bundled tube structure can be selected in tall buildings. This statement is established with the higher specific performance of peak characteristics is found in comparison with the framed tube structure for the similar seismic characteristics.*

**Key words:** Framed tube structure, Bundled Tube Structure, Response spectrum analysis; IS- 1893:2016

**Cite this Article:** Patil. Kiran Kumar, Chandan Kumar. Patnaikuni, Balaji .K.V.G.D and B. Santhosh Kumar, Seismic Performance of Bundled Tube Structures in Seismic Zone IV & Zone V of India, *International Journal of Advanced Research in Engineering and Technology*, 11(6), 2020, pp. 328-337.
http://www.iaeme.com/IJARET/issues.asp?JType=IJARET&VType=11&IType=6

## 1. INTRODUCTION

The design of tall buildings with Different structural forms have been evolved from 1890 onwards in the USA. These have been transformed into other modern typologies in Asian content from 1990 onwards. The lateral loading intensity increases with the height of the building for wind loads. similarly, the seismic loads of the tall building increase with the high of the building since seismic weight increases with the height. In both cases, the vulnerability index is proportional to the height of the structure.

The tall buildings are designed with Architectural, structural and mechanical design approaches. In the structural approach method for the structural members are further classified as interior structural resistance method and exterior structural resistance method. The perimeter of the tall building has a significant effect for lateral load resistance, hence in the latter, structural classification the most of the lateral load resisting systems are concentrated on the perimeter of the structure.

Recognizing the importance of the premium for heights for tall buildings, the tall building typology has been significantly revolutionized with the inception of the tubular structural form which has the three-dimensional structural response for and the buildings utilize the total perimeter of the building for lateral load resistance in contrast with the conventional planar rigid frame beam-column structural forms.

Fazlur Rahman Khan is considered the “father of tubular design who innovated this system in the early 1960s. These are either framed tube, tube in the tube or Bundled tube structures. For very tall structures, a single framed tube is not adequate, since the width of the building at its base should be large to maintain reasonable slenderness (i.e., height-to-width) ratio such that the building is not excessively flexible and does not sway too much. The system efficiency is considerably diminished in a single framed tube of enormous height due to shear lag effect. This effect can be mitigated by bundle tube design, where the rigidity of the structural system against lateral loads can be combining more than one tube (bundled-tube).

A bundled tube is a cluster of individual tubes connected to act as a single unit bundle tube. Tube systems can be used in several geometrical forms like rectangular, square, triangular, circular and even free-forms in the plan. The most advantage of the bundle tubes is to free to create the tubes of different heights in the system and to control the aspect ratio [1].

The highest vulnerability specified in zone IV and zone V [2]. Most of the cities have a scarcity of the land for construction of the individual buildings or shopping complexes, hence the multi-storey, high rise and tall building structures formed as an alternative to mitigate the land problem. But the tall buildings have to be designed as the large lateral load resistant systems for both Wind loads and Seismic loads.

In this paper, the seismic resistance of the bundled tube structure over the framed tube structure is presented. The seismic parameters are modelled with IS 1893-2016 code version. The 150- meter height of bundle tube and framed tubes are modelled in STAAD Pro Connect V22 version Programme [3].

## 2. LITERATURE REVIEW

The definition height of tall buildings varied internationally. And No exception to Indian codes includes IS 875-PART3-2015, IS 1893-2016 and IS 16700-2017 defined the different height ranges for the definition of high rise and tall building concepts. The height of the building over 20m is defined as high rise building in IS 875-part3 code [4], however, the design criteria of tall buildings code are 16700-2017 defined the limit between 50m and 200m height.

The Code 16700 -2017 restricts the use of Moment Framed Structures in Zone 4 and 5 because the structural performance with structural walls effect cannot be increase beyond the 1.5% improvement. Hence alternative structural forms are preferred with Belt structures, Outrigger structures and tubular structures [5].

As the height of a structure increases, the flexibility also increases and the required acceleration is expected to be less than in low-rise buildings. The high rise buildings are more vulnerable to the EQ forces than the low rise buildings. The structural behaviour of framed and tubular structures are different for the same EQ loads [2,4].

Hence the framed tube structure is idealised for comparing the bundled tube structure. Further, the tube in tube and bundle tube structures have the versatile structural form to create the tubes up to the desired level with required aspect ratio at ground level [1].

The EQ code(1893-2016code) specified the dynamic analysis for structure heights greater than 40m in zone 4 and 5. it is not possible to provide the time history records at every location, further simply based on the peak value of the ground acceleration as the response of the structure cannot be considered, earthquake response spectrum is the popular tool in the seismic analysis of structures.in this building internal parameters are obtained in each mode shape of the structure. the peak response quantities for an MDOF system are Absolute Sum (ABSSUM) Method, Square root of the sum of squares (SRSS) method, and Complete quadratic combination (CQC) method. Many Country Have adopted the Response Spectrum Analysis Including IBC –2000, NBCC –1995, EURO CODE –1995, NZS 4203 –1992, IS 1893 –2016 [1-3,5-6].

Vikram J et.al Illustrated the different types of the Tubular structures and advantages of the reduced cladding load with curtain walls is specified [7]. Mr Gauri et.al presented a comparison of static and dynamic analysis multi-storied building with regular and irregular plan shapes with internal parameters. It was concluded that the static method is sufficient for low rise buildings and the dynamic analysis provides higher values for high rise buildings [8].

Mr Hojat Allah Ghashemi et.al presented the design parameters variation on the tube action and shear lag behaviour of a typical reinforced concrete bundled tube building and enlightened about the optimal design approaches. [9]. Mr M. Ali et.al studied the response of the tall tube structures are quite different in comparison with Low Rise Buildings. The performance of Tubular structures includes the optimization of the building plan, elevation configurations, maximization of Building-frame and connection ductility without loss of adequate strength and stiffness parameters were apprised [10].

Mr Mohammad Usman Alvi et.al presents Static and Dynamic of G+20 Storey's using ETABS and IS1893: 2016 with irregular floor plan dimensions. The tall structures (Tower 1 and Tower 2) with different orientation located in seismic zone V. Tower 1 is oriented in Global X and Global Y direction, whereas Tower 2 is rotated 7º in the anti-clockwise direction about the centre. The Difference in Modal Participating mass ratio in both Global X and Global Z Direction [11]. Bungale et.al Different types of tall RCC design of tall structures including design of bundled tube structures is explained in detailed [12].

Mr Jignesha Patel et.al The more lateral load capacity of frame tube structure over the framed structure is studied. Exterior tube carries all the lateral loading. Structurally, the framed-tube is superior to a rigid frame because the maximum lateral loading is on the exterior of the building. The interior structural system is a secondary system to carry only gravity loads only. The tube frame buildings left the interior floor plan relatively free of core bracing and heavy columns, enhancing the net usable floor area. The reduction of the material makes the buildings economically much more efficient [13]. Mr Jay P. Patel et.al have made a comparative study between 48 storey Triangular and the square-shaped bundled tube buildings. The Square tube bundled system is more economical than triangle tubes bundled system [14].

Mahesh et.al studied the behaviour of G+11 multi-storied building of regular and irregular configuration under earthquake Loads both in Staad pro and ETABS software programme have been analysed and observed that the Base Shear and Storey Drift values are more in Regular Configuration rather than in Irregular Configuration Structure and the Steel percentage is more in Staad pro rather than in E tabs programme [15]. Mohit Sharma et.al a G+30 storied regular building. The static and dynamic analysis has been made with the IS-1893- 2002 code for the seismic zones- 2 and 3. No appreciable variation of the Axial Forces obtained for Static and Dynamic Analysis for both the zones.

The torsion is negative for static analysis and positive for Dynamic Analysis. About 10 to 15% Higher moment values are obtained for Dynamic Analysis. Similarly, 17 to 28 % higher displacement values are obtained for Dynamic Analysis [16]. Mohammed Rizwan Sultan et.al Presented Dynamic Analysis of Multi-Storey Building for Different Plan Shapes in high seismic zones. The lower base shear is getting in L shape building and the higher base shear is getting in Rectangular shape building. The irregular shape building has more deformation and hence regular shape building is prescribed. Results have been proved that C shape building is more vulnerable in comparison to all other shapes of buildings [17].

Balaji U et.al studied a residential building G+13 storied subjected to Earthquake Loads. The variation of displacement is increasing along with the height of the structures in comparison with the base shear [6]. Anirudh Gottala et al studied static and dynamic analysis of G+9 multi- storied building with the IS-1893-2002-Part-1. The higher moments and nodal displacements are obtained for Dynamic analysis [18]. Mahesh et.al has compared the manual and software results of 8 Storey building with IS 1893:2002 [19].

Ali et.al presented the different lateral load resisting system and history of the development of the tall structure system. And by Explaining about the Sears Tower the 1st steel bundled tube Structure and the Chicago tower the 1st Concrete Tube Structure then the Tube structures of different shapes like square, rectangular, trapezoidal etc. [1]. NI WIN et.al A comparative study of twelve-storied reinforced concrete building static and dynamic analysis of irregular reinforced concrete building have been analysed. He evaluated the difference between the results obtained by static and dynamic analysis [20]. The effect of shear walls for low rise building is inspected [23].The revised EQ code2016 version provisions on Pounding gaps was explored [24]. The revised code provisions on elevated water tanks was reviewed. [25].

## 3. OBJECTIVES OF THE PAPER

The revised EQ code 2016 methodology for 150 m high bundle tubes was not dealt with the above literate and moreover the comparison of the framed tube and bundle tube is not observed. Hence the response spectrum analysis was performed for distinguishing the parameters of bundle tube and framed tube structures.

## 4. METHODOLOGY

The 150 m height 50 storey Structure with framed tube and bundle tube structures with a plan area of 50 m x 56 m are drafted in AUTO CAD software and imported to STAAD Pro Connect Edition V22 software programme for analysis [21,3]. The geometrical properties of the frames are shown in the table 1. The response spectrum method with IS1893-2016 Code provisions was adopted to find the internal parameters**.** The parameters including Bending moments, Peak Storey Shear values, Displacements, Maximum Participation Factors, Base Shear, Modal Base Actions, Acceleration, Modal masses are compared for seismic zone 5 and zone 4 [2].

The loading and other parameters are conveyed in table2. The soil structure is considered as Hard soil in both the Zones in STAAD PRO Connect Edition V22 Software [2,3]. The floor plans of FRAMED TUBE and Bundle tubes are shown in figures1&2. Since the plan dimensions are rectangular dimensions, Hence both X and Z directions are considered for critical analysis.

**Table 1** Specifications of Rigid tube and Bundled Tube Structures:

| CONTENTS | RIGID TUBE STRUCTURE | BUNDLED TUBE STRUCTURE |
|---|---|---|
| Plan Area | 50mX56m | 50mX56m |
| Size of Column | 0.8mX0.8m | 0.8mX0.8m |
| Size of Beam | 0.8mX0.6m | 0.8mX0.8m |
| Spacing in X-Direction | 5 metres | 4 metres, 5metres |
| Spacing in Z-Direction | 4 metres | 4 metres |
| Supports | Fixed | Fixed |
| fck | 30 | 30 |
| fy | 415 | 415 |
| Height of Floor | 3m | 3m |

In the Response Spectrum follows the CQC Method it means Complete Quadratic combination method for the assessment of the structural efficiency [6].

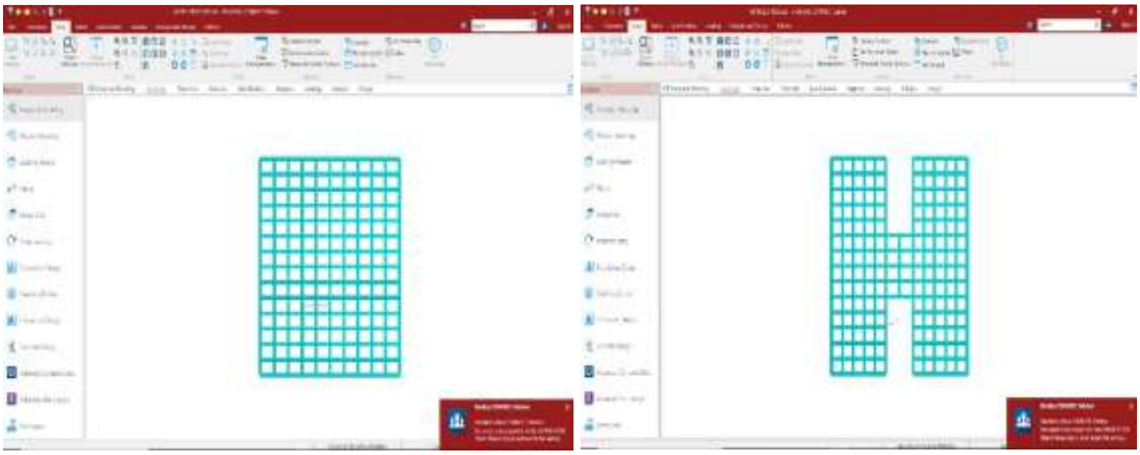

**Figure 1** Floor plan of the Rigid Tube Structure and bundle tube structures

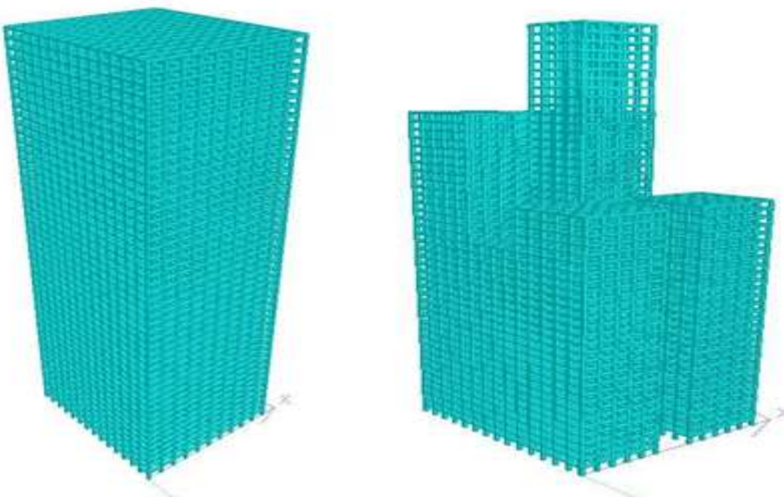

**Figure 2** Elevation View of the Frame Tube Structure& Bundle tube structures

## 5. RESULTS & DISCUSSIONS

With the Design Basis described in the methodology, both the structures are analysed in STAAD Pro Connect Edition V22software programme with IS1893:2016 code provisions for Zone 4 and Zone5 with hard soil criteria [2] . The time periods, Accelerations, frequency, lateral forces in Longer and shorter directions, Base Shear variations, Peak storey variations, Model participations for Zone 4 and zone 5 are indicated through the Figures [3-9].

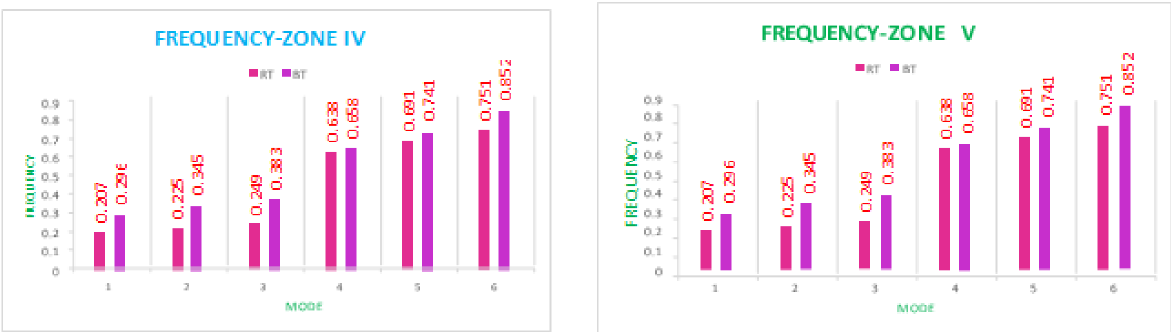


**Figure 3** Frequency in Zone IV & Zone V

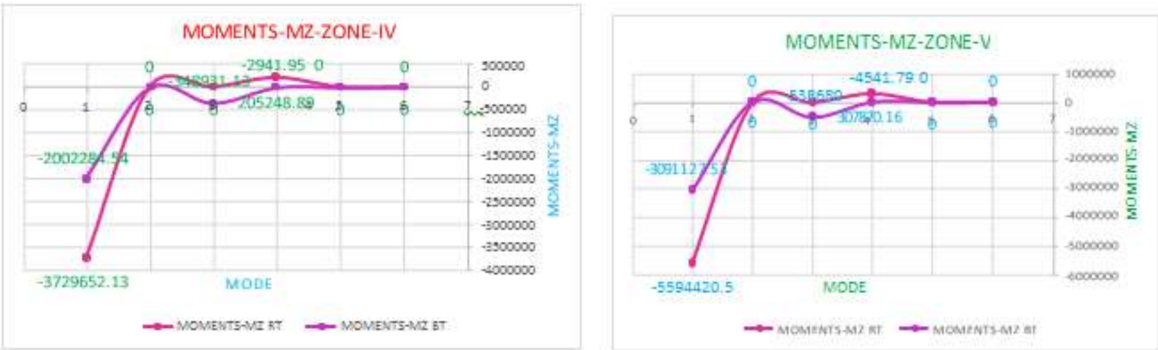


**Figure 4** Forces in Longer Direction for in Zone IV & Zone V

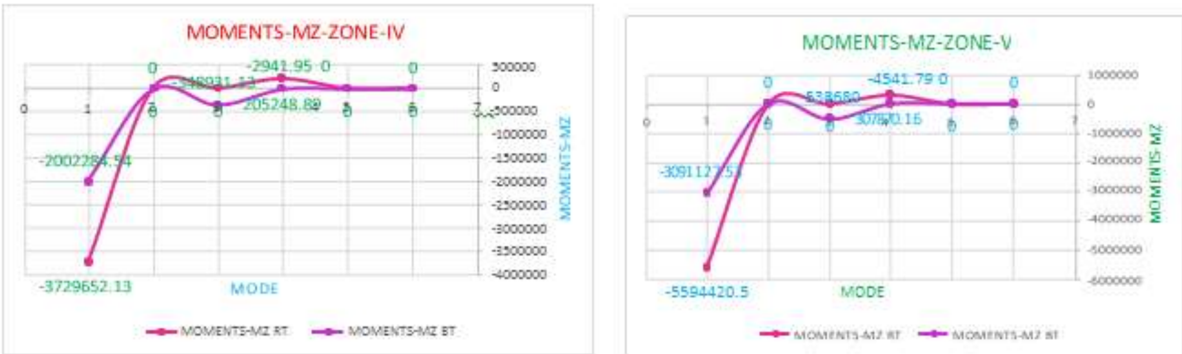


**Figure 5** Moments in Shorter Direction in Zone IV & Zone V

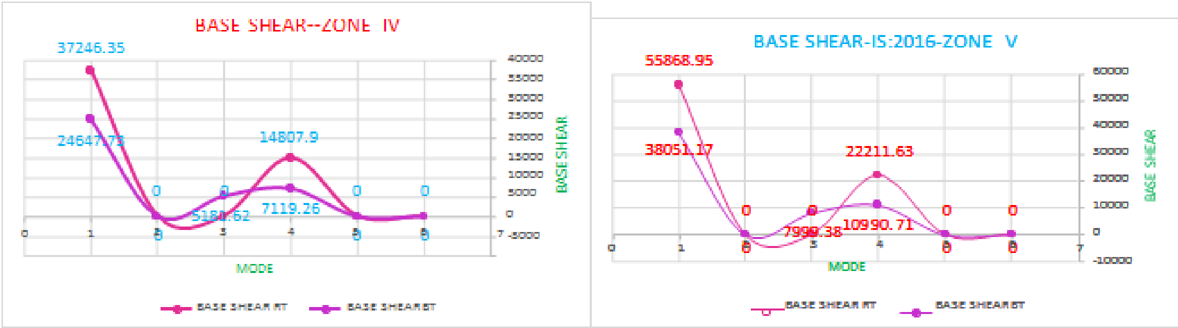


**Figure 6** the Base Shear in Zone IV & Zone V

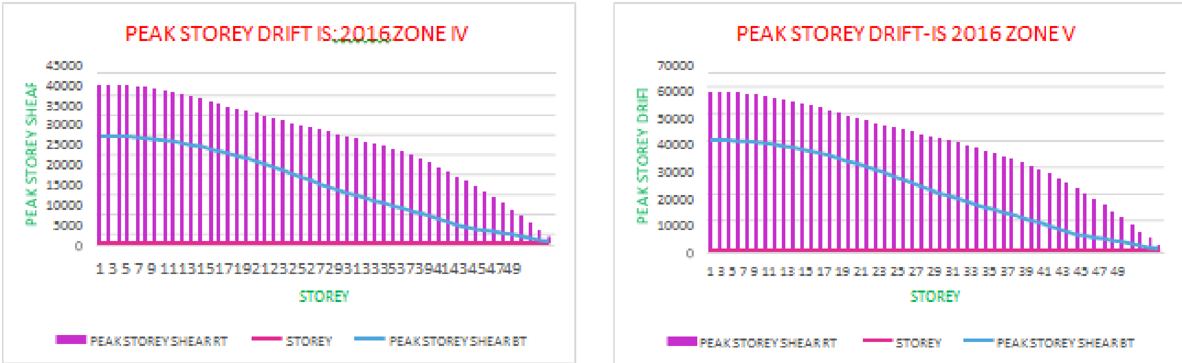


**Figure 7** Peak Storey Shear values in Zone IV & Zone V

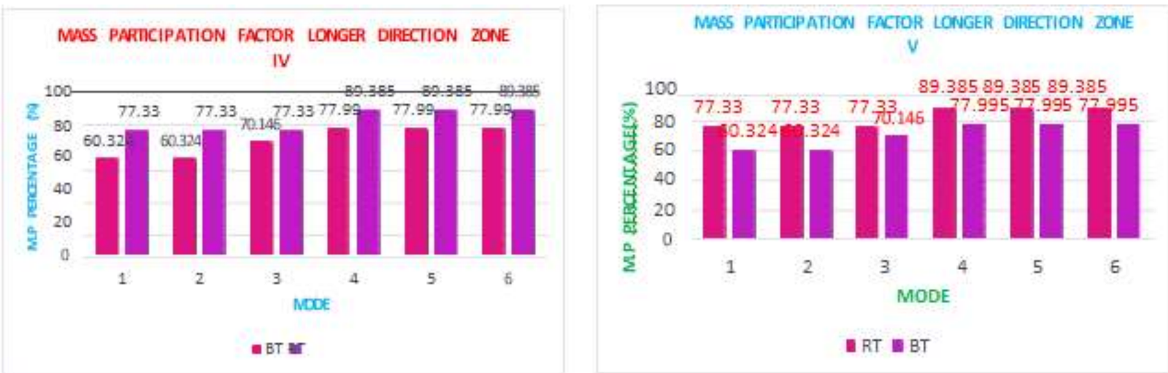


**Figure 8** Modal Participation Factors in Longer Direction in Zone IV & Zone V

## 6. DISCUSSION

It is to state with the methodology adopted to predict the internal parameters of framed Tube and Bundled Tube structures with the Response Spectrum Analysis in the IS: 1893-2016 code provisions. The following points are notified consequently on the basis of the output of the STAAD Pro CONNECT version V22 Program for of Indian Seismic Zones IV and V [2,3].

### 6.1. The Variations of Parameters for ZONE-IV

The Acceleration-G varies from 0.25 to 0.75 for framed Tube and 0.296 to 0.852 for Bundled Tube.

The Lateral Forces varies from 37246 kN to 14808 kN for framed Tube and 24647 kN to 7120 kN for Bundled Tube Longer Direction.

The Base Shear varies from 37246 kN to 14808 kN for framed Tube and 24647 kN to 7120 kN for Bundled Tube Longer Direction.

Peak Storey Shear varies from 40081 to 1670for Rigid Tube and 26936 to 431 in Bundled tube.

The Mass Participation percentage varies from 77%to 90% for Rigid Tube and 60 % to 78% for Bundled Tube in Longer direction.

The Mass Participation percentage varies from 77%to 89% for framed Tube and 71 % to 83% for Bundled Tube in Shorter direction.

### 6.2. The Variations of Parameters for ZONE-V

The Acceleration-G varies from 0.25 to 0.75 for Rigid Tube and 0.296 to 0.852 for Bundled tube.

The Lateral Forces varies from 55869 kN to 22212 kN for Rigid Tube and 38051 kN to 10990 kN for Bundled Tube Longer Direction.

The Base Shear varies from 55869 kN to 22212 kN for framed Tube and 38051 kN to 10990 kN for Bundled Tube Longer direction.

Peak Storey Shear varies from 60122 to 2506 for Rigid Tube and 41585 to 665 in the Bundled tube in Zone IV.

The Mass Participation percentage varies from 77%to 90% for Rigid Tube and 60 % to 78% for Bundled Tube in Longer direction.

The Mass Participation percentage varies from 77%to 89% for Rigid Tube and 71 % to 83% for Bundled Tube in Shorter direction.

## 7. CONCLUSIONS

Comparisons of Seismic performance of Bundled Tube structures and framed tube structures for a 150m tall with 50mx56m rectangular plan dimensions have been analysed with STAAD PRO connect Edition V22 version software programme for IS1893-2016 provisions. CQC method in Response spectrum analysis was selected for assessing the parameters. To portray the seismic performance relationships between the Framed and Bundle tube structures, the ground accelerations, frequency, model participations and top displacement, storey shear, Base shear, Base Bending Moment parameters are quantified. With the detailed discussion in the paper the following conclusions have been drawn.

- The bundle tube structure resists the higher seismic frequency in both the zones.
- Higher accelerations are need for bundle tube structures
- The bundle tube has 29% lesser displacement in zone 4 and 25% lesser displacement in Zone5.
- Similarly, Base shear of the bundle tube has 19% lower in zone 4 and 16% lower in Zone5
- Similarly, the base bending moment for bundled tube has 26% lesser in zone4 and 24% lower in Zone5
- First mode shape has the dominate character with the CQC method of Response Spectrum analysis
- With the unique structural flexibility for adopting the different tube shapes, the bundle tube structures can be selected for super-tall structures without any limitations.

## REFERENCES


[1] Mir. M. Ali and Kyoung Sun Moon, (2014). Structural Developments in tall Buildings: Current Trends and Future Prospects. Article Accessed in Research gate website, *DOI: 10.3763/asre.2007.5027.*

[2] BIS-1893 (2016) (Revised Version), Criteria for Earthquake resistant design of structures: Part-1, General Provisions and Buildings, Bureau of Indian Standards, New Delhi.

[3] STAAD PRO CONNECT: Bentley Structural Analysis and Design Software, Structural Analysis and Design software.

[4] BIS-875 (2015) (Revised Version), code of Practice for Design Loads (Other than Earthquake) for Buildings and Structures, Part 3, Bureau of Indian Standards, New Delhi.

[5] BIS-16700 (2017) (Revised Version), Criteria of Structural Safety of Tall Concrete Buildings, Bureau of Indian Standards, New Delhi.

[6] Balaji u. and Selvarasan M.E. (2016) Design and Analysis of Multi-storeyed Building Under Static and Dynamic Loading Conditions Using ETABS. "*International Journal of Technical Research" and Applications Volume 4, Issue 4. (July-Aug, 2016). Volume 4, Issue 4 (July- Aug, 2016), PP. 1-5.*

[7] Vikram J & Geethu Varghese, (2015). Concept of Tubular Design in High Rise Structures. "*Institute of Research Engineers and Doctors" (IRED). ISBN: 978-1-63248-083-5. DOI: 10.15224/ 978-1- 63248-083-5-17.*

[8] Gauri G. Kakpure, (2016). Comparative Study of Static and Dynamic Seismic Analysis of Multi- storeyed RCC Building by ETAB: A Review *International Journal of Emerging Research in Management &Technology (Volume-5, Issue-12).*

[9] Hojat Allah Gashemi, (2016). Optimal Design of High-Rise Building Bundled Tube Systems. "*Advances in Science and Technology Research Journal Volume 10, No. 30, June 2016, pages 96– 102". DOI: 10.12913/22998624/62732.*

[10] Mir. M. Ali, (1996). Performance characteristics of a tall framed tube Buildings in Seismic Zones. "*Eleventh World Conference on Earthquake Engineering". Paper No.1169, ISBN: 0080428423.*

[11] Mr Mohammad Usman Alvi, (2017). Effect of Orientation on Response Spectrum Analysis of Plan Irregular Building. *"International Research Journal of Engineering and Technology (IRJET), Volume: 04 Issue: 07,July -2017.*

[12] Taranath, (2010), B.S. Reinforced Concrete Design of Tall Buildings; Pages 203-230, "*CRC Press: Boca Raton, FL, USA, 2010".*

[13] Jignesha Patel, (2015). Seismic Analysis of Frame Tube Structure. "*International Journal of Scientific & Engineering Research*", Volume 6, Issue 12, December-2015.

[14] Mr Jay P Patel, Mr Vishal B. Patel, Elizabeth George, (2017). Comparative Study of Triangle Tubes Bundled System and Square Tubes Bundled System. "*International Conference on Research and Innovations in Science, Engineering &Technology" (ICRISET). Kalpa Publications in Civil Engineering Volume1, 2017, Pages 484-489.*

[15] Mr S. Mahesh and Dr B. Panduranga, (2014). Comparison of analysis and design of the regular and irregular configuration of multi-Storied building in various seismic zones and various types of soils using ETABS and STAAD. *"IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)", Volume 11, Issue 6 Ver. I (Nov- Dec. 2014), PP 45-52.*

[16] Mr Mohit Sharma, Dr Savita Maru (2014) Dynamic Analysis of Multi-Storied Regular Building. "IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)", *Volume 11, Issue 1 Ver. II (Jan. 2014).*

[17] Mr Mohammad Rizwan Sultan and D. Gouse Peera, (2015). Dynamic Analysis of Multi-Storey Building for Different Shapes. *"International Journal of Innovative Research in Advanced Engineering (IJIRAE)", Issue 8, Volume 2 (August 2015).*

[18] Mr Anirudh Gottala, (2015). Comparative Study of Static and Dynamic Analysis of a Multi-Storied Building. *"International Journal of Science Technology & Engineering*" Volume 2 Issue 01 July 2015, *DOI: 10.9790/9622-0705054651*-Research Gate.

[19] Mahesh N Patil, (2015). Seismic Analysis of a Multi-Storied Building. *"International Journal of Engineering and Innovative Technology (IJEIT) Volume 4, Issue 9, March 2015*" ISSN: *2277-3754.*

[20] Ni Win and Kyaw Lin Htat, (2014).Comparative Study of Static and Dynamic Analysis of Irregular Reinforced Concrete Building due to Earthquake, "*International Journal of Scientific Engineering and Technology Research (IJSETR)"*, Vol.03, Issue.07, May-2014, Pages:1205- 1209.

[21] AutoCAD: Autodesk 2017 Edition based Computer-Aided Design Software, 2-D & 3-D Designing Software

[22] BIS-456, Indian Standard of code and practice for plain and Reinforced concrete "Bureau of Indian Standards, New Delhi.

[23] CH. Lokesh, Chandan Kumar. Patnaikuni, Balaji, K. V. G. D, Santhosh Kumar. B, E. V. Raghava Rao, (2019) Shear Wall Effect on G+9 and G+5 Storey Buildings in Hilly areas. "*International Journal of Innovative Technology and Exploring Engineering (IJITEE*)*", Volume-9 Issue-1, November.*

[24] Bolem Pavan Kumar, Balaji, K.V.G.D, B. Santhosh Kumar, Chandan Kumar. Patnaikuni, (2017) Essence of pounding gaps in seismic zone IV and V with & without shear walls. "*International Journal of Civil Engineering and Technology (IJCIET), Volume 8, Issue 12, December".*

[25] Balaji, K.V.G.D, T. Santhosh Kumar, B. Santhosh Kumar, K. Chitti Babu, (2019) Impact of Revised Code Provisions of Seismic and Wind Loads on RCC Elevated Water Tanks. "*International Journal of Innovative Technology and Exploring Engineering (IJITEE)", Volume-8 Issue-11, September.*

[26] Anuj K. Chandiwala and Dr. S. A. Vasanwala, (2018) A Parametric Study on Behaviour of Piled Raft Foundation-Structure Interaction Effects on Seismic Performance of Multi-Story Regular RC MRF Building, *International Journal of Civil Engineering and Technology,* 9(7), pp. 558–567

[27] Anusha M, Priyanka S, Syed Faraz Siddique and Siddalingesh B Malagi, (2018) A Study on Seismic Performance of Multi-Storey Frame using Steel Plate Shear Walls, *International Journal of Civil Engineering and Technology,* 9(4), pp. 1129–1144

[28] Prerna Nautiyal, Saurabh Singh and Geeta Batham, (2013) A Comparative Study of the Effect of Infill Walls on Seismic Performance of Reinforced Concrete Buildings, *International Journal of Civil Engineering and Technology,* 4(4), pp. 208–218