PARAMETRIC STUDY ON BRACED TUBE STRUCTURAL SYSTEM

Hardik J. Patel[1], Prof. A.R.Darji [2], Prof Dr. K.B. Parikh[3]
[1]PG student, Master of Structural Engineering, GEC- Dahod,
[2]Assistant Professor, Applied Mechanics Department,GEC-Dahod
[3]Head of Department Applied Mechanics Department, Government Engg. College, Dahod, Gujarat, India

ABSTRACT: The advanced construction technologies, evolution of efficient structural system, necessity of vertical growth because of scarcity of urban land and rapidly increasing population caused the development of the high rise buildings all over the world. Lateral loads i.e. earthquake loads and wind loads requires special attention in design of high rise buildings along with gravitational loading. Lateral loads can be taken care by interior structural system or exterior structural system. Generally shear wall core, braced frame and their combination with other frames are interior structural systems where lateral load is borne by centrally located structural elements. While framed tube, braced tube structural system bear lateral loads by the elements provided on periphery of the buildings. It is very much important that the selected structural system must be optimized and should utilize structural elements effectively while satisfying design requirements.

In the past decades, the Braced tube structural system is widely adopted and used for the construction of tall steel buildings due to its structural efficiency and aesthetic potential provided by the unique geometric configuration of the system. Compared to closely-spaced vertical columns in framed tube, Braced tube structural system consists of widely spaced column with inclined X- brace members on the exterior surface of building. Due to inclined brace members, lateral loads are resisted by axial action of the diagonals, compared to bending of vertical columns in framed tubular structure. Braced tube structures generally do not require gravity core because lateral shear can be managed by the diagonals on the periphery of building. The aim of study is to decide the best suitable variable pattern of X-Braced pattern under gravity and lateral loading. Analysis of 60, 90 and 120 storey braced tube steel structural system is illustrated. Exact analysis using ETABS software* (ETBS'15, a 30 days trial version 2015) is carried out for 60, 90 and 120 story Braced tube building.

1.1 INTRODUCTION

The advanced construction technologies, evolution of efficient structural system, necessity of vertical growth because of scarcity of urban land and rapidly increasing population caused the development of the high rise buildings all over the world. Lateral loads i.e. earthquake loads and wind loads requires special attention in design of high rise buildings along with gravitational loading. Lateral loads can be taken care by interior structural system or exterior structural system. Generally shear wall core, braced frame and their combination with other frames are interior structural systems where lateral load is borne by centrally located structural elements. While framed tube, braced tube structural system bear lateral loads by the elements provided on periphery of the buildings. It is very much important that the selected structural system must be optimized and should utilize structural elements effectively while satisfying design requirements. Tube is a system where in order to resist lateral loads. A building is designed to act like a hollow cylinder cantilevered perpendicular to ground. This system was first introduced by Fazlur Rahman Khan. The first example of tube is 43-storey Dewitt-chestnut apartment building in Chicago. The main idea of tubular system is to arrange the structural elements so that the system can resist the loads imposed on the structural efficiently particularly horizontal loads. In this arrangement several elements contribute to the system i.e., slabs, beams, girders, columns. Unlike most often, the walls system the horizontal loads are resisted by columns and spandrel beams at the perimeter of the tubes. First building designed using tubular concept was sears tower.

In tubular structure, interior columns are comparatively few and located at the core. The distance between the interior and the exterior is spanned with beams or trusses and intentionally left column free. This maximizes the effectiveness of the perimeter tube by transferring some of the gravity loads within the structure to it and increase its ability to resist overturning due to lateral loads. Tubular structure is a structure with closed column space between two or four meters and joined by spandrel beam at the floor level, the structure behaves as a cantilever tube. Group of column perpendicular to the horizontal load is called flanged frame and parallel to the direction of horizontal load is called web frame. Therefore, It is obvious that 75% of overturning moment is carried by flange and remaining 25% by webs. Braced tube is formed by intersecting horizontal and vertical component. The example of braced tube structure all around the world are Bank of China Tower in Chicago, Onterie centre in Chicago, Renaissance tower in Dallas, Pearl River town in Guagzhou, The Brunswick Building. The John Hancock Building in Chicago is also one of the examples of utilization of Braced tube structural system to support the perimeter column Braced tube is an improvement of tubular structure made by cross bracings the frame with X bracings over many stories. Diagonal of braced tube are connected to the column at each intersection, they virtually eliminate the effect of shear lag in flange and web .As a result, the structure behaves under lateral loads more like a braced frame reducing bending in the members of the frame. In braced tube structure, the braces transfer axial load from more highly stressed columns to less highly stressed columns and eliminates difference between load stresses in columns. Hence, spacing of the column can be increased and depth of girders will be less, thereby allowing large size windows than in conventional framed tube structures. In braced tube structure, the distribution of axial forces along the flanged frame columns at one floor is not uniform and the distribution of shear forces along the web is not linear. This is mainly due to the flexibility of the tubular structures and is called shear lag effect. Along the flanges, this non-linearity can result in the corner or exterior columns experiencing greater stress than the centre or interior columns. This is known as positive shear lag. However, negative shear lag has been discovered to exist and this is opposite of positive shear lag and the corner are less stressed than the centre columns.

1.2 OBJECTIVES

2 Carry out Parametric study of 60, 90 and 120 storey structure having three different braced pattern as shown in fig. and decide the best suitable one.

Various parameters are listed below

• Lateral displacement of storey	• Inter storey drift
• Base shear	• Time period at first mode
• Storey shear	• structural steel mass

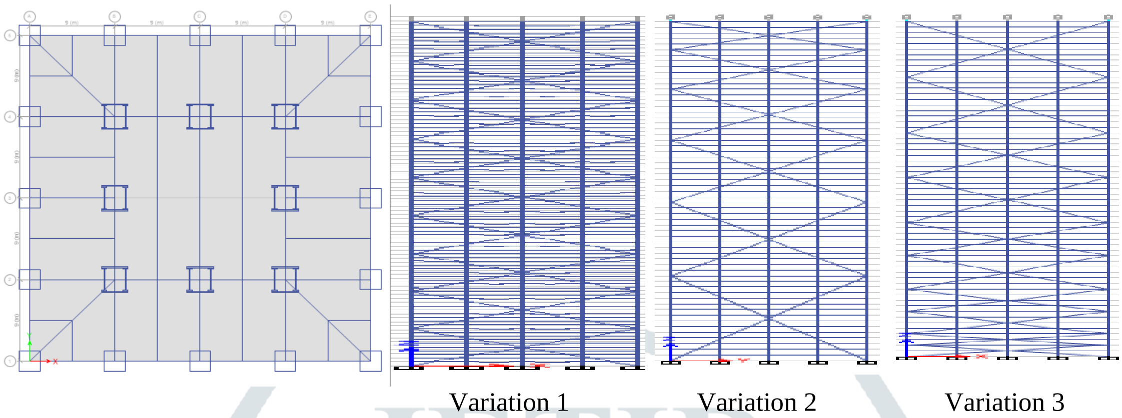


Fig: Plan and elevation of 60, 90 and 120 storey braced tube structure having 36X36 plan dimension

1.3 SCOPE OF WORK

The scope of present work is as follows:-

- Modeling of the Braced tube structural system with the help of ETABs software.
- To validate the Procedure of Modeling with reference.
- Evaluation of different variable X- braced- pattern for both lateral load (wind load and earthquake load) and gravity load(dead lad, live load and floor finishes) from following parameters for 60, 90 and 120 storey.
  - Lateral displacement of storey
  - Base shear
  - Inter storey drift
  - Time period of first mode
  - Storey shear
  - structural steel mass
- Carry out manual calculation of wind load by dynamic wind load method. (Gust factor method) for 60, 90 and 120 storey
- Carry out linear dynamic Earthquake analysis of braced tube structure by Time history method for 60, 90 and 120 storey.
- To analyze braced tube structural system with help of ETABs software by IS codes.
- Carry out optimum value of‗s' (ratio of deformation due to bending to the deformation due to displacement) for 60, 90 and 120 storey structure and Derive conclusion based on obtained results.

Standard Building Configuration

The 60 storey building is having 36 m x 36 m square plan with diagonals at slope 45 degrees as external braces as shown in Fig. 6.7. The plan and side view of the building are shown in Fig. 6.7. The pair of columns are provided at nine meter spacing along the perimeter. For analysis the beams and columns are modeled by beam elements and braces are modeled by truss elements.

1.4 Design Data:

- No. of story = 60
- Total height of building= 216 m
- Typical Floor height= 3.6 m
- Braced tube structure with slope of 45°

1.5 Loading Data:

Following loadings are considered for the analysis and design of structure;

Dead Load: Dead load of slab is 3.75 kN/m^2 and Self-weight of the structural members

Live Load: 3 kN/m^2

Wind Load:

- Basic wind speed:- 39 m/sec,
- Terrain category:- III,
- Class:- C

Static wind loading is calculated as per IS: 875(III)-1987[24]. Dynamic along wind loading is calculated using Gust factor factor method as per IS: 875(III)-1987. Calculation of along wind equivalent static load is presented in Appendix A.

Earthquake Load:

- Location : Ahmedabad
- Zone factor : II
- Importance factor : 1
- Response reduction factor : 5
- Soil condition : Medium

1.6 Combined Analysis Results of 60 storey Braced tube Building for EQ and wind in x and y direction:-

Time Period:

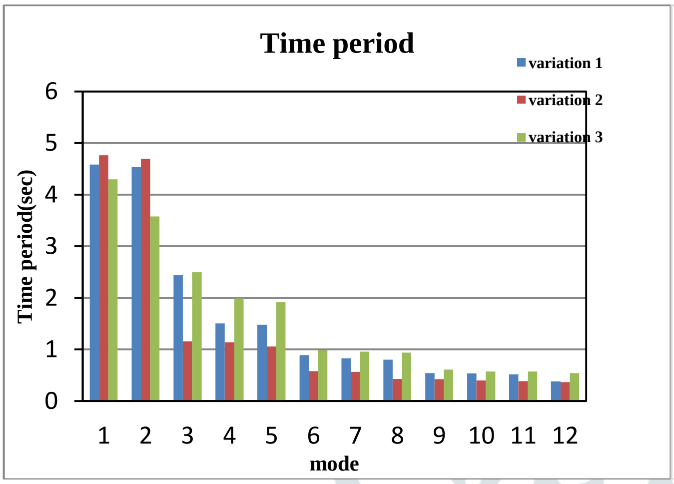


Fig: time period of 60 storey

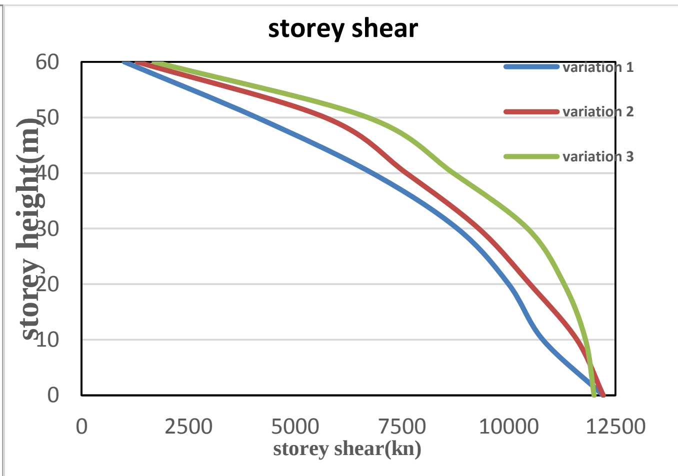


Fig: storey shear for 60 storey

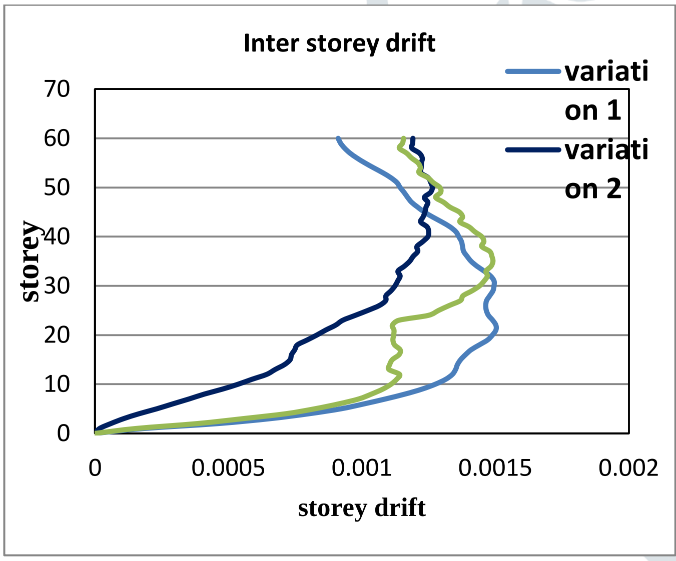


Fig: Inter storey drift of 60 storey

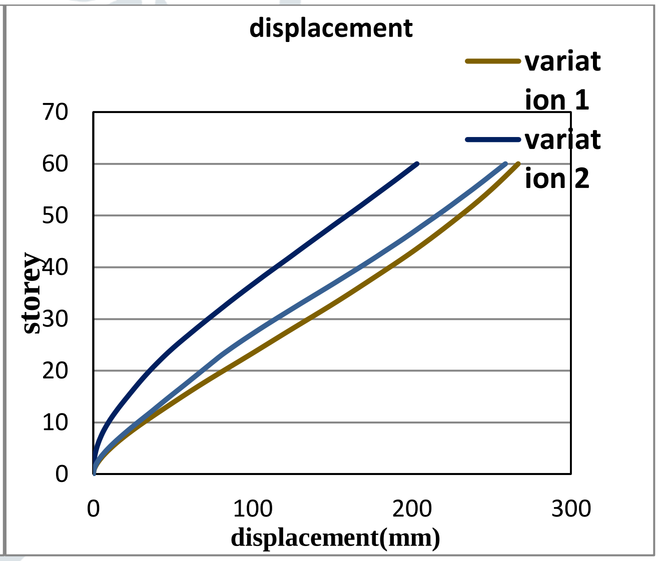


Fig: storey displacement of 60 storey

Base Shear: Maximum base shear is 12214.91KN due to dynamic wind load

Design Data of 90 storey structure:

- No. of story = 90
- Total height of building= 324 m
- Typical Floor height= 3.6 m
- Braced tube structure with slope of 45°

1.7 Loading Data:

Following loadings are considered for the analysis and design of structure;

Dead Load: Dead load of slab is 3.75 kN/m^2 and Self-weight of the structural members

Live Load: 3 kN/m^2

Wind Load:

- Basic wind speed:- 50 m/sec,
- Terrain category:- III,
- Class:- C

Static wind loading is calculated as per IS: 875(III)-1987[24]. Dynamic along wind loading is calculated using Gust factor factor method as per IS: 875(III)-1987. Calculation of along wind equivalent static load is presented in Appendix A.

Earthquake Load:

- Location : Bhuj
- Zone factor : II
- Importance factor : 1
- Response reduction factor : 5

Soil condition: Medium

1.8 Combined Analysis Results of 90 storey Braced tube Building for EQ and wind in x and y direction:-

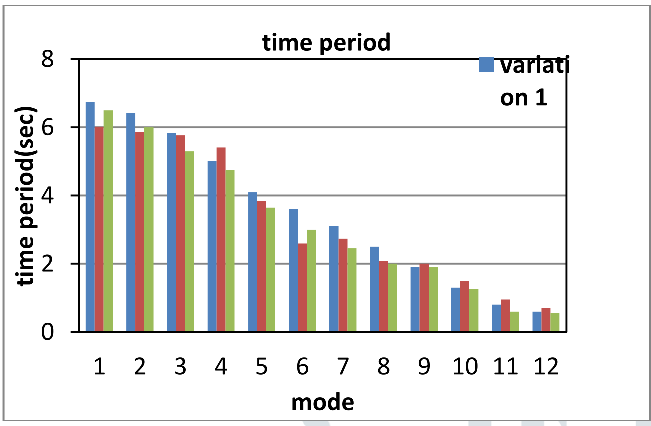


Fig: time period of 60 storey

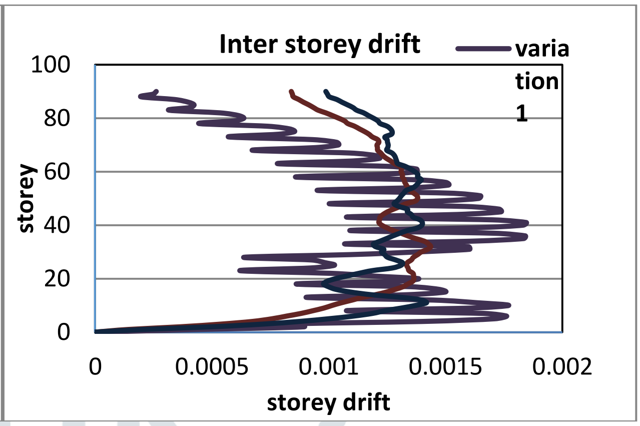


Fig: Inter storey drift of 60 storey

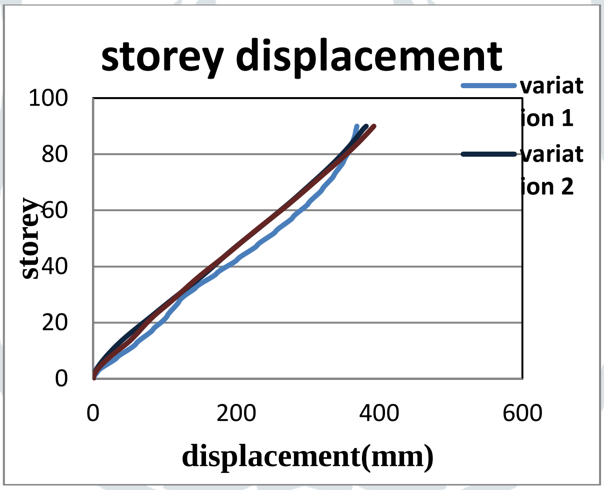


Fig: storey displacement of 60 storey

Design Data of 120 storey structure:

- No. of story = 120
- Total height of building= 324 m
- Typical Floor height= 3.6 m
- Braced tube structure with slope of 45°

1.9 Loading Data:

Following loadings are considered for the analysis and design of structure;

Dead Load: Dead load of slab is 3.75 kN/m^2 and Self-weight of the structural members

Live Load: 3 kN/m^2

Wind Load:

- Basic wind speed:- 50 m/sec,
- Terrain category:- III,
- Class:- C

Static wind loading is calculated as per IS: 875(III)-1987[24]. Dynamic along wind loading is calculated using Gust factor factor method as per IS: 875(III)-1987. Calculation of along wind equivalent static load is presented in Appendix A.

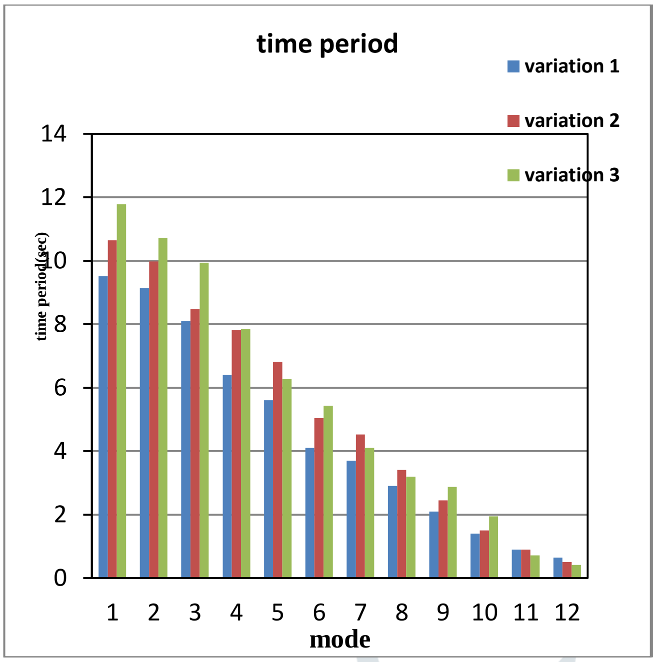
Earthquake Load:

- Location : Bhuj
- Zone factor : II

- Importance factor : 1
- Response reduction factor : 5

Soil condition: Medium

1.10 Combined Analysis Results of 120 storey Braced tube Building for EQ and wind in x and y direction:-



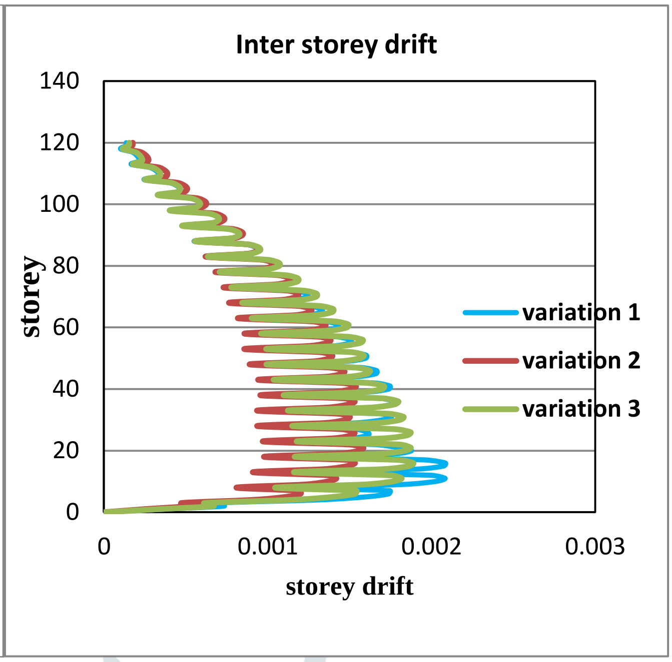
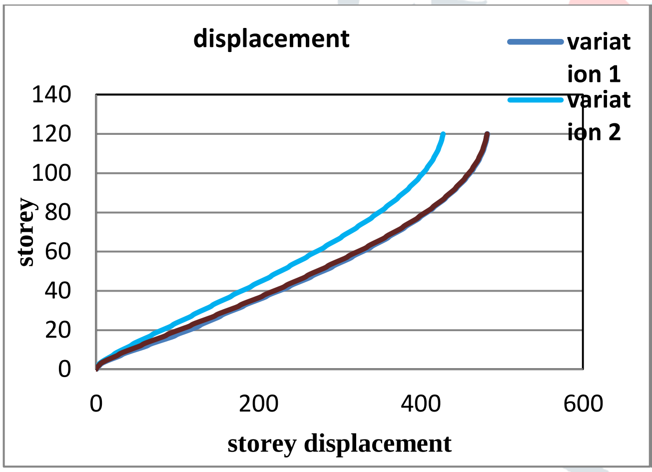


Fig: time period of 120 storey

Fig: Inter storey drift of 120 storey



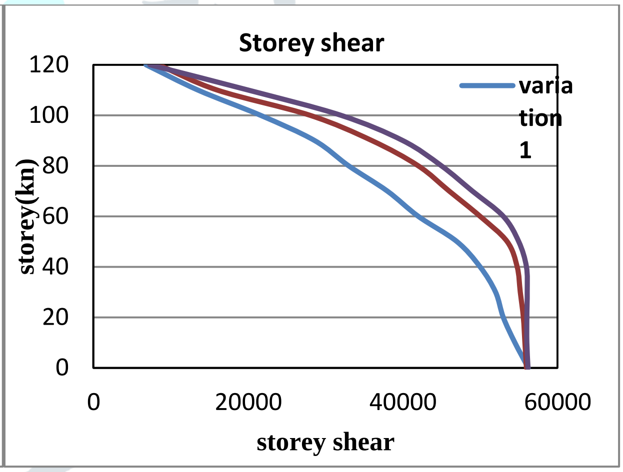


Fig: storey displacement of 120 storey

Fig: storey shear of 120 storey

1.11 Summary

From the comparison of results of approximate analysis considering stiffness based approach and exact analysis using ETABS software for 60, 90 and 120 storey Braced tube building, following observations are made.

- optimum value of ‘S’ for 60, story Braced tube structure of variation pattern 1, variation pattern 2 and variation pattern 3 are 2, 2 and 1, for 90 storey structure for the same pattern are 2.1 and 1 and for 120 storey structure are 4,2 and 4 respectively.
- Variable pattern 1 has 11.012% and 24.357% reduction in steel mass than variable pattern 2 and 3 for 120 storey structure, for 60 storey structure has 8% and 16.67% reduction than variable pattern 2 and 3 and for 90 storey structure has 14.5% and 5.62% reduction than variable pattern2 and 3.So,for steel mass based variable pattern 1 is suitable than other.
- The time period of 60 storey structure of 10 storey module having variable pattern 1, 2, and 3 are around 4.583, 4.764 and 4.3 sec, for 90 storey structure having variable pattern 1, 2, and 3 are around 6.74,6.02 and 6.5 sec and that for 120 storey structure having variable pattern 1, 2, and 3 are around 9.512, 10.647 and 11.784 sec respectively.
- Maximum Drift of 60 storey structure of three variation pattern are around 0.001502, 0.000901 and 0.001114, for 90 storey are 0.001846, 0.001215 and 0.001401 and that for 120 storey are 0.002085,0.001534 and 0.00189 respectively.

  Maximum displacement of three variable pattern of 60 storey structure are around 387mm, 345mm and 320mm , for 120 storey structure are 723mm, 764mmand 784 smm and that for 90 storey structure are 584, 572 and 588mm

1.12 Conclusion

From the parametric study and above summary, it has been conclude that the

- For 60 storey structure, variation pattern 3 is performing better compare to variation 1 and 2.
- For 120 storey structure, variation pattern 1 is performing better compare to variation 2 and 3.
- For 90 storey structure, variation pattern 2 is performing better compare to variation 1 and 3.

1.13 REFERENCES

[1] Ali and Moon, " Structural Development in Tall buildings: Current Trends and Future Prospects", Architectural science Review, Volume 50.3, pp 205-223

[2] Kyoung Sun Moon, "Stiffness Based Design Methodology For Steel Braced Tube Strctures: A Suistanable Approach",Engineering Structures Vol.32,(2010) Pages-3163-3170

[3] Kyoung Sun Moon, "Material Saving Design Strategies For Tall Building Structures", CTBUH 2008 8th World Congress, Dubai

[4] Iman Mazinani, Mohd- Zamin Jumaat, Z.Ismail, Ong Zhi, Chao, "Comparision of Shear-lag in structural steel building with framed tube and braced tube", Structural Engineering and Mechanics, Vol.49, No 3(2014)

[5] Kyoung Sun Moon, School Of Architecture, Yale University, "Comparative Evaluation Of Structural Systems For Tilted Tall Buildings"International Journal Of High Rise Buildings,June 2014,Vol.3,No.2,Pages-89-98

[6] Moon, "Structural Design and Construction of Complex shaped tall buildings", IACSIT international Journal of Engineering and Technology, Vol. 7, No.1 February 2015

[7] Fazlur R. Khan," 100 Storey John Hancock Center, Chicago: A case study of the design process", Eng. structure,1983,vol.5, january

[8] Young Andy, Annereau, Nigel, Butler, Brian , "The Leadenhall Building, London", CTBUH Journal 2013

[9] Baker, Besjak, McElhatten and Li, "Pearl River Tower: Design Integration towards Sustainability" Structural Congress 2014@ASCE 2014

[10] Yesh K.Jain, S. Mandal, "A Case Study On Shear Lag Effect In Tubular Structures Under Wind Load", National Conference On Wind Engineering 2012,Dec.Pages-14-15

[11] D.C. Rai ,S.C. Goe," Seismic evaluation and upgrading of chevron braced frame, ELSEVIER, pages-971-994(2003)

[12] Kim, Park and min, "Seismic Performance Of Tubular Structures With Buckling Restrained Brace", Wiley Interscience, pages-351-370(2009)

[13] M.Gu, Y. Quan, "Across Wind Loads Of Typical Tall Buildings", Journal Of Wind Engineering And Industrial Aerodynamics Vol.92(2004) Page:1147-1165

[14] Peter C.Chang, D.A. Foutch, A.M.ASCE, "Static And Dynamic Modeling And Analysis Of Tube Frames", Journal Of Structure Engineering, Vol.110(1984) Pages-2955-2975

[15] Rai and Goel, "Seismic evaluation and upgrading of chevron braced frame, ELSEVIER, Journal of constructional steel research 59 (2013) pg 971-994

[16] Farshid Nouri, Mohammad Yassami, Payam Ashtari, "Evaluating Optimum Topology Of Braced Tube Tall Steel Structures Using Non-Linear Time-History Analysis",10th International Congress On Civil Engineering 5-7 May 2015, University Of Tabriz, Iran

[17] Yoo, Lehman and Roeder, "Influence of connection design parameters on the performance of braced frames", ELSEVIER, Journal of Constructional Steel Research 64(2008) pg 607-623