COMPARATIVE STUDY OF USAGE OF OUTRIGGER AND B-ELT TRUSS SYSTEM FOR HIGH-RISE CONCRETE BUILDINGS

B Putlaiah[1], P Hanuma[2]

[1]M.Tech, Structural Engineering, Sri Sunflower College of Engineering and Technology, Lankapalli, Andhra Pradesh

[2]Assistant Professor, Sri Sunflower College of Engineering and Technology, Lankapalli, Andhra Pradesh

---***---

Abstract: Tall building development has been rapidly increasing worldwide introducing new challenges that need to be met through engineering judgment. In Metro cities like Mumbai, Delhi, Chennai, Bangalore, Kolkata, Hyderabad etc multi-storied buildings are common and in spite of that people are willing to stay in high rise buildings. The lateral stability of tall building plays an important role in safe analysis and design. 3D model is generated in ETAB 2016. A relatively new concept of Virtual Outrigger is introduced in this paper. In which, using only the belt truss in the building in order to increase the performance of the building under the dynamic loads is studied. Emphasis is given to the various benefits of employing Virtual Outriggers instead of Conventional ones. The building is strengthened in lateral direction by providing Outrigger and Belt truss system at every 9 to 10 storey level. Two methods of analysis have been taken into account for lateral stability analysis viz linear static and linear dynamic for both seismic and wind. The various parameters like (1) Lateral displacement, (2) Maximum storey drift, (3) Storey shear forces, (4) storey moments and (5) Storey overturning moments are considered for better understanding of Tall building when it is subjected to large seismic and wind forces.

Keywords: Outrigger, Belt truss system, Lateral stability, Maximum storey, Lateral displacement, Storey shear, storey moments, Storey stiffness.

1. INTRODUCTION

Earthquake-resistant construction requires that the building be properly grounded and connected through its foundation to the earth. Building on loose sands or clays is to be avoided, since those surfaces can cause excessive movement and nonuniform stresses to develop during an earthquake.

Rapid growth of infrastructure to accommodate modern civilization is demanding tall structures in cities. As the buildings are becoming taller the problem of their lateral stability and sway has to be tackled by engineering judgment. Structural system development has evolved continuously to overcome the problems related to lateral stability and sway, one such structural system is outrigger and belt truss structural system. The outrigger and belt truss structural system has proved to be most promising structural system in resisting problem related to lateral stability and sway.

The outrigger and belt truss system is commonly used as one of the structural system to effectively control the excessive drift due to lateral load, so that, during small or medium lateral load due to either wind or earthquake load, the risk of structural and non-structural damage can be minimized. For high-rise buildings, particularly in seismic active zone or wind load dominant, this system can be chosen as an appropriate structure.

The outrigger and belt truss system is one of the lateral loads resisting system in which the external columns are tied to the central core wall with very stiff outriggers and belt truss at one or more levels. The belt truss tied the peripheral column of building while the outriggers engage them with main or central shear wall. The aim of this method is to reduce obstructed space compared to the conventional method.

II. METHODOLOGY

Adequate and economical tall buildings cannot be designed without taking into account the factors that affect for the selection of structural system for tall buildings. In modern tall buildings, lateral loads induced by wind or earthquake are often resisted by a system of coupled shear walls. The lateral load resisting system effectively control the excessive drift due to lateral load, so that, during small or medium lateral load due to either wind or earthquake load, the risk of structural and non-structural damage can be minimized. For high-rise buildings, particularly in seismic active zone like north-east states of India and west India particularly north part of Gujarat, the system that can be used to developed the tall building.

Lateral Load Resisting System:

Following are the lateral load resisting system which can be used in tall building:

- Rigid frame system
- Braced frame system
- Shear wall frame system
- Outrigger system
- Tube system

a. Frame tube system

b. Braced tube system

c. Bundled tube system

d. Trussed tube

- Dia-grid Frame

Rigid Frame System:

Rigid frame construction provides many benefits, such as decreased deflections, decreased internal bending moments, and increased rigidity. However, the columns are experiencing some degree of internal bending themselves as the beams stay rigid.

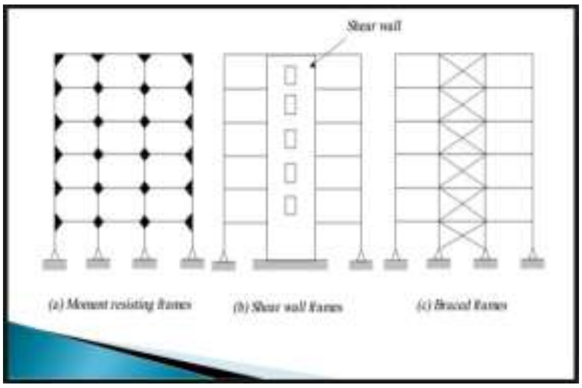


Figure 1: Frame Systems

Braced Frame System:

Braced frames are a very common form of construction, being economic to construct and simple to analyse. Economy comes from the inexpensive, nominally pinned connections between beams and columns. Bracing, which provides stability and resists lateral loads, may be from diagonal steel members or, from a concrete 'core'. In braced construction, beams and columns are designed under vertical load only, assuming the bracing system carries all lateral loads.

Shear Wall Frame System:

In this system RCC frame is braced with Concrete Shear wall. The main reason to brace a shear wall with RCC frame is to counter the effects of lateral loads acting on a structures due to earthquake, wind etc. Shear wall in its plane has tremendous load carrying capacity but for out of its plane loads its capacity decreases i.e. its moment resistance capacity decreases. Moments that are resisted by wall are ultimately transferred to foundation and as a large amount of moment has to be resisted by shear wall, foundation of shear wall becomes heavy.

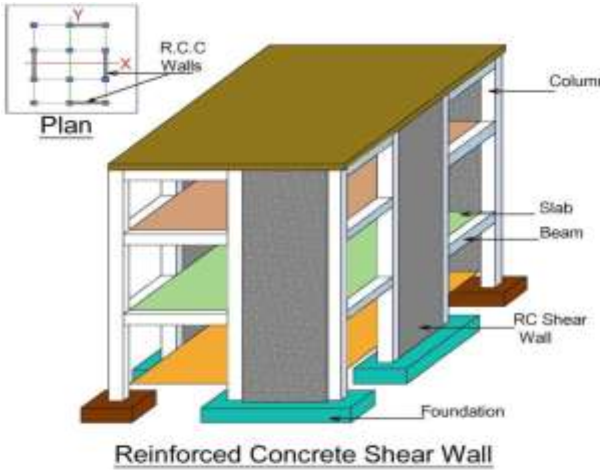


Figure 2: Shear Wall Frame System

Outrigger System:

Today, all the tall buildings even Shanghai tower has shear walls and the forces on such buildings are magnanimous. So in order to take them under control all the buildings have outriggers located at not just one but 2 or 3 different levels. Let me share a picture showing the greater advantage of using an outrigger and how it can help in reducing the thickness of core wall.

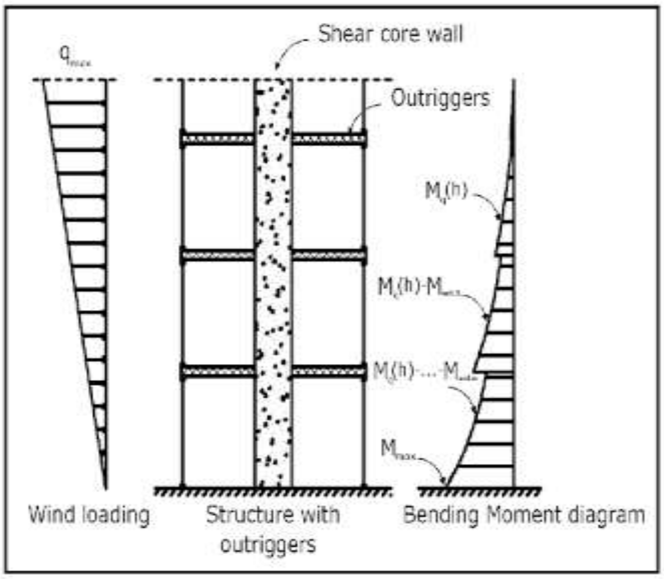


Figure 1: Outrigger Systems

Tube System:

In structural engineering, the tube is a system where, to resist lateral loads (wind, seismic, impact), a building is designed to act like a hollow cylinder, cantilevered perpendicular to the ground. Willis Tower, finished in 1973, introduced the bundled tube structural design and was the world's tallest building until 1998.

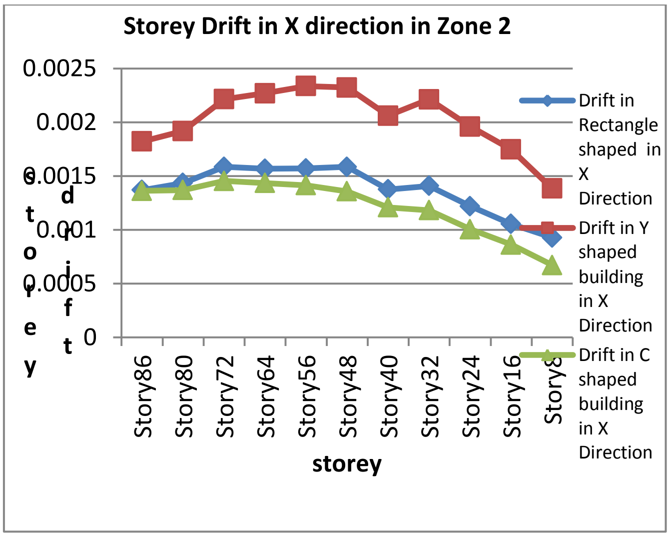
Figure 2: Tube Structural Design Tower

PROBLEM STATEMENT:

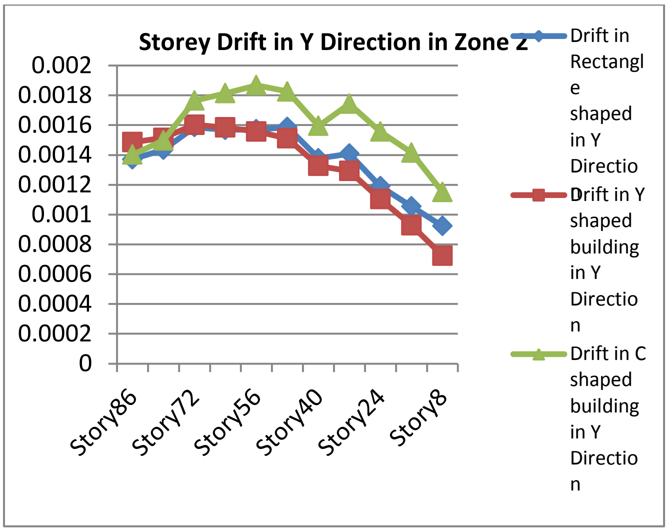
S No	Anatomical details	Type of location
1	Utility of Edifices	Office Building
2	No of Storey	G+85
3	Area	2304 sq.mts
4	Height of Building	259 mts
5	Shape of the Building	Rectangle, Y shaped, C shaped building
6	Types of Walls	SHEAR Wall -130 mm thickness Masonry wall – 230 mm thickness
7	Geometric Details Ground Floor	4 mts
	Story to story height	3.0 mts
	Beam	0.75X0.75 mts
	Columns (outer)	0.80X0.80 mts
	Columns (Inner)	0.60X0.60 mts
	Slab	0.150 mts
8	Material Details Concrete Grade All Steel Grades	M50 (All structural elements) FE 500 (All structural elements)
9	Type Of Construction	R.C.C FRAMED STRUCTURE
10	Place of construction	Bhuj - Gujurat.
11	Loads considered in building	Dead load , Live load , Wind load, Earthquake
12	Wind Speed	50 m/s (Bhuj wind speed)
13	Seismic Zone	Zone – V (Bhuj)
14	Method of Analysis	RESPONSE SPECTRUM ANALYSIS EQUIVALENT STATIC ANALYSIS
15	NON Ductile properties	5 (Response reduction factor)
16	STATIC COMBINATION USED	1.2(Dead load + Live load + Earthquake in X direction)
17	IS codes used	IS456 :2000,IS1893:2002, IS 16700:2017,IS 875:1987 (Part 1, Part 2, Part 3)

III. RESULTS & DISCUSSIONS

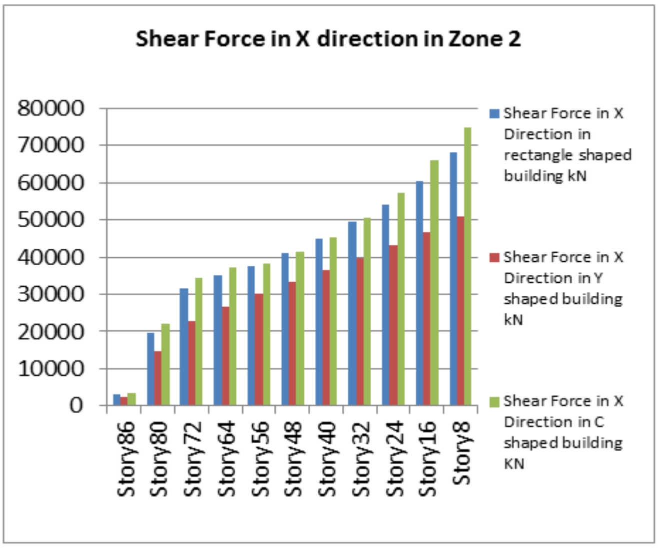
➢ ***ZONE II RESULTS:***



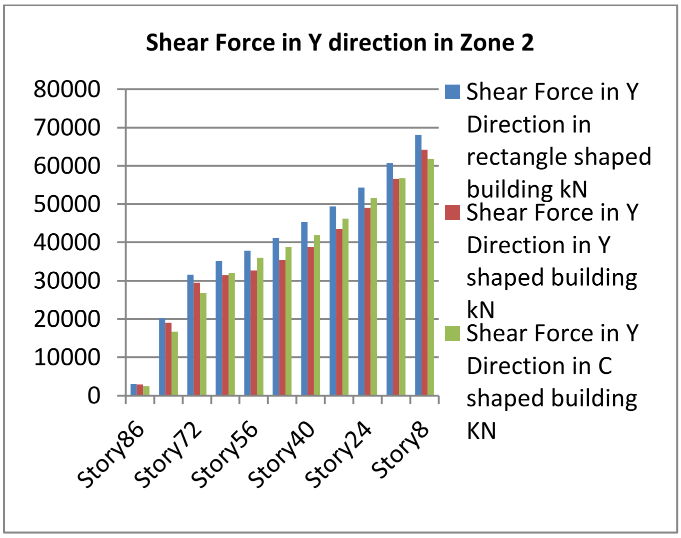
Graph 1: Storey Drift in X direction in Zone 2



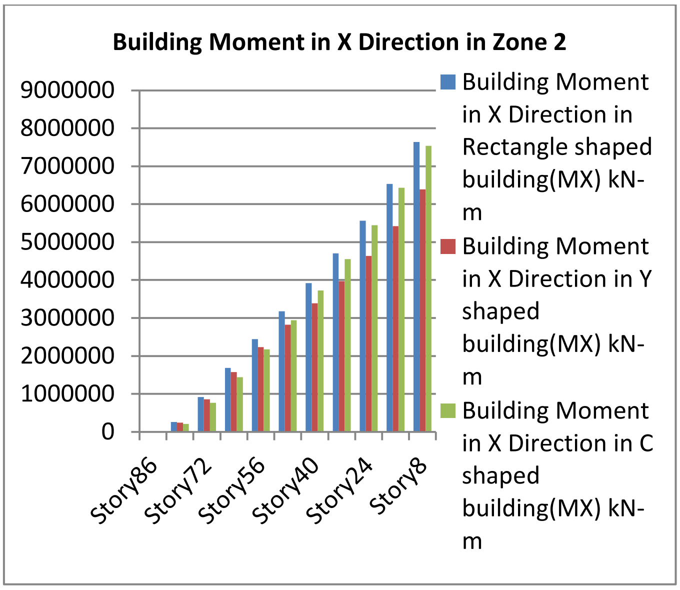
Graph 2: Storey Drift in Y direction in Zone 2



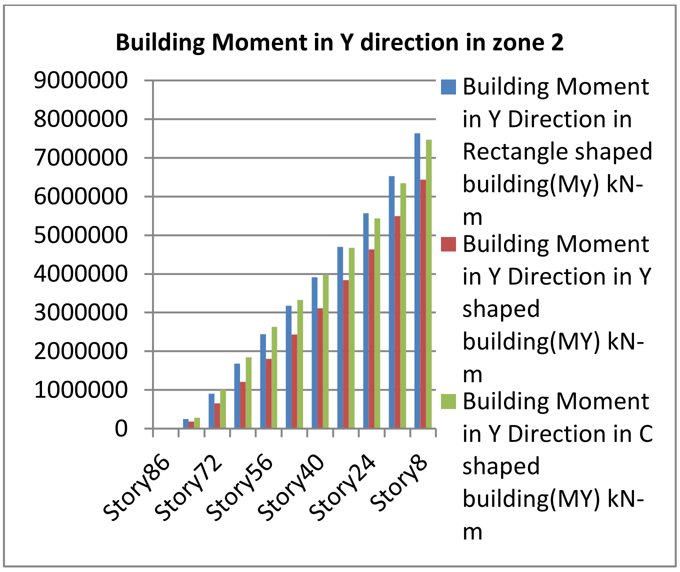
Graph 3: Shear Force in X direction in Zone 2



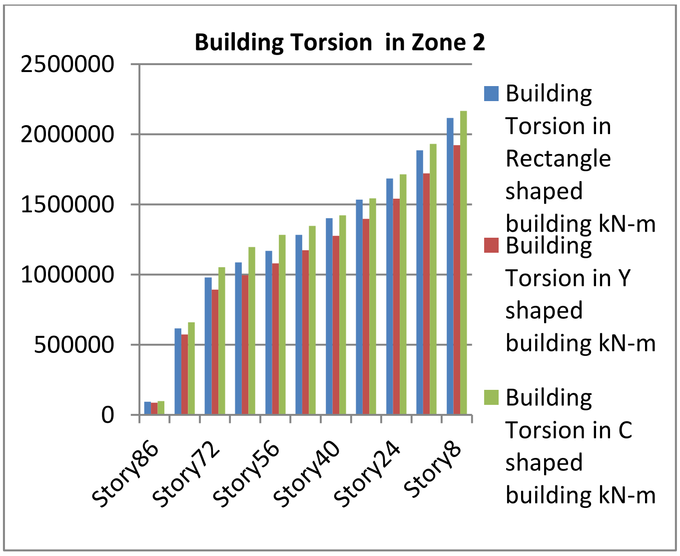
Graph 4: Shear Force in Y direction in Zone 2



Graph 5: Building Moment in X direction in Zone 2

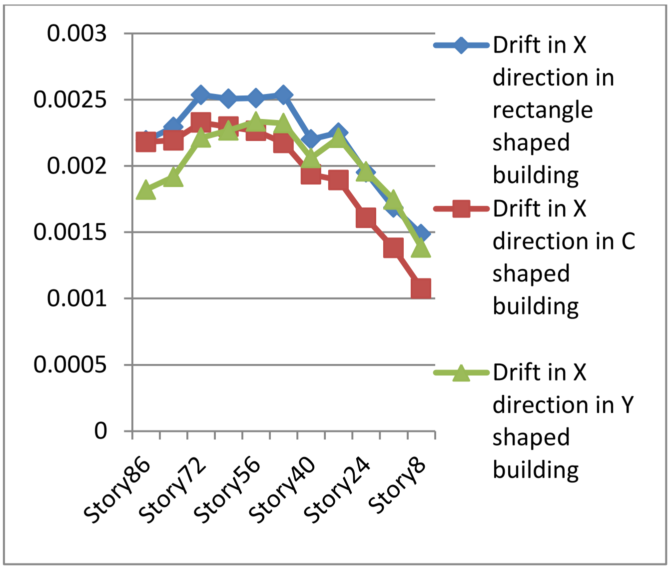


Graph 6: Building Moment in Y direction in Zone 2

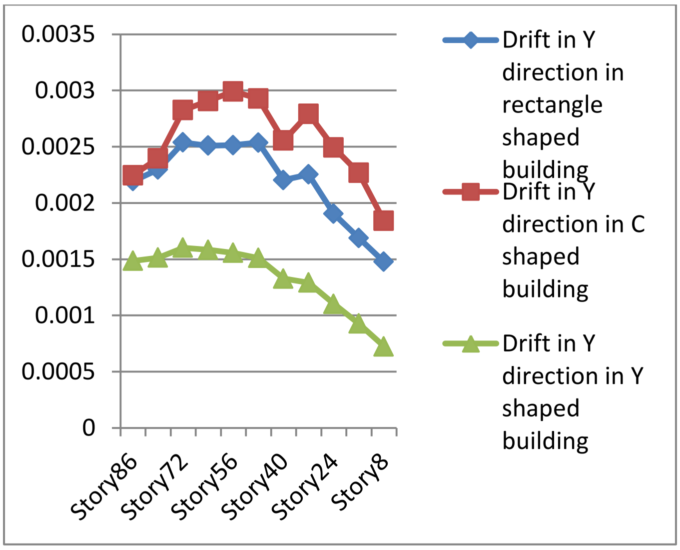


Graph 7: Building Torsion in Zone 2

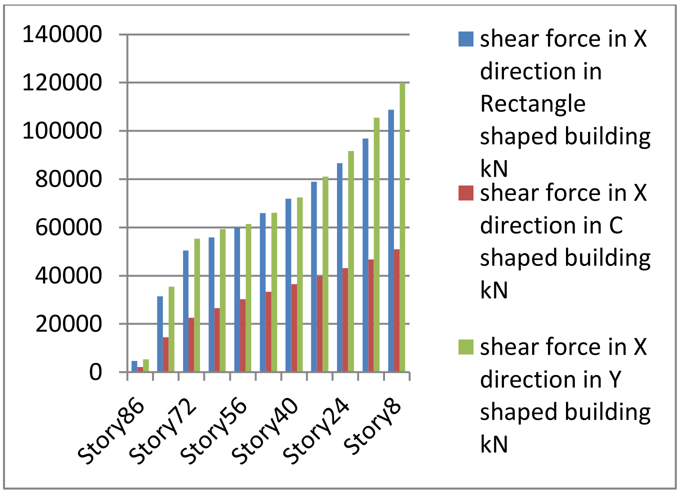
- **ZONE III:**



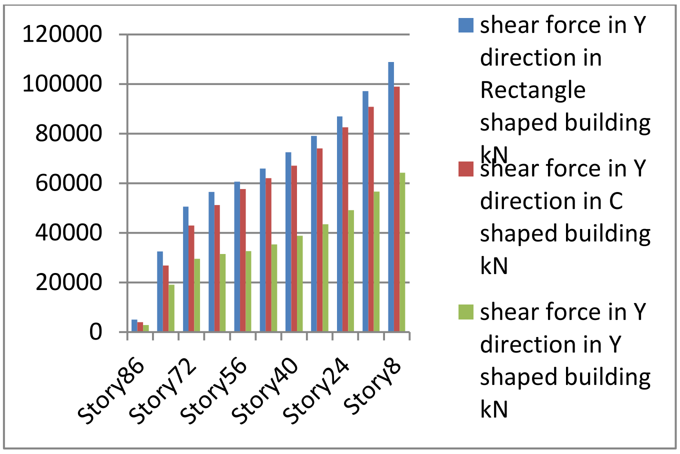
Graph 8: Storey Drift in X direction in Zone 3



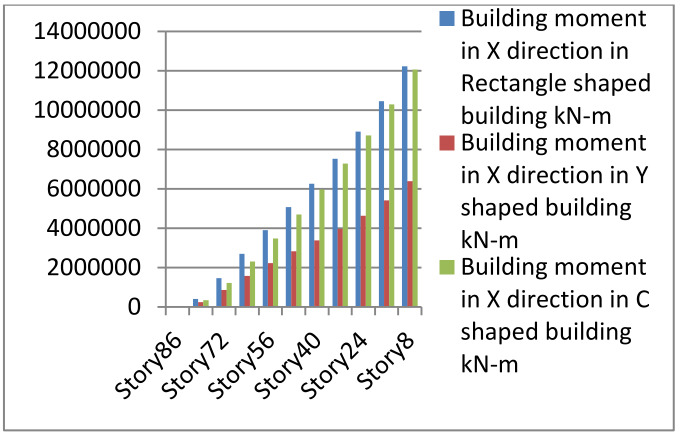
Graph 9: Storey Drift in Y direction in Zone 3



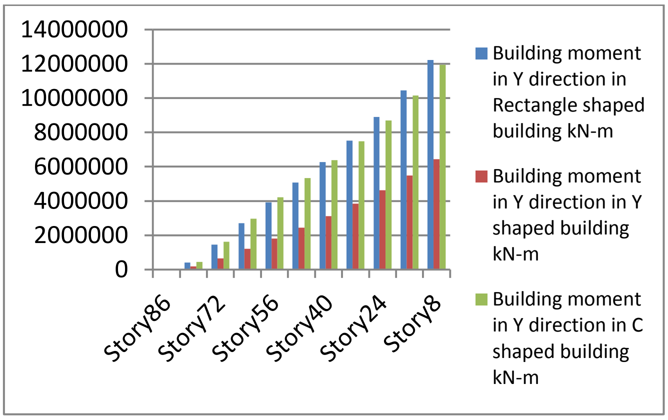
Graph 10: Shear Force in X direction in Zone 3



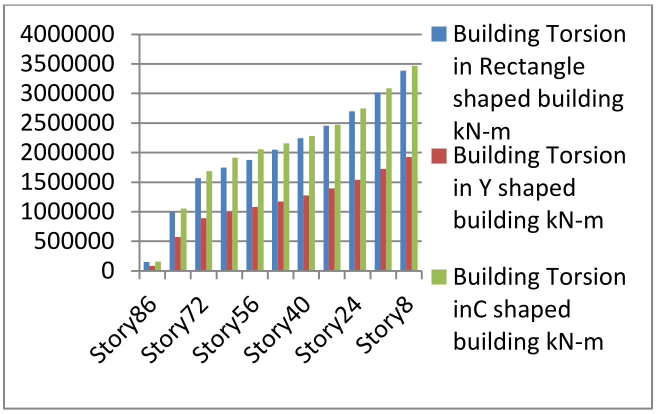
Graph 11: Shear Force in Y direction in Zone 3



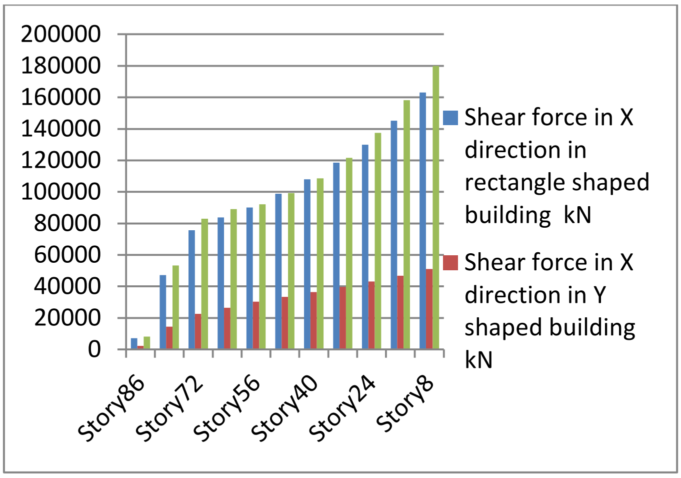
Graph 12: Bending Moment in X direction in Zone 3



Graph 13: Bending Moment in Y direction in Zone 3

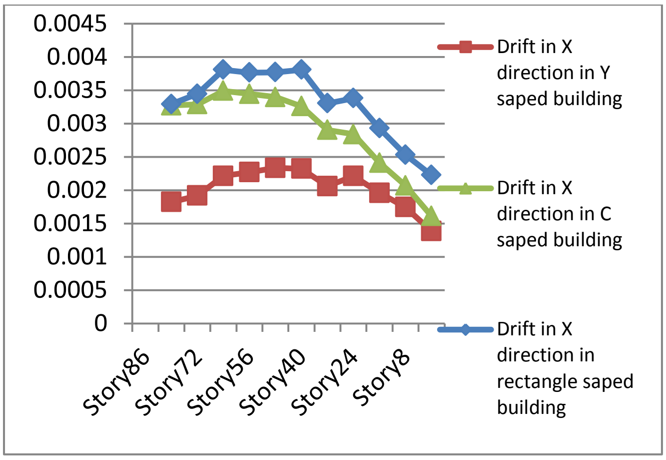


Graph 14: Building Torsion in Zone 3

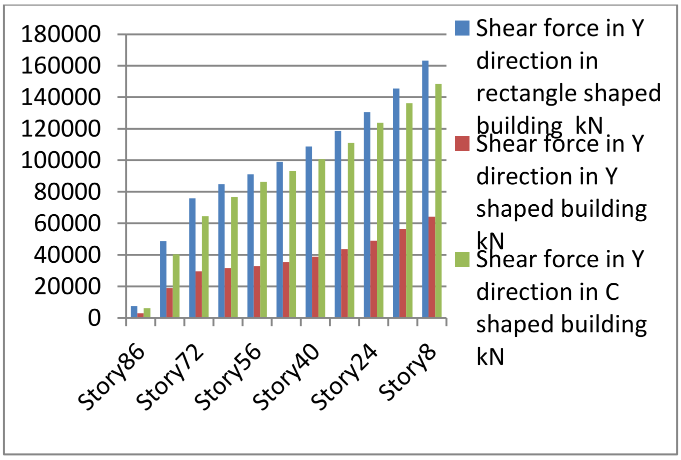


Graph 17: Shear Force in X direction in Zone 4

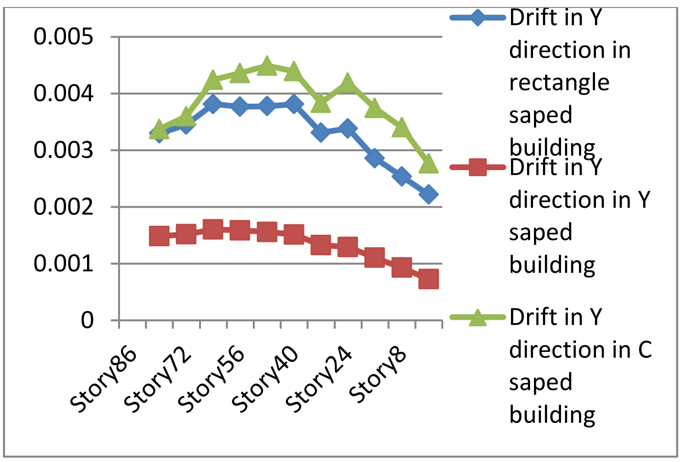
➢ **ZONE IV**



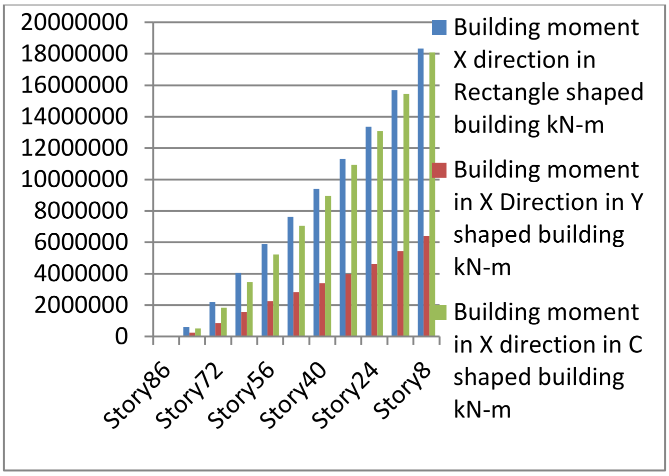
Graph 15: Storey Drift in X direction in Zone 4



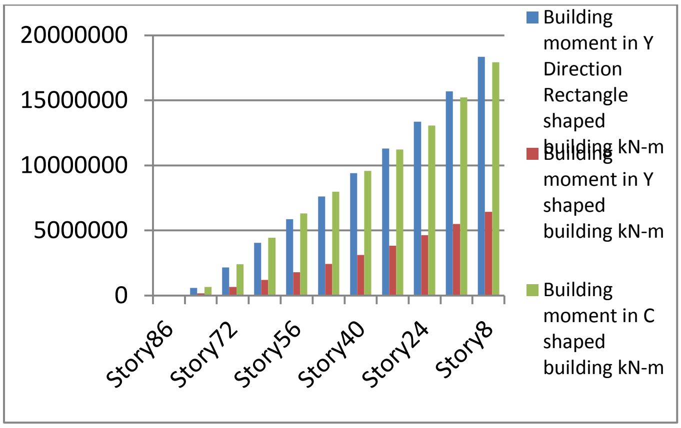
Graph 18: Shear Force in Y direction in Zone 4



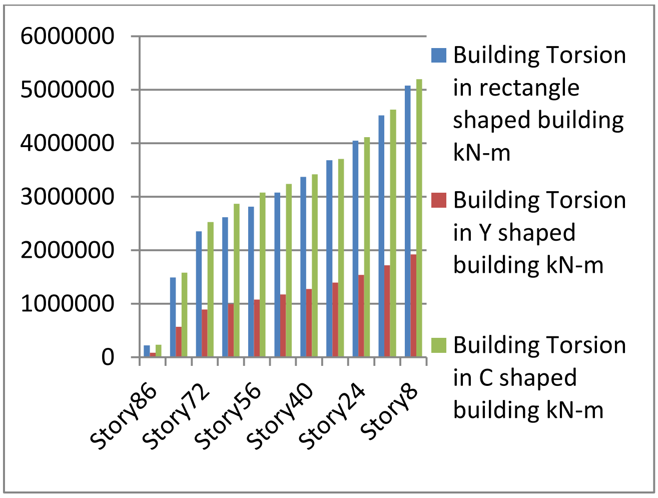
Graph 16: Storey Drift in Y direction in Zone 4



Graph 19: Bending Moment in X direction in Zone 4

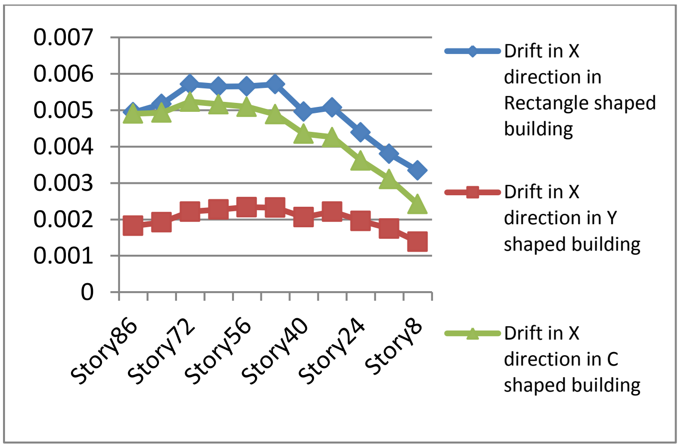


Graph 20: Bending Moment in Y direction in Zone 4

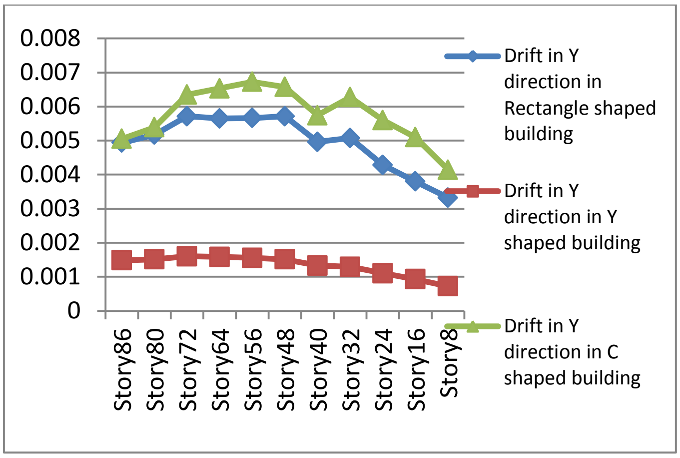


Graph 21: Building Torsion in Zone 4

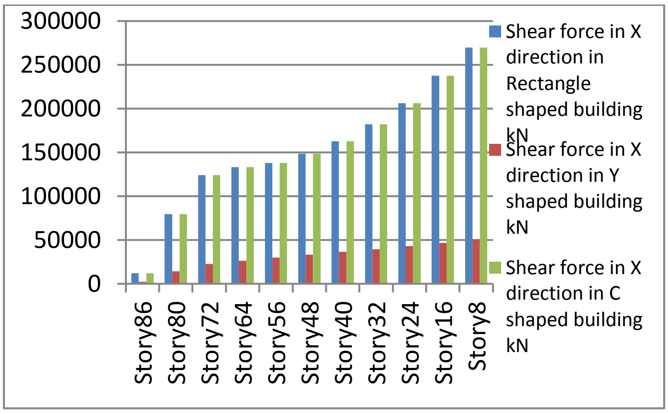
- **ZONE V**



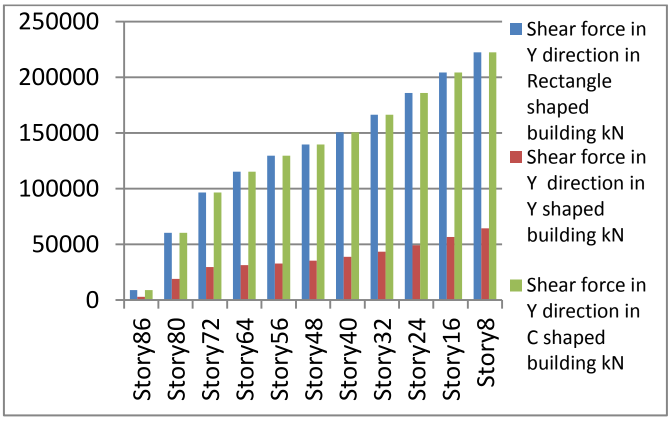
Graph 22: Storey Drift in X direction in Zone 5



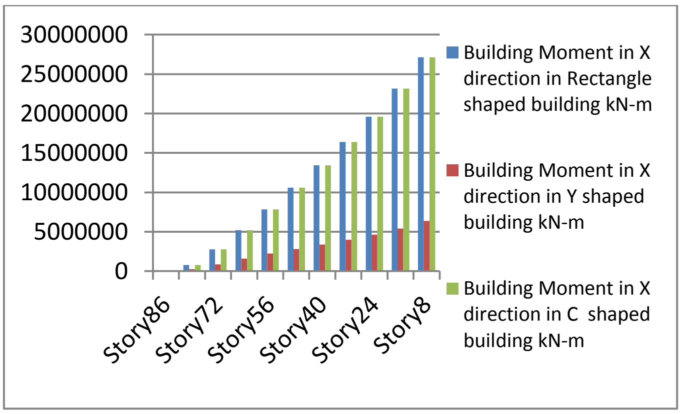
Graph 23: Storey Drift in Y direction in Zone 5



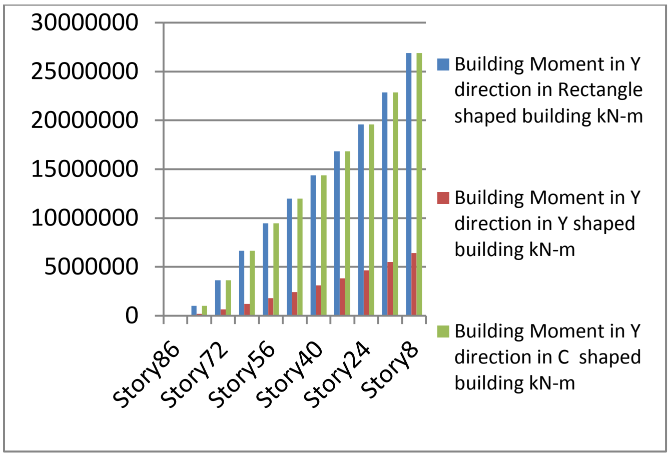
Graph 24: Shear Force in X direction in Zone 5



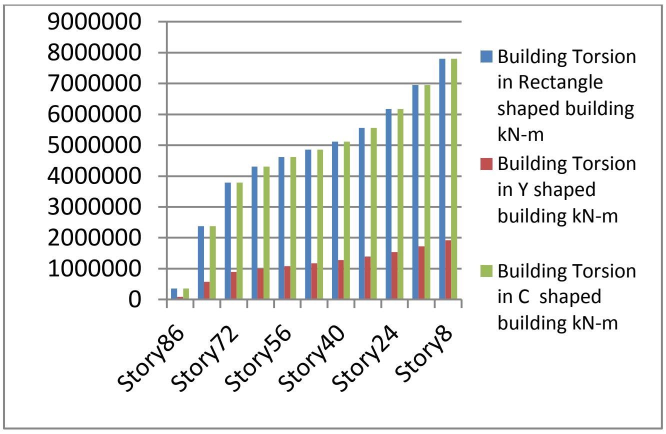
Graph 25: Shear Force in Y direction in Zone 5



Graph 26: Bending Moment in X direction in Zone 5

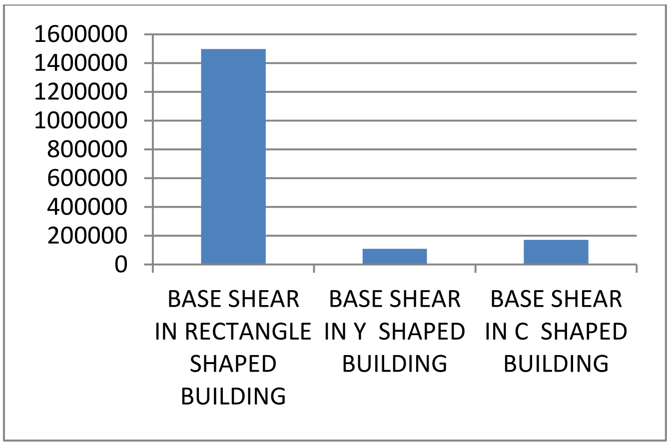


Graph 27: Bending Moment in Y direction in Zone 5



Graph 28: Building Torsion in Zone 5

BASE SHEAR:



Graph 29:Base Shear

IV. DISCUSSIONS

- The use of outrigger and belt truss system in high-rise buildings increase the stiffness and makes the structural form efficient under lateral load.
- Single outrigger provided at the middle of the structure height reduces the maximum displacement by 56 %, while providing first outrigger at the top and second outrigger at the middle of the structure height reduces displacement by 65%.
- For three dimensional structural model subjected to the earthquake load, reduction in lateral displacement can be achieved with optimum location of the outrigger truss at the top and 40TH level. (In order to improve the performance of the structural aspect, the maximum displacement at the top floor becomes one of the most important factors affecting the occupant's comfort)
- For the second optimum position of outrigger base shear is significantly high compared to first optimum position and bare frame with shear wall. Shear wall stress and axial load in the columns to the opposite side of the earthquake direction.
- Using second outrigger with 0.68h gives the reduction of 16.65% and 13% for drift and deflection. The optimum location of second outrigger is middle height of the building.
- The use of outrigger and belt truss system in high rise buildings increase the stiffness and make the structural form efficient under lateral load.
- The lateral bracing system consisting of core with outriggers is one of the most efficient systems used for high rise construction to resist lateral forces caused by wind and earthquakes.
- Outrigger beams connected to the core and external columns are relatively more complicated and it is understood that the performance of such coupled wall systems depends primarily on adequate stiffness and strength of the outrigger beam.

V. CONCLUSIONS

After performing analysis and studying the results we can come to the below conclusions:

- The behavior of a formation under earthquake freight is different from earthquake to Earthquake. This well known phenomenon is well presented in the tangential displacement results obtained for both of the options.
- The location of the outrigger beam has a critical influence on the tangential behavior of the formation under earthquake freight and the optimum outrigger locations of the edifice have to be carefully selected in the edifice design.
- Comparison drift values both in the equivalent static analysis and response spectrum analysis the drift values show the less values in Rectangle shaped edifice (symmetrical) in static analysis. The response spectrum analysis shows much higher values due to the combination of all forces including static and dynamic freight.
- Considering the shear force in the both static and response spectrum analysis the static analysis is

having the least values in negative as compared to the response spectrum analysis.
- The edifice minute demonstrates that the minute in response spectrum having less quality as compared to the static analysis.
- Considering all the above results and graphs the best reasonable formation is C formed edifice for the unsymmetrical shapes as compared to other edifice Y molded edifice both in static and response spectrum technique.
- The utilization of outrigger and belt truss scheme in elevated formations increase the stiffness and make the anatomical form efficient under tangential burdens.
- Outrigger scheme is observed to be efficient in controlling the tangential freight s and has proved to be Economical.

Considering all the above buildings the most advantage building when compared to the other buildings types are Y shaped building shows the least displacements, least building moments so the most advantages building is Y shaped building. When compared in all seismic zones of India.

VI. REFERENCES

IS CODE BOOKS:

- IS456:2000 Plain and Reinforced Concrete - Code of Practice is an Indian Standard code of practice for general structural use of plain and reinforced concrete.
- IS800:2007 Indian Standard. GENERAL CONSTRUCTION IN. STEEL — CODE OF PRACTICE. (Third Revision). ICS 77.140.01. Q BIS 2007.
- IS16700:2017 'Criteria for Structural Safety of Tall Concrete Buildings'

OTHER REFERENCES:

- Shruti Badami and M.R. Suresh: "A Study on Behavior of Structural Systems for Tall Buildings Subjected To Lateral Loads", International Journal of Engineering Research & Technology (IJERT) Vol. 3 Issue 7, July – 2014
- Thejaswini R.M. And Rashmi A.R.: "Analysis and Comparison of different Lateral load resisting structural Forms" International Journal of Engineering Research & Technology (IJERT) Vol. 4 Issue 7, July – 2015
- Po Seng Kian, Frits Torang Siahaan: "The use of outrigger and belt truss system for high-rise concrete buildings"
- N. Herath, N. Haritos, T. Ngo & P. Mendis: "Behaviour of Outrigger Beams in High rise Buildings under Earthquake Loads", Australian Earthquake Engineering Society 2009
- Kiran Kamath, N. Divya, Asha U Rao: "A Study on Static and Dynamic Behavior of Outrigger Structural System for Tall Buildings", Bonfiring International Journal of Industrial Engineering and Management Science, Vol2, No 4, December 2012
- Alpana L. Gawate J.P. Bhusari: "Behaviour of outrigger structural system for high-rise building", International Journal of Modern Trends in Engineering & Research, e-ISSN No.:2349-9745, Date: 2-4 July, 2015
- Vijaya Kumari Gowda M R and Manohar B C: "A Study on Dynamic Analysis of Tall Structure with Belt Truss Systems for Different Seismic Zones", International Journal of Engineering Research & Technology (IJERT) Vol. 4 Issue 8, August – 2015
- Kiran Kamath, Shashikumar Rao and Shruthi : "Optimum Positioning of Outriggers to Reduce Differential Column Shortening Due to Long Term Effects in Tall Buildings", International Journal of Advanced Research in Science and Technology, Volume 4, Issue 3, 2015, pp.353-357.
- Abbas Haghollahi, Mohsen Besharat Ferdous and Mehdi Kasiri: "Optimization of outrigger locations in steel tall buildings subjected to earthquake loads", 15th world conference of earthquake engineering 2012.
- rateek N. Biradar, Mallikarjun S. Bhandiwad:"A performance based study on static and dynamic behaviour of outrigger structural system for tall buildings", International Research Journal of Engineering and Technology (IRJET), Volume: 02 Issue: 05 | Aug-2015
- Shivacharan K, Chandrakala S , Karthik N M: "Optimum Position of Outrigger System for Tall Vertical Irregularity Structures", IOSR Journal of Mechanical and Civil Engineering, Volume 12, Issue 2 Ver. II (Mar - Apr. 2015), PP 54-63
- Abdul Karim Mulla and Shrinivas B.N: "A Study on Outrigger System in a Tall R.C. Structure with Steel Bracing", International Journal of Engineering Research & Technology (IJERT) Vol. 4 Issue 7, July – 2015
- Dr. S. A. Halkude, Mr. C. G. Konapure and Ms. C. A. Madgundi: "Effect of Seismicity on Irregular Shape Structure" International Journal of Engineering Research & Technology (IJERT) Vol. 3 Issue 6, June – 2014
- Mr.Gururaj B. Katti and Dr. Basavraj Baapgol: "Seismic Analysis of Multistoried RCC Buildings Due to Mass Irregularity by Time History Analysis", International Journal of Engineering Research & Technology (IJERT) Vol. 3 Issue 6, June – 2014.