COMPARATIVE ANALYSIS OF SEISMIC PERFORMANCE ON RC STRUCTURE WITH OUTRIGGER AND BELT TRUSS SYSTEM

Ashwini C N[1], Dr Kiran T[2]

[1]*M.Tech. (Earthquake Engineering), UVCE, Karnataka, India.*
[2]*Associate Professor, Civil Engineering Department, UVCE, Karnataka.*

---***---

Abstract: *Tall building development has been rapidly increasing worldwide introducing new challenges that need to meet through engineering decision. As the height of the structure increases the stiffness of the structure reduces. Hence to develop the performance of the structure under seismic loading, Outrigger and Belt truss system is proposed in the current study of work. The main objective of this research is to compare models with outrigger, belt truss, outrigger with belt truss and bare frame model. In this research work, the structure be analysed for a 40 storey residential building, there are three types of modelling arrangements and one bare frame model for comparison of parameters like storey displacement, storey drift, natural time period and base shear. Models of only outrigger, models of only belt truss and models with outrigger and belt truss system at three different positions 1/4,1/3,1/2 of the storey height is considered for analysis. A 40 storey structure is subjected to static and dynamic analysis (response spectrum method) as per IS 1893 (Part1): 2016 using finite element software "ETABS" Program. Present study concluded that in condition of only outrigger, only belt truss and outrigger with belt truss system, it can be predicted that building with outrigger and belt truss system performs better compared to the other two models. The comparative results shows that all the results obtained are within the limits as per the codal limitations.*

Keywords: Outrigger, Belt truss, Tall Building, Storey displacement, Base shear, Storey drift and ETABS

1. Introduction

Tall Building has always been a vision of dreams and technical advancement leading to the progress of the world. Presently, with the rapidly increasing urbanization, tall building has become a more convenient option for office and residential housing. Tall buildings are usually designed for Residential, office or commercial use. They are primarily a reaction to the rapid growth of the urban population and the demand by business activities to be as close to each other as possible.

A large portion of India is susceptible to damaging levels of seismic hazards. Hence, it is necessary to consider the seismic load for the design of high-rise structure. The different lateral load resisting systems are used in high-rise building as the lateral loads due to earthquake as a matter of concern. These lateral forces can produce critical stresses in the structure, inducing undesirable stresses in the structure, and undesirable vibrations or cause excessive lateral sway of the structure.

1.2 Outrigger system: Outriggers are stiff beam and horizontal members that which connect the interior core or shear wall of the structure to the outermost columns and hence it helps to resist the lateral loading and to enhance building overturning stiffness and strength. When tall building subjected to the lateral forces developed by the wind or earthquake, that forces are resisted by the system of outriggers. Column resists the rotation of shear wall. This would result in significant reduction in lateral displacement at the top and base movement.

1.3 Belt Truss System The belt truss will tie together all the external columns located at the periphery of the structure. The outriggers connect these belt trusses to the central core of the structure thus inhibiting the periphery columns from experiencing rotation and help the entire structure to act as a single unit.

1.4 Outrigger and Belt Truss System

The outrigger and belt truss system is one of the lateral load 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 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. The outriggers without belt truss and outriggers with belt truss (Fig 1) are shown below.

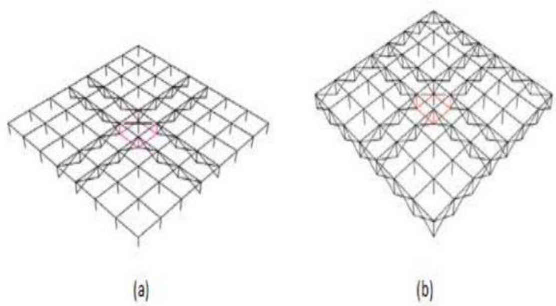


Fig-1: a) **only outriggers without belt truss**
b) **Outriggers with belt truss**

2. Objective of the present study

1. The analysis of the building model is carried by finite element software ETABS.
2. For the model additional outrigger and belt truss system is implemented and analysed.

3. Presenting comparative analysis between the models with outrigger, belt truss and outrigger with belt truss by introducing steel bracing in a R.C tall structure.
4. To study parameters such as storey displacement, storey drift and base shear by introducing outriggers, belt truss, outrigger with belt truss system at positions 1/4, 1/3, 1/2 of the storey height.
5. Finite element analysis involving modal, Equivalent static, Response spectrum method as per IS 1893-2016 for zone IV is carried out on all models.
6. To get efficient lateral load resisting system.

3. LITERATURE REVIEW

Abbas Hangollahi et al., (2012) In this research paper they worked for high rise steel frame building structure, subjected to seismic load for optimize location of outrigger. In this work basic concept to take out study of results obtain from lateral displacement and storey drift by non-linear time history and response spectrum method. By taking 20 and 25 storey model has been analysed by considering ground accelerations of several actual earthquakes in earlier period study about drift and displacement. They have taken 0.44 times and 0.5 times of stature of building as from top. By employing non-linear time history analysis, the optimum location of outriggers and belt trusses were on high storey 14 and 16. So accordingly the researcher it may be secure that outriggers optimum location must be placed at high level.

Rahul Y. et al., (Feb 2017) In this research work they have considered dynamic analyse of tall rise steel by shear wall. The outrigger performs to lateral stiffness that provides drift controller for tall structure. They include shear wall, rigid frame, wall frame and outrigger of structure. The main objective is to perform outrigger structural system in tall structure subjected to wind load and seismic loads as per Indian standard codes. They compared on static and dynamic analysis on the conduct of comparative structure of various cases of 50 storey structure by using finite element method. They mainly compared bare frame with steel bracing with centre core of structural in efficiency by measured of lateral displacement, storey shear, base shear and time period values. The provision of outrigger along a shear wall increases the force and stiffens of structure against seismic and wind load. And shear walls without openings and by reduction at inner storey drift can be achieved.

4. METHODOLOGY

The main aim of the present work is to study the influence of outrigger and belt truss system with steel bracing at different positions of placing at 1/4, 1/3, 1/2 of storey height in a tall structure subjected to modal, static and dynamic analysis. The structure be analysed for a 40 storey RC structure, there are three types of modelling arrangements and one bare frame model for comparison of parameters like storey displacement, storey drift and base shear. Models of only outrigger, models of only belt truss and models with outrigger and belt truss system at three different positions 1/4, 1/3, 1/2 is considered for analysis. In outrigger with steel bracing selecting the best system to resist lateral loads and restrict the displacement and drift. The 40 storey R.C.C building frame situated in earthquake zone IV considered for analysis. The analysis is done with a static method and dynamic method by using E-TABS 2017 software. Design data are presented in table 1.

Table: 1 Model data

Sl. No.	**Design Data of Building**	
1.	**Details of Building**	
i	Structure	SMRF
ii	Number of stories	40
iii	Type of building	Residential
iv	Height of each floor	3.0 m
v	Building Plan Dimension	48m x 48m Each bay 6 m
vi	Support condition	fixed
2.	**Material Properties**	
i	Grade of Concrete	M30
ii	Grade of Steel	Fe500
iii	Grade of outrigger and belt truss	Fe345
iv	Youngs modulus of concrete, E_c	$25x10^6$ kN/m^2
v	Density of concrete	25 kN/m^3
vi	Damping	5 %
3.	**Member Properties**	
i	Thickness of Slab	200 mm
ii	Size of Beam	(300 x 450) mm
iii	Size of Column	(700 x 700) mm
iv	Outrigger Steel Bracing	Outside diameter 300 mm Wall thickness 10 mm
v	Thickness of Shear Wall	200 mm
4.	**Loads and Intensities**	

i	Floor finish	1.0 kN/m²
ii	Live Load on all the floors	3 kN/m²
iii	Wall load	12.75 kN/m²
5.	**Seismic Properties from IS: 1893 (part 1)-2016**	
i	Zone factor	0.24 (Zone IV)
ii	Importance factor	1.2
iii	Response reduction Factor	5.0
iv	Soil Type	Medium (Type II)

4.1 Modelling Arrangements

MODEL 1: Bare frame model
MODEL 2: Only outrigger at positions 1/4th, 1/3th, 1/2th of the storey height
MODEL 3: Only belt truss at positions 1/4th, 1/3th, 1/2th of the storey height
MODEL 4: With outrigger and belt truss at positions 1/4th, 1/3th, 1/2th of the storey height.

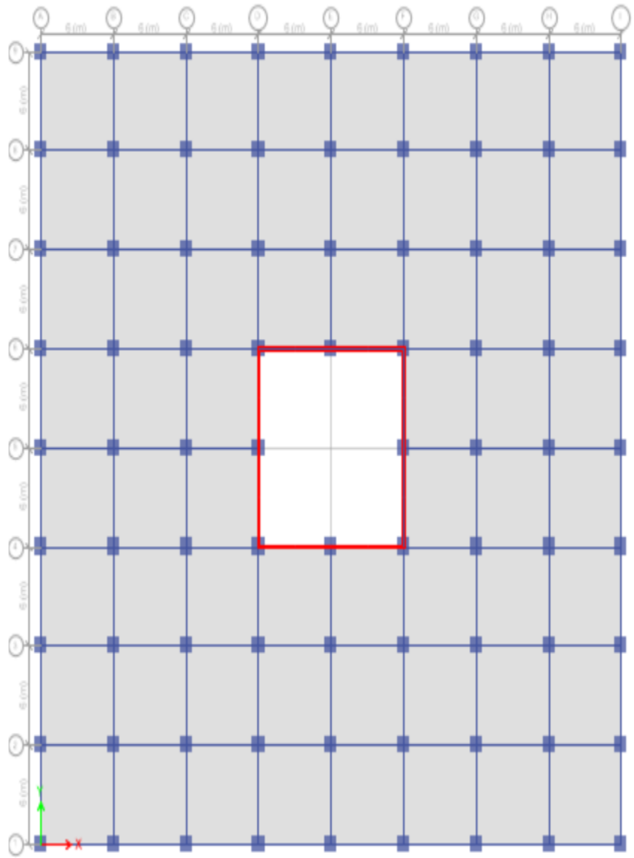


Fig-2: Plan of the structure

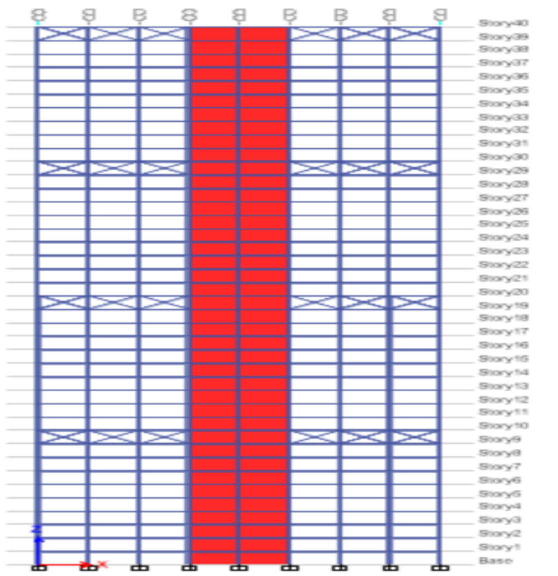


Fig- 3: elevation of outrigger and belt truss system

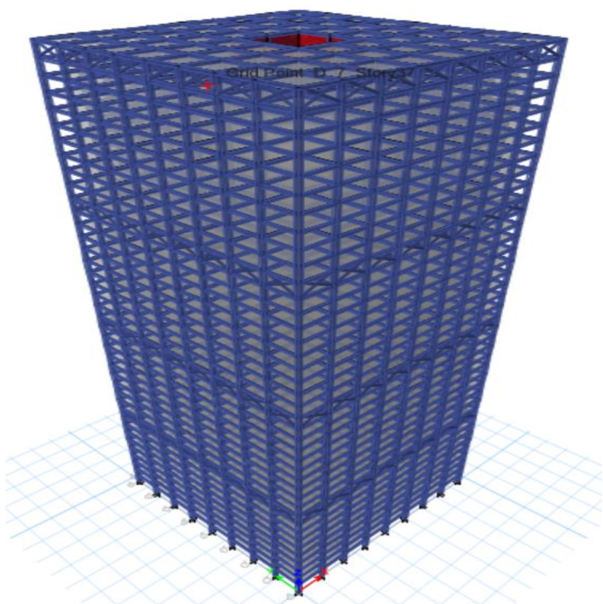
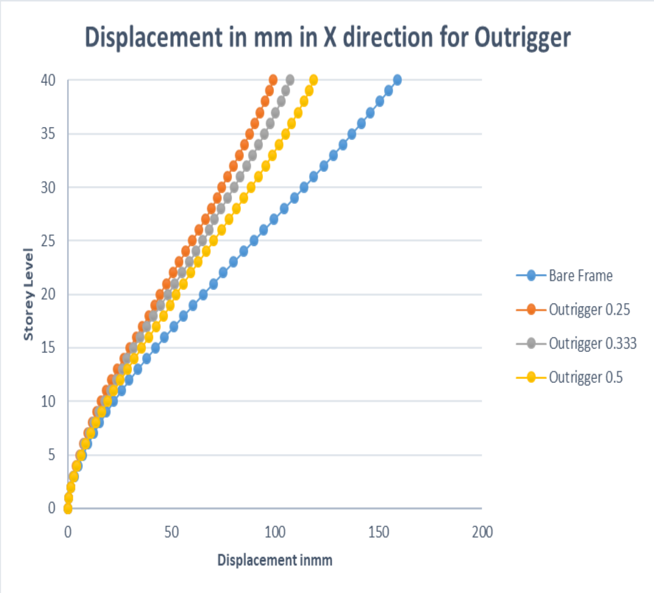
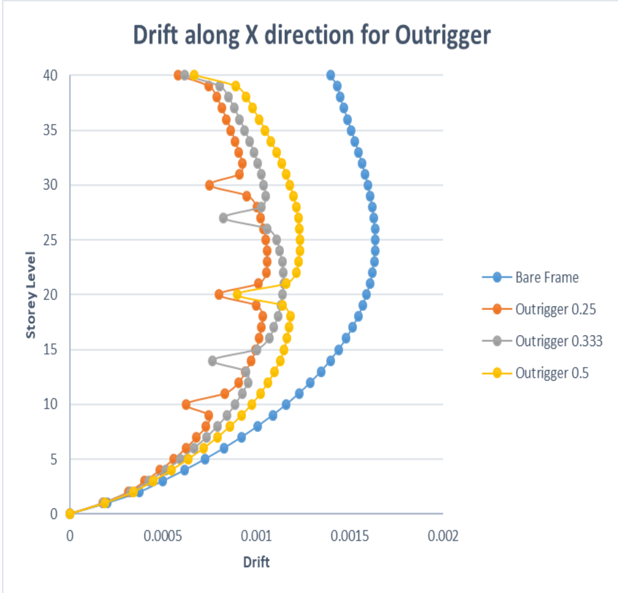


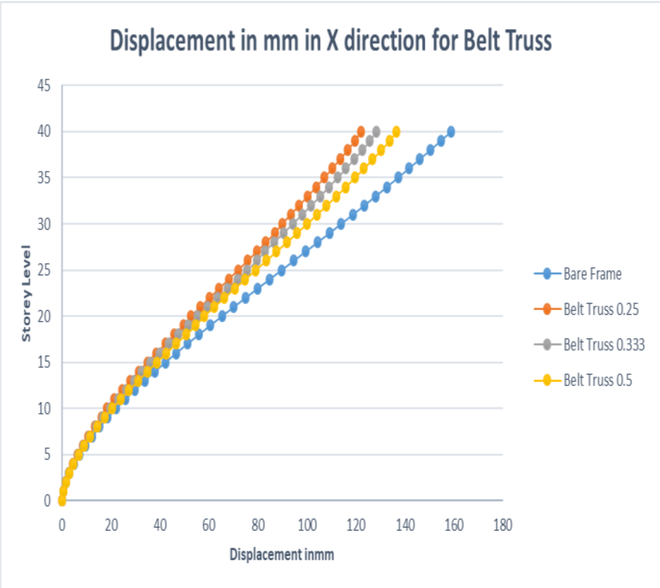
Fig-4: 3D view of outrigger and belt truss system

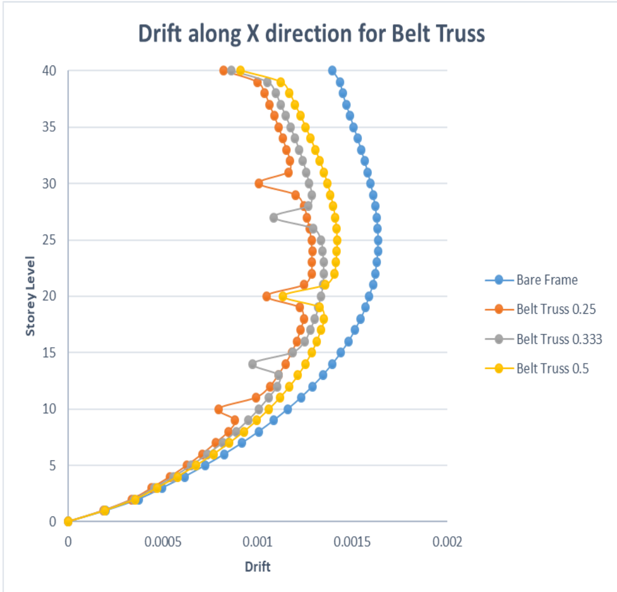
4.2 RESULTS

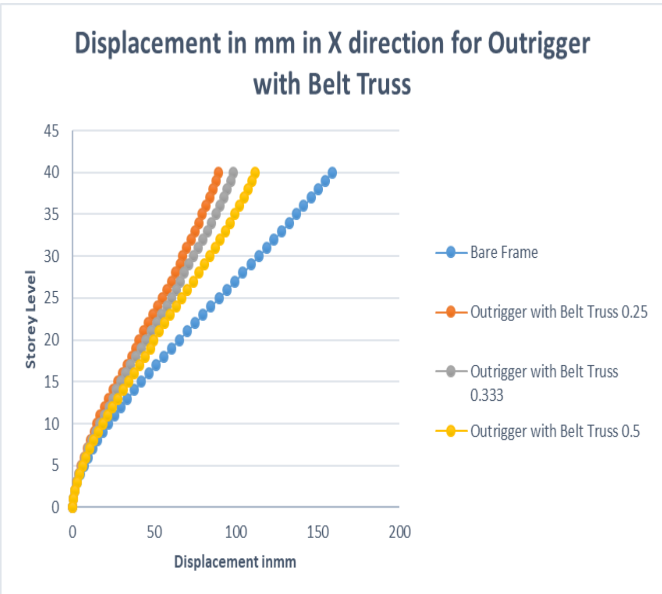
MODEL 1: considered analysis for a model of forty storey building without outrigger and belt truss system.
MODEL 2: considered analysis for a model of forty storey building with only outrigger at positions 1/4, 1/3, 1/2th of the storey height.
MODEL 3: considered analysis for a model with forty storey building with only belt truss at positions 1/4, 1/3, 1/2th of the storey height.
MODEL 4: considered analysis for a model with forty storey building with outrigger and belt truss system at positions 1/4, 1/3, 1/2th of the storey height.

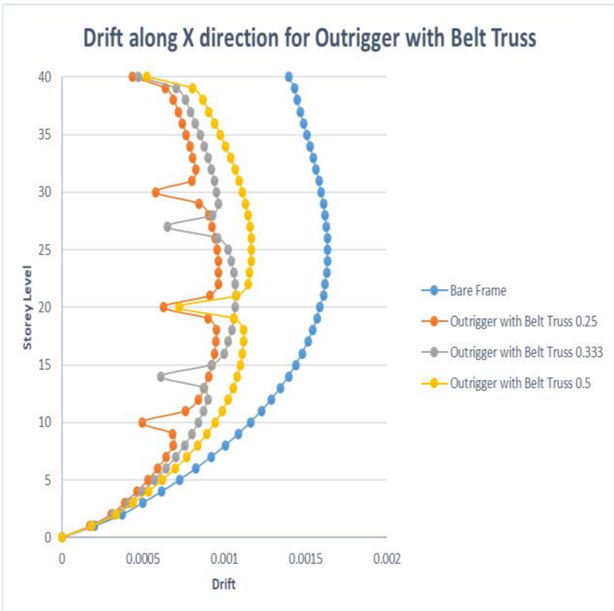

Displacement in mm in X direction for Outrigger
Storey Level
Displacement inmm
Bare Frame
Outrigger 0.25
Outrigger 0.333
Outrigger 0.5

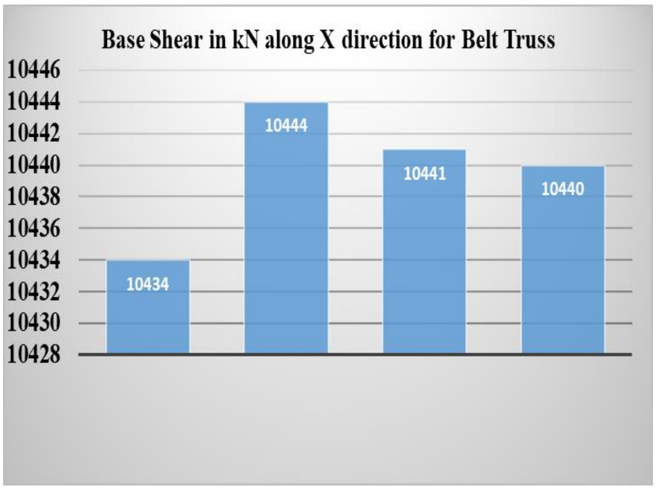

Drift along X direction for Outrigger
Storey Level
Drift
Bare Frame
Outrigger 0.25
Outrigger 0.333
Outrigger 0.5

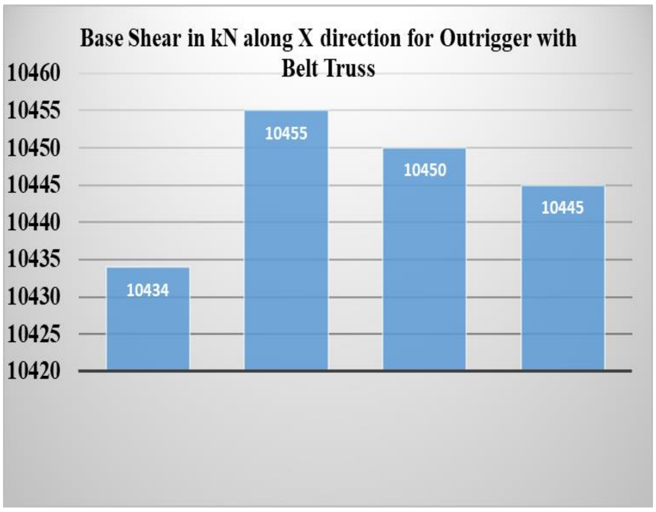

Displacement in mm in X direction for Belt Truss
Storey Level
Displacement inmm
Bare Frame
Belt Truss 0.25
Belt Truss 0.333
Belt Truss 0.5


Drift along X direction for Belt Truss
Storey Level
Drift
Bare Frame
Belt Truss 0.25
Belt Truss 0.333
Belt Truss 0.5


Displacement in mm in X direction for Outrigger with Belt Truss
Storey Level
Displacement inmm
Bare Frame
Outrigger with Belt Truss 0.25
Outrigger with Belt Truss 0.333
Outrigger with Belt Truss 0.5


Drift along X direction for Outrigger with Belt Truss
Storey Level
Drift
Bare Frame
Outrigger with Belt Truss 0.25
Outrigger with Belt Truss 0.333
Outrigger with Belt Truss 0.5





5. DISCUSSIONS

- It was observed that 0.25 position of storey height had more reduction of displacement and drift. And 0.5 position of storey height had less reduction in displacement and drift.
- It can be observed from graphs, that there is curvature change at the outrigger locations this is due to the rotation of the wall which is partially restrained at these points by outrigger-column interaction.
- It was observed that 0.25 position of storey height had more incremental of Base shear when compared with 0.33 and 0.5 position of storey height.

6. CONCLUSIONS

1. Outrigger with Belt truss condition with comparison of the models such as 0.25 position, 0.33 position and 0.5 position of storey height, decreases the displacement values when compared with Bare frame model. At 0.25 position of storey height had more reduction of displacement compared to other position of storey height.
2. When compared to displacement criteria at 0.25 position is 43.81% reduction in lateral displacement at top has been observed for the outrigger with belt truss system model, when compared with a models of only outrigger and belt truss.
3. The displacement reduction at the top floor of the building is less compared to the outrigger provided at middle floors.
4. In case of storey drift, building with both outrigger and belt truss system performs better than the building with only outrigger and building with belt truss system.
5. When compared to storey drift criteria at 0.25 position is 69% reduction in drift value has been observed for the outrigger with belt truss system model, when compared with a models of only outrigger and belt truss.
6. The outrigger and belt truss system not only proficient in controlling top displacements but also play substantial role in reducing the inter storey drift.
7. Base shear condition Outrigger with Belt truss system by comparison of the models such as 0.25 position, 0.33 position and 0.5 position of storey height, increases Base shear values when compared with Bare frame model and the values are 20%, 15% and 11% respectively and It was observed that 0.25 position of storey height had increases of Base shear when compared to the other position of storey height.
8. The outriggers are adopted as X-steel bracing as it gives better output on tall structure it minimizes lateral load.
9. In the present study we can see that all the results obtained are within the limits as per the codal limitations.
10. Based on the above conclusions, it can be predicted that building with outrigger and belt truss performs better compared to the other two models.
11. The load resisting capacity of the tall building structure increases by providing outriggers and belt truss due its strength characteristics.

REFERENCES

1. Abbas Haghollahi, Mohsen Besharat Ferdous and Mehdi Kasiri: "Optimization of outriggers locations in steel tall buildings subjected to earthquake loads", International Journal of engineering research & technology (IJERT) vol.3 issue 7, July 2016.
2. Alpana L, Gawate and 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.
3. Rahul Y, Mohan K. T, & Virendra Kumar K. N: "Dynamic analysis of high rise steel structure with R.C shear wall and outrigger", International Journal of Enginneering Research &Technology(IJERT) Vol. 4 Issue 10, June-2017.
4. 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.
5. 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.
6. Vijaya Kumara 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.
7. 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.
8. Kiran Kamath, N. Divya, Asha U Rao: "A Study on Static and Dynamic Behaviour of Outrigger Structural System for Tall Buildings", Bonfiring International Journal of Industrial Engineering and Management Science, Vol2, No 4, December 2012.
9. Richard J, Balling S E, and Jacob S. Lee: "Simplified Model for Analysis and Optimization of Skyscrapers with outrigger and Belt Trusses" American Society of Civil Engineers 2014.
10. Preethi .M. Nagargoje and Shilpa Kewate: "Analysis of Outrigger Structural System for Tall Building Subjected to Lateral Loads" International Journal of Science Technology and Engineering 2017.
11. Pankaj Sharma and Gurpreeth Singh: "Dynamic Analysis of Outrigger Systems in High Rise Buildings against Lateral Loading" International Journal of Science Technology and Engineering 2018.
12. Daril John Prasad and Srinidhilakshmish Kumar: "Comparison of Seismic Performance of Outrigger And Belt Truss System in a RCC Building with Vertical Irregularity" International Journal of Science Technology and Engineering 2016.
13. Po Seng Kian and Frits Torang Siahaan : " The use of Outrigger and Belt Truss system for high rise Concrete Buildings" Dimensi Teknik Sipil, Vol. 3, 2001.
14. Akshay Khanorkar and Shruti Sukhdeve : " Outrigger and Belt Truss System Building to Control Deflection" - Global Research and Development Journal for Engineering 2016.
15. Indian Standard IS 456-2000 "Plain and Reinforced Concrete-Code of Practice," BIS, New Delhi, India.
16. Indian Standard IS 1893 (Part 1):2016, Criteria for earthquake resistant design of structures, Part 1: General Provisions and Buildings, Sixth Revision, BIS, New Delhi, India.

BIOGRAPHIES

Dr. KIRAN T

Associate Professor at Department of Civil
Engineering, UVCE, Bangalore University, Bengaluru.

ASHWINI C N

IV sem M.Tech. (Earthquake Engg.), Dept. of Civil Engg.
UVCE, Bangalore University, Bengaluru.