International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Dynamic Analysis of High-Rise Building with Outrigger System under Seismic Loading

Vaibhav Kare[1], Murtaza Safdari[2]

[1]M.Tech Scholar, Dept. of Civil Engineering, Alpine Institute of Technology, Ujjain, M.P, India
[2]Asst. Prof. Dept. of Civil Engineering, Alpine Institute of Technology, Ujjain, M.P, India
DOI: https://doi.org/10.55248/gengpi.2022.31287

ABSTRACT-

The present work has been done by observing the behaviour of outrigger structure using non dimensional parameter α and β under the action of earthquake load. The earthquake load calculation has been done by IS 1893 (Part-1):2016. In the structure, the outriggers and belt truss are placed at two different locations. The location has been decided by the study of many research paper that at top level of the building (i.e., floor no. 40) and other at 0.55H of the building (i.e., floor no. 22). In this study the non-dimension parameter α remain constant and β change their value by varying depth of outrigger beams to compare the analysis result. In this research, a 40-story 3D reinforced concrete structure with plan area of 25.0 m X 25.0 m and height of building is 128 m is considered in modelling. Location of first outrigger at 40th floor and second outrigger at 22th floor (0.55H) of the building is also modelled in CSI ETABS V19.0 software considering the time history analysis of proposed work. The depth of first outrigger beam is taken same as the floor height of the 40th floor and for second outrigger beam the depth of beam varied as one storey, one and half storey and two storey depth of floor. Key parameter discussed in this paper includes the lateral displacement, story drift and Base shear. The conclusion comes from the study is that when the stiffness of outrigger beam with belt truss is increased by increasing the depth from one storey to two storeys then it will increase the overall lateral stiffness of model that control storey drift.

Keywords- Outrigger Structure, Lateral displacement, Base Shear, Storey drift Ratio, ETABS

I. Introduction

Elevated towers and buildings have enthralled mankind from the establishment of civilization. Contemporary tall buildings begin to development in the 1880. Traditionally, the function of tall buildings has been as commercial office building, other uses such as residential, mixed use and hotel tower developments have since rapidly increased. Due to quick augmentation of population and pressure on the limited space available tends to increase tall buildings. From the past, tall structures have always seen as a symbolic example of power and development. The key reasons for the demand of tall building are population and migration trends, global competition and proliferation, agglomeration, urban reformation, climate change, land prices and energy, infrastructure, conservation and transportation, human endeavour and ego, emerging technologies. The design of skyscrapers is usually governed by the lateral loads imposed on the structure. As buildings have gotten taller and narrower, the structural engineer has been increasingly challenged to meet the imposed drift requirements while minimizing the architectural impact of the structure. In response to this challenge, the profession has proposed a multitude of lateral schemes that are now expressed in tall buildings across the globe.

II. Objective

The objectives of the present work are as follows:

1. To understand the behaviour of outrigger structural system available in literature.

2. To carry out a study of outrigger structural system by changing the depth of outrigger beam with belt truss.

3. To understand the response of building and compare the analysis under the action of earthquake load.

4. To study the two non-dimension parameter α & β change their value by varying depth of outrigger beams.

5. To find out the lateral displacement and storey drift under the response spectrum analysis by placing the outrigger beam with belt truss at different storey level.

6. To find out the spectral acceleration and base shear under the time history analysis.

III. MODELLING & ANALYSIS

DESCRIPTION OF BUILDING MODEL

Details of Structure

In this research, a 40-story 3D reinforced concrete structure with plan area of 25.0 m X 25.0 m and height of building is 128 m is modelled in CSI ETABS V19.0 application software (Fig. 3.1). Models with different arrangements of depth of outrigger beam.

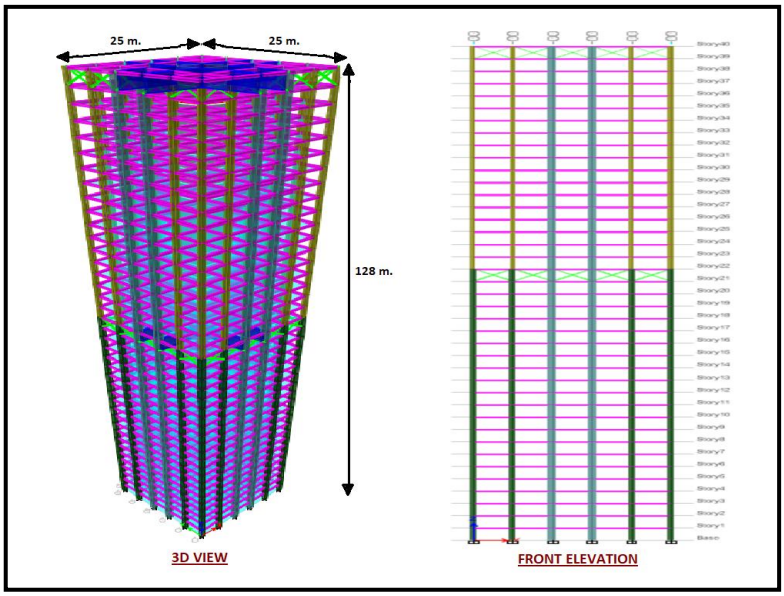

Figure 3.1 Representation of the Model

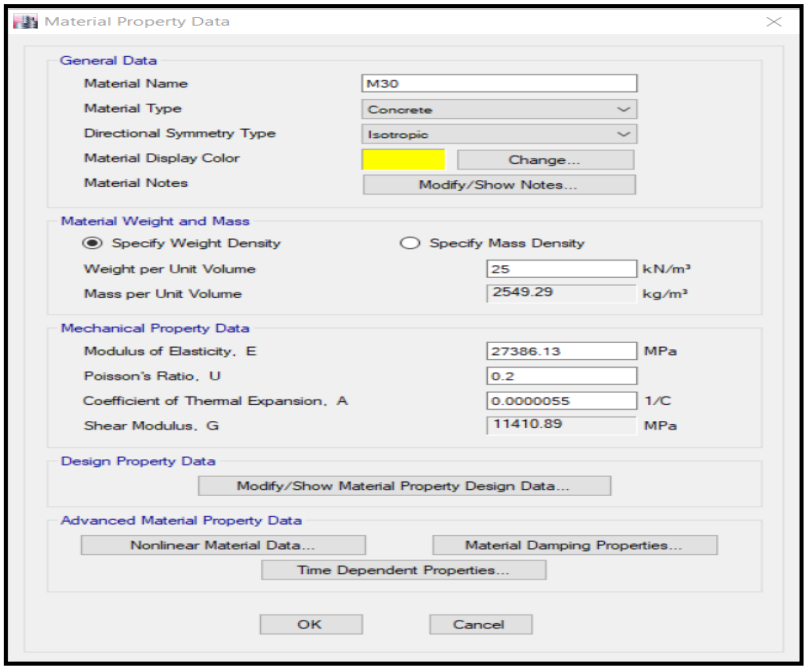

Figure 3.2 Definition of concrete material properties

S. No.	**TABLE: 3.1 CONCRETE MATERIAL PROPERTIES**			
1	Material Name	**M30**	**M35**	**M40**
2	Weight per unit volume (KN/m^3)	25	25	25
3	Modulus of Elasticity, E (MPa)	27386.13	29580.4	31622.78
4	Poisson's Ratio, U	0.2	0.2	0.2

5	Coefficient of thermal expansion, α (1/C°)	5.5 x 10-6	5.5×10^{-6}	5.5×10^{-6}
6	Shear Modulus, G (MPa)	11410.89	12325.17	13176.16
7	Concrete Cube Compressive Strength, f_{ck} (MPa)	30	35	40

Rebar/Reinforcement

The characteristic yield strength f_y of steel is assumed as minimum yield stress or 0.2% of proof stress for steel having no definite yield point. The modulus of elasticity of steel is taken to be 20000 N/mm^2. The grade of high yield strength deformed bars used as steel reinforcement are HYSD 500 with the values of f_y 500N/mm^2.

The representative stress-strain curves for steel having not having definite yield point shown in Fig.4.4. The value of minimum yield strength and minimum tensile strength shall be taken as per table.3 of IS 1786 for HYSD 500.

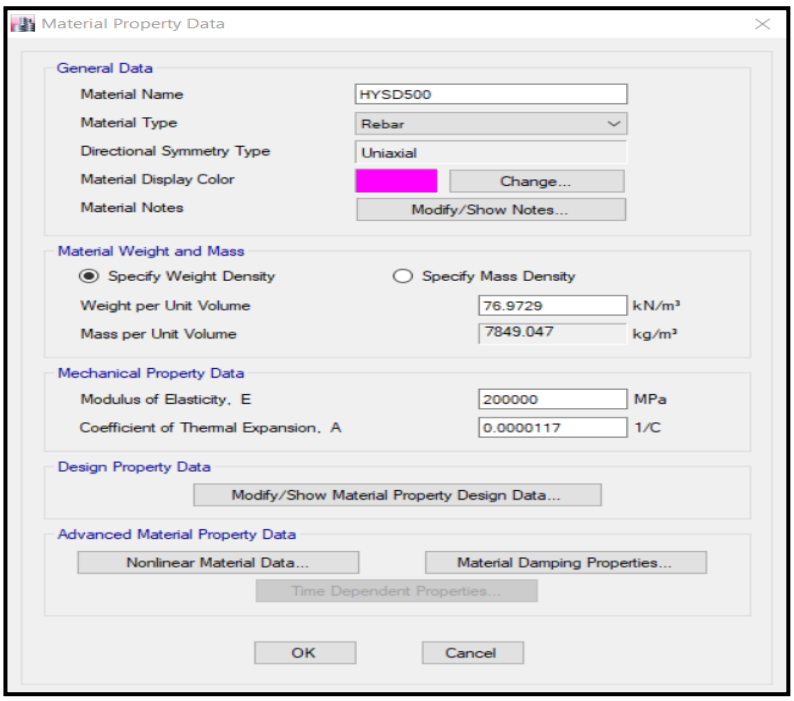

Figure 3.3 Definition of Rebar/Reinforcement Material Properties

S.No.	**TABLE: 3.2 REBARS/REINFORCEMENT MATERIAL PROPERTIES**	
1	Material Name	**HYSD 500**
2	Weight per unit volume (KN/m^3)	76.972
3	Modulus of Elasticity, E (MPa)	200000
4	Coefficient of thermal expansion, α (1/C°)	0.0000117
5	Minimum Yield Strength, F_y (MPa)	415
6	Minimum Tensile Strength, F_u (MPa)	585
7	Expected Yield Strength, F_{ye} (MPa)	550
8	Expected Tensile Strength, F_{ue} (MPa)	599.5

Steel Section

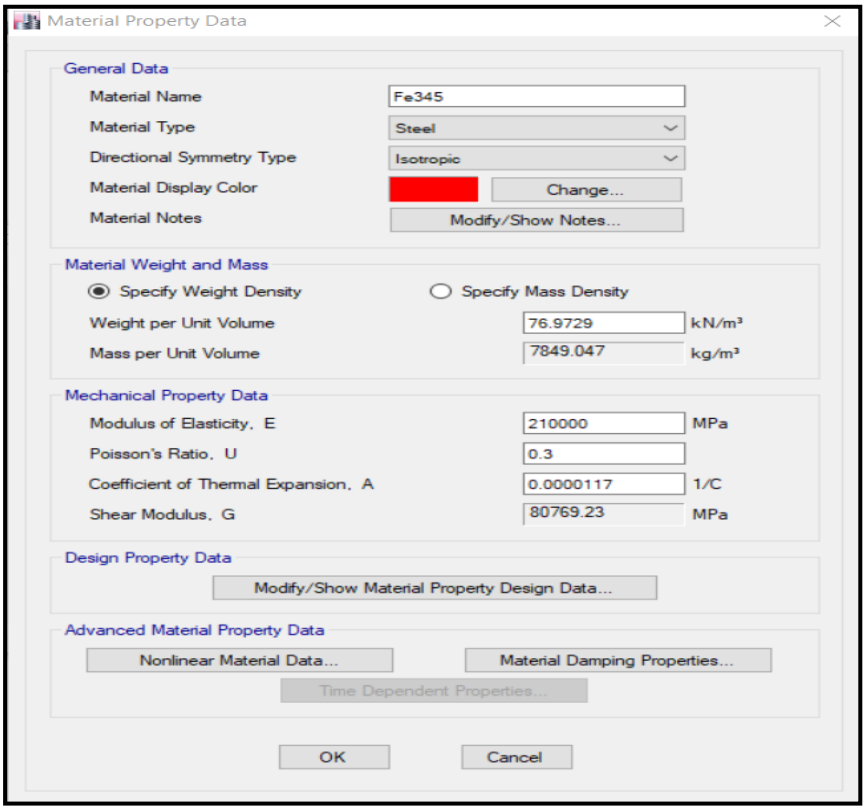

Figure 3.4 Definition of Structural Steel Material Properties

S.No.	TABLE: 3.3 STEEL SECTION MATERIAL PROPERTIES	
1	Material Name	**Fe 345**
2	Weight per unit volume (KN/m^3)	76.9729
3	Modulus of Elasticity, E (MPa)	210000
4	Poisson's Ratio, U	0.3
5	Coefficient of thermal expansion, α (1/C°)	0.0000117
6	Shear Modulus, G (MPa)	80769.23
7	Minimum Yield Strength, F_y (MPa)	345
8	Minimum Tensile Strength, F_u (MPa)	450
9	Expected Yield Strength, F_{ye} (MPa)	379.5
10	Expected Tensile Strength, F_{ue} (MPa)	495

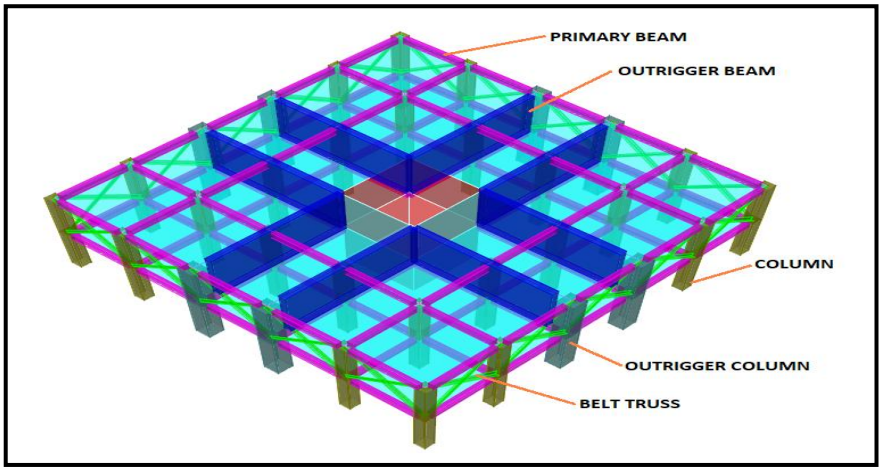

Figure 3.5 Representation of the structural elements

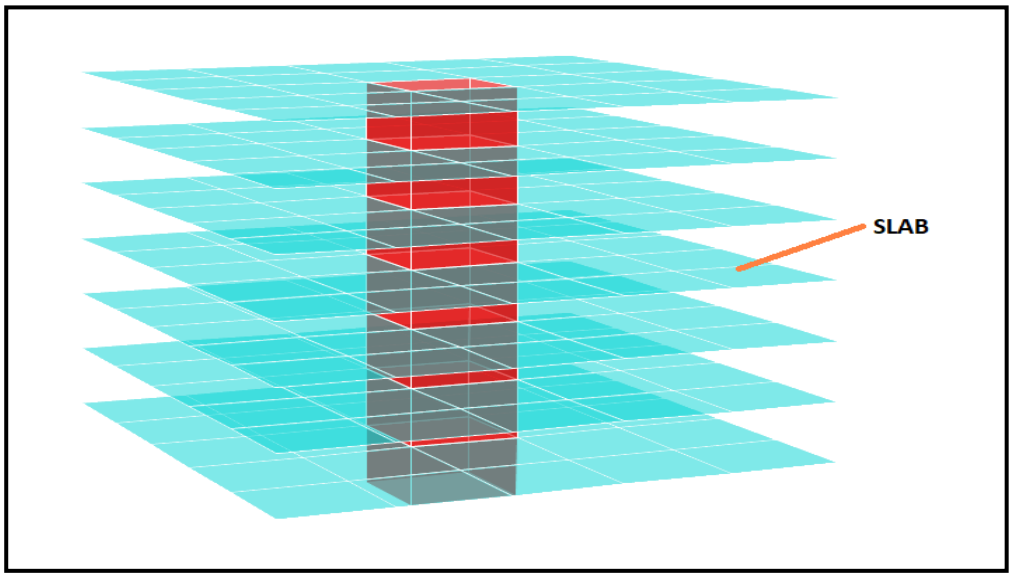

Figure 3.6 Representation of the Slab in Model

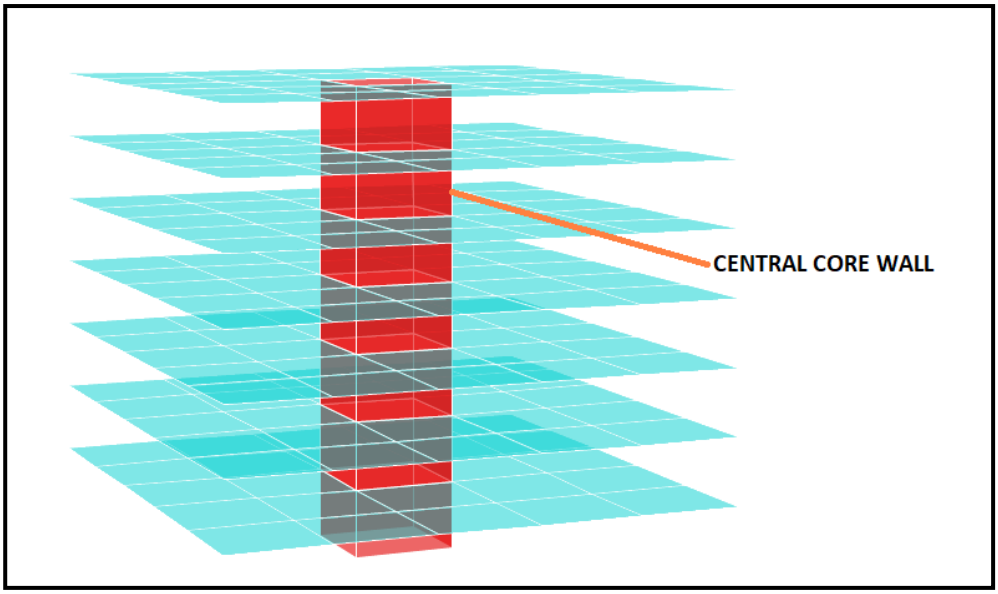

Figure 3.7 Representation of the Central Core Wall in Model

TYPES OF OUTRIGGER BEAM WITH BELT TRUSS

TABLE: 3.4 TYPES OF OUTRIGGER BEAM

Types	**Outrigger Beam Depth**	**Belt Truss Depth**	**Figure**
Type 1	One storey (300X3200 mm^2)	One storey	Fig.3.8
Type 2	One and half storey (300X4800 mm^2)	One storey	Fig.3.9
Type 3	Two storeys (300X6400 mm^2)	One storey	Fig.3.10

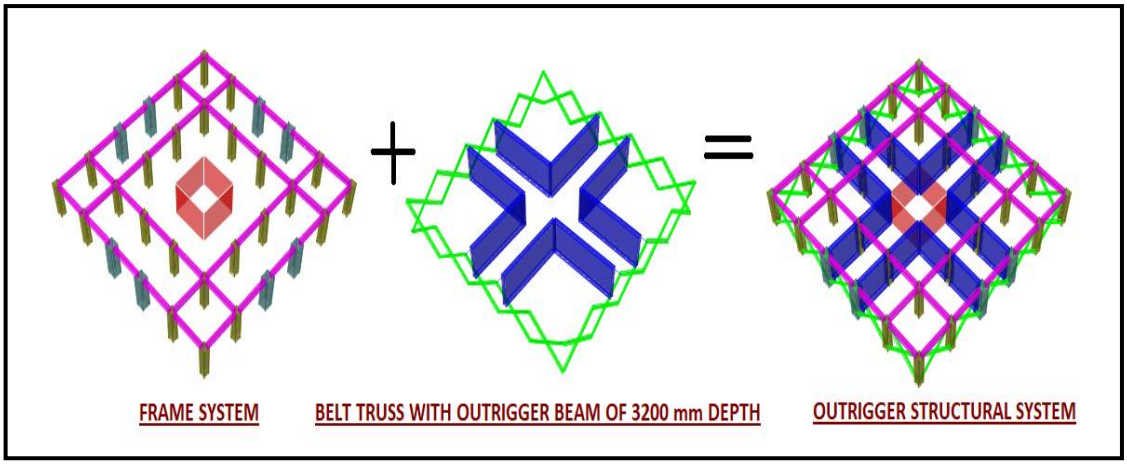

Figure 3.8 One Storey Depth of Outrigger Beam & One Storey Depth of Belt Truss

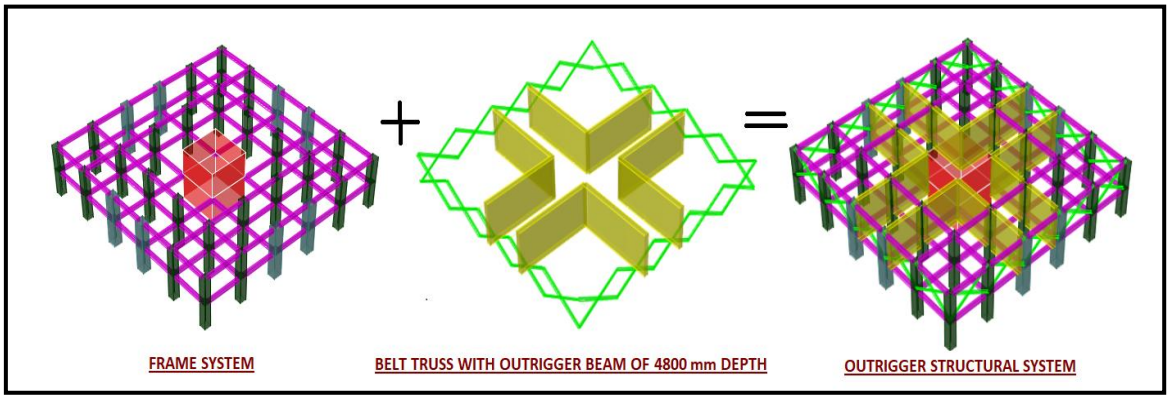

Figure 3.9 One and Half Storey Depth of Outrigger Beam & one Storey Depth of Belt Truss

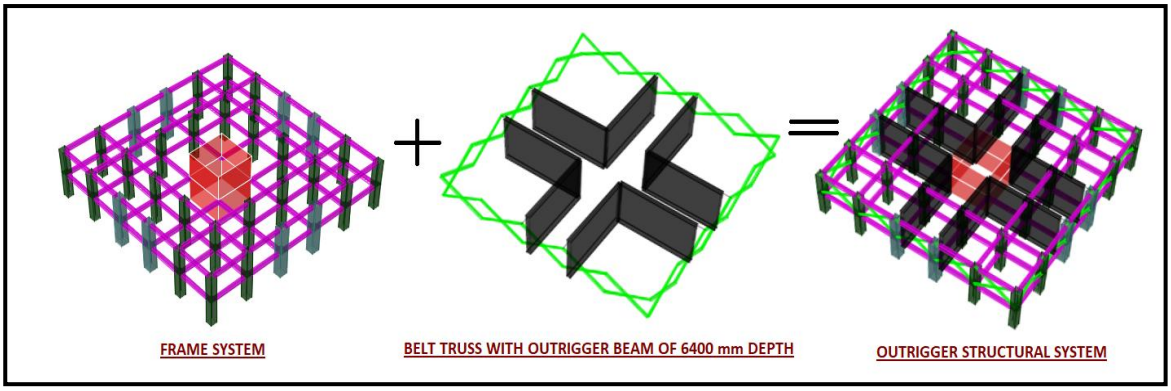

Figure 3.10 Two Storey Depth of Outrigger Beam & One Storey Depth of Belt Truss

IV. Results & Discussion

MAXIMUM LATERAL DISPLACEMENT

As discuss above β has impact on displacement along storey height. Now below Fig. 4.1 and Fig. 4.2 show the maximum lateral displacement at outrigger storey i.e., top storey (40th floor) in X-direction and Y-direction respectively.

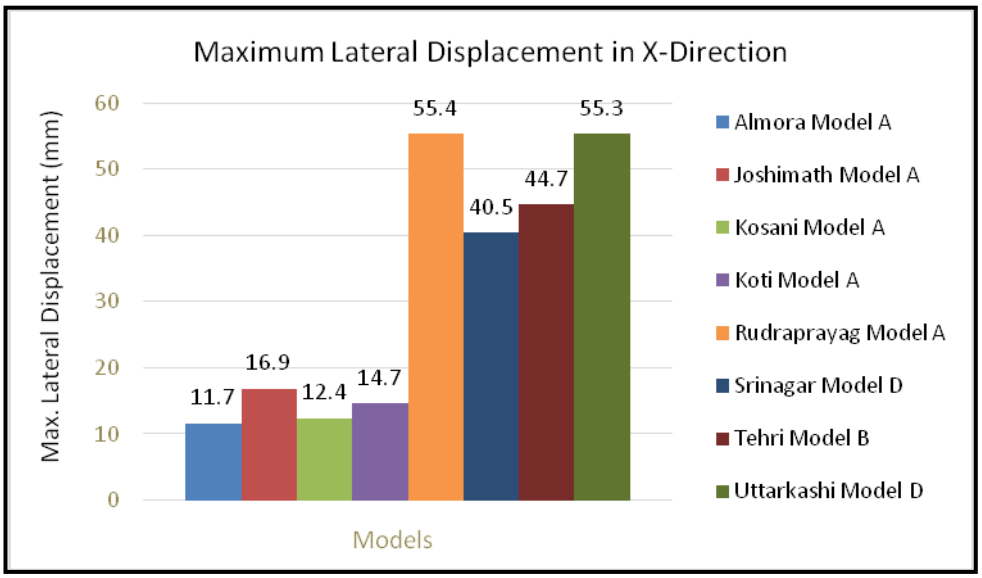

Figure 4.1 Maximum Lateral Displacement in X-Direction

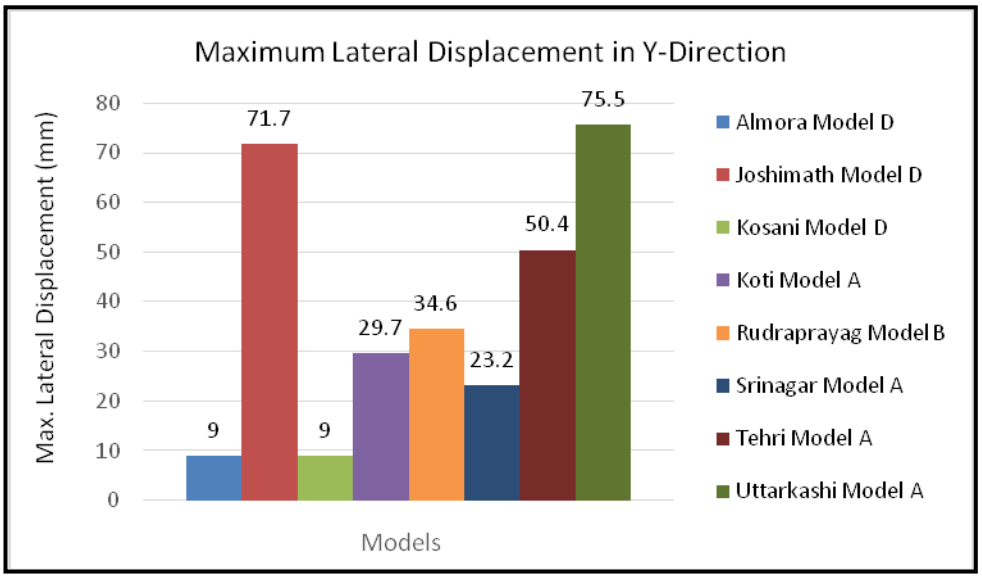

Figure 4.2 Maximum Lateral Displacement in Y-Direction

Here it was observed that in case of X-Direction maximum lateral displacement was 55.4 mm in Model A for Rudraprayag station and in case of Y-Direction maximum lateral displacement was 75.5 mm in Model A for Uttarkashi station. This result concludes that the structure without outrigger showing maximum displacement meanwhile in case of Uttarkashi and Srinagar max displacement shown in Model D.

STOREY DRIFT RATIO

As per above discussion, similar results obtained corresponding to storey drift ratio are in X-direction and Y-direction. Appendix-1 to 8 showing the value of storey drift ratio corresponding to the eight different time history for all models.

MAXIMUM STOREY DRIFT RATIO

Now below Fig. 4.3 and Fig. 4.4 show the maximum storey drift ratio corresponding to model having maximum displacement observed in previous stated.

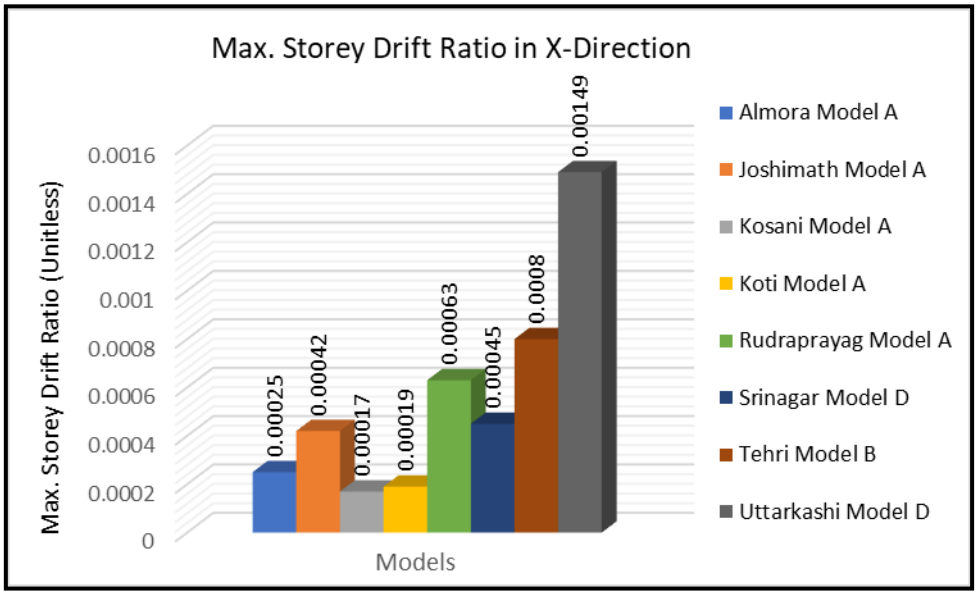

Figure 4.3 Maximum Storey Drift Ratio in X-Direction

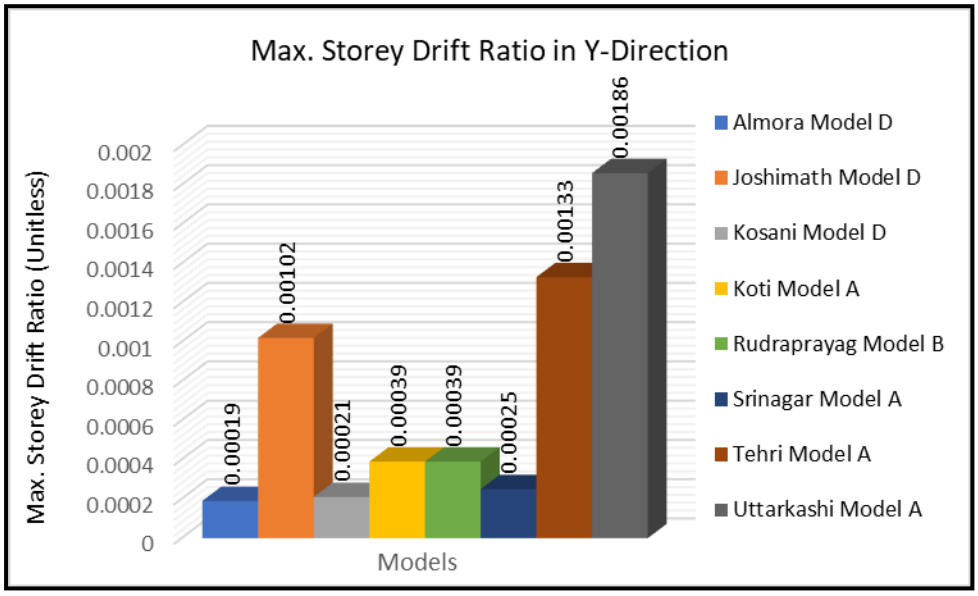

Figure 4.4 Maximum Storey Drift Ratio in Y-Direction

It was observed that during Uttarkashi Time history analysis maximum storey drift ratio was 0.00149 in Model D and 0.00186 in Model A corresponds to X-direction and Y-direction respectively.

BASE SHEAR

As per statement mention in previous chapter. Base shear represents the horizontal force with respect to time induce during earthquake motion. From Fig. 4.5 to Fig. 4.12 show the results of Time periods v/s Base shear in X-direction of all models for every time history records.

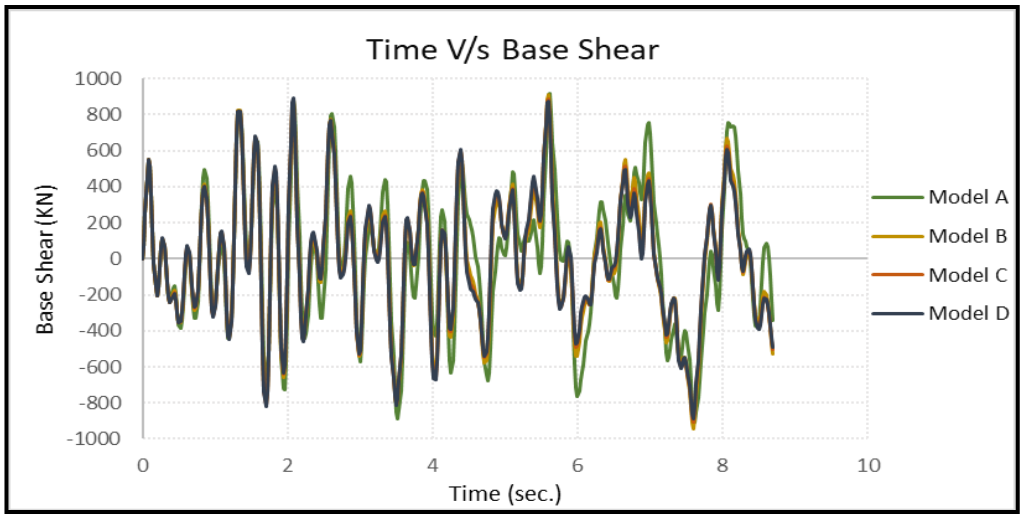

Figure 4.5 Time periods (sec.) v/s Base shear (KN) in X-direction of Almora

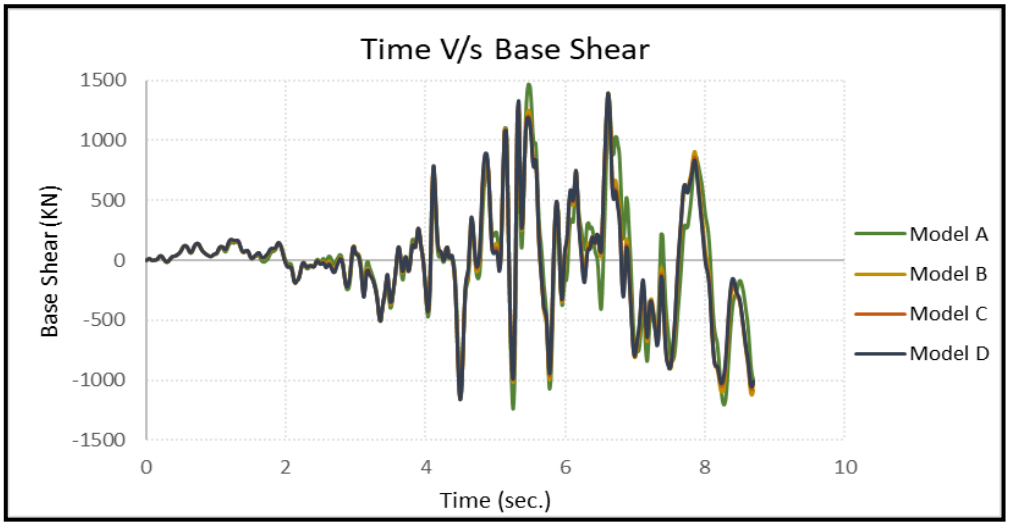

Figure 4.6 Time periods (sec.) v/s Base shear (KN) in X-direction of Joshimath

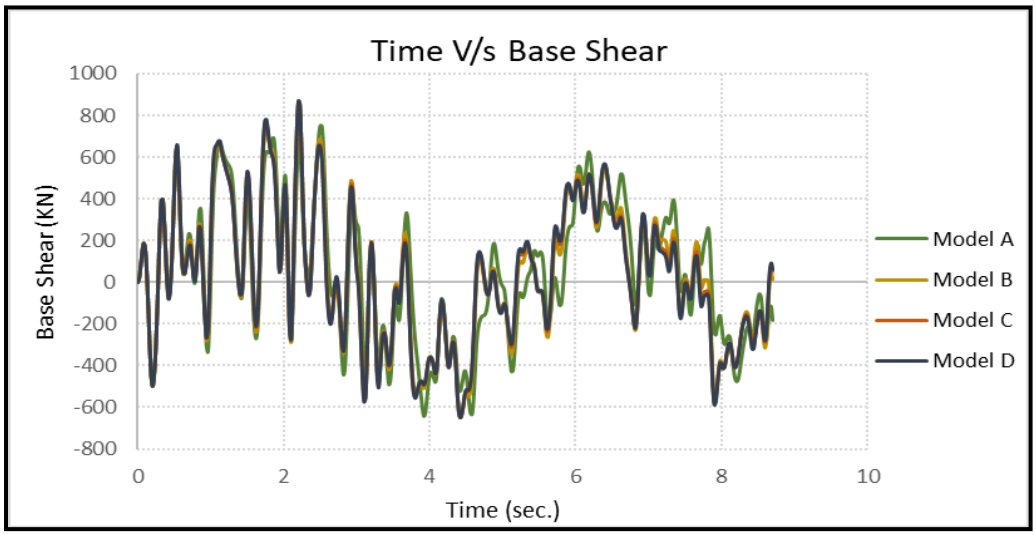

Figure 4.7 Time periods (sec.) v/s Base shear (KN) in X-direction of Kosani

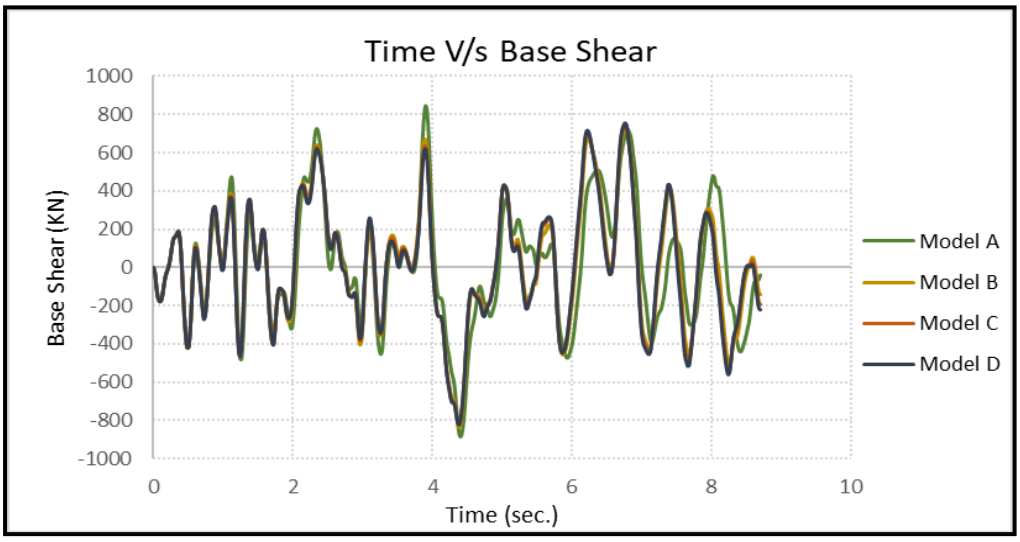

Figure 4.8 Time periods (sec.) v/s Base shear (KN) in X-direction of Koti

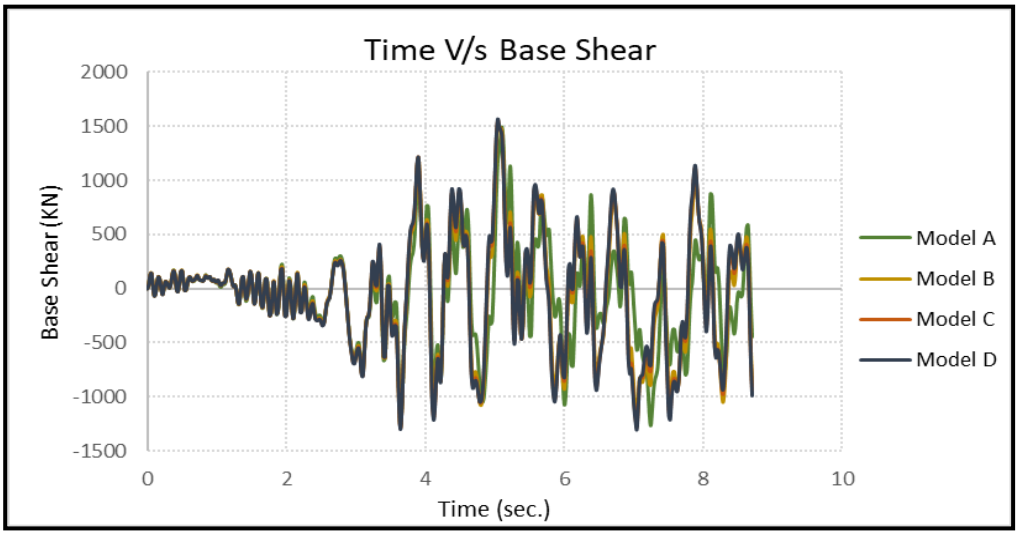

Figure 4.9 Time periods (sec.) v/s Base shear (KN) in X-direction of Rudraprayag

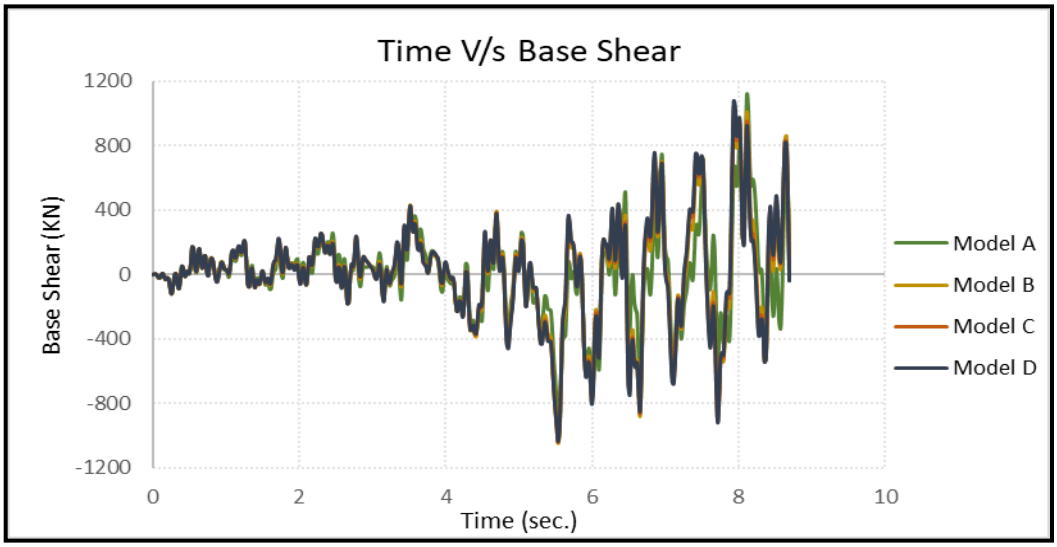

Figure 4.10 Time periods (sec.) v/s Base shear (KN) in X-direction of Srinagar

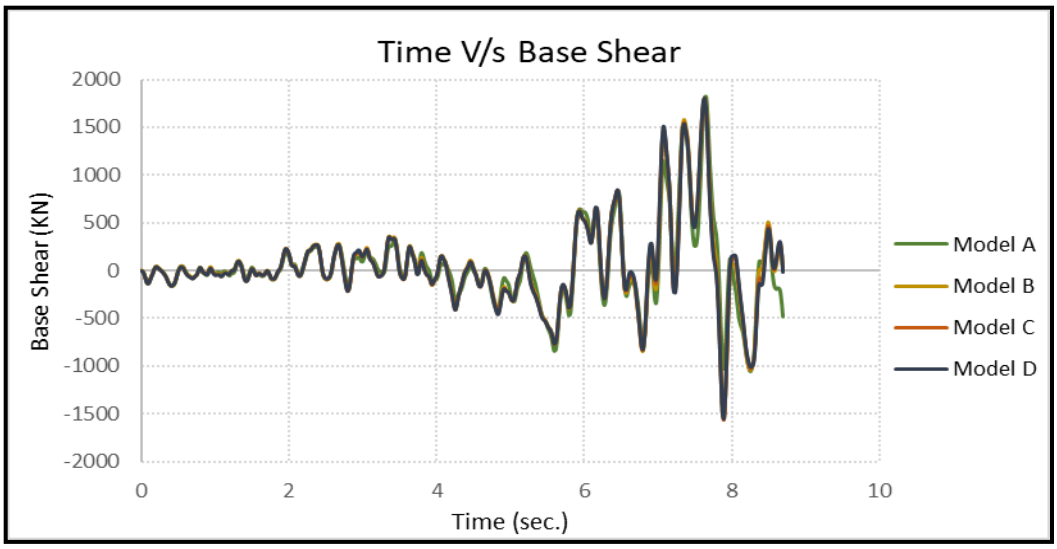

Figure 4.11 Time periods (sec.) v/s Base shear (KN) in X-direction of Tehri

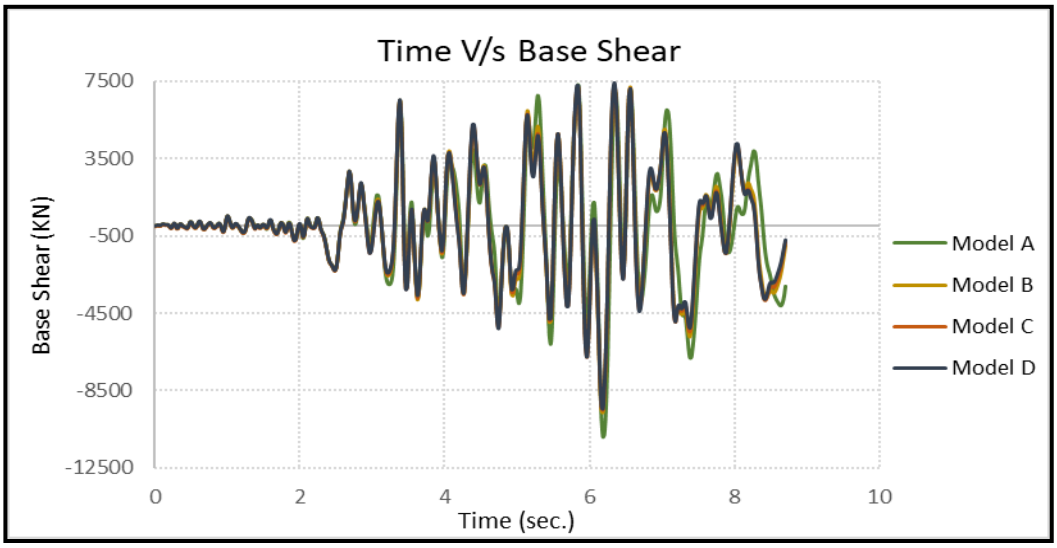

Figure 4.12 Time periods (sec.) v/s Base shear (KN) in X-direction Uttarkashi

After analysis, the value of maximum base shear was compared in Table 5.9 for all the time history stations. It was found that among all the time history station the Uttarkashi have maximum base shear value as 7389.56 KN in Model D and minimum was observed 844.7797 KN in Model A corresponds to Koti.

V. Conclusion

Conclusion drawn from the study are as follows:

1. The stiffness and stability increase on using outrigger structural system against the seismic load. There is reduction in lateral displacement and storey drift on seismic load in both directions.
2. By increase in depth of outrigger beam, stiffness of outrigger beam in increased thus result to decrease in value of non-dimensional parameter β.
3. Non-dimensional parameter having contribution in reduction of lateral displacement of structure.
4. Storey drift ratio was reduced when outrigger was introduced in structural system.
5. Base shear of structure depends on time history acceleration, base shear of structure varies depend on configuration of structural element, stiffness of lateral earthquake resisting elements and seismic mass of structure.

6. Time period of structural model depend on stiffness and seismic mass of structure. Time period increase as stiffness increase at constant seismic mass of structure and decrease with increase in seismic mass at constant stiffness.
7. In case of Almora, Joshimath, Kosani and Koti showing the lateral displacement nearly same but in case of Rudraprayag showing higher lateral displacement value in model A. As Rudraprayag PGA value is 0.56 g and Almora, Joshimath, Kosani and Koti PGA value varies 0.02g to 0.28 g.
8. As per Base shear result comparison, Uttarkashi shows maximum base shear in model having outrigger beam depth of two storey.

References

1. Abeena Mol N M, Rose Mol K George "Performance of Different Outrigger Structural Systems". International Research Journal of Engineering and Technology, Volume: 03, Issue: 09, Sep-2016.
2. Alok Rathore, Dr. Savita Maru "A Performance Based Analysis of Outrigger Structural System for Vertical Irregular Tall Building". International journal of trends in engineering and research, Volume 4, Issue 12, December 2017.
3. Anju Akbar, Sadic Azeez "Effect of Outrigger System in Multi Storied Irregular Building". International Journal of Modern Trends in Engineering & Research, Volume 03, Issue 07, July– 2016.
4. Bishal Sapkota, Surumi R.S, Jeyashree T.M "Comparative Study on Seismic Performance of High-Rise Building with Energy Dissipation and Outrigger Belt Truss System". International Journal of Civil Engineering and Technology, Volume 8, Issue 4, April 2017.
5. C. Bhargav Krishna, V. Rangarao "Comparative Study of Usage of Outrigger and Belt Truss System for High-Rise Concrete Buildings". International Journal of Recent Technology and Engineering, Volume-7, Issue-6C2, April 2019.
6. Chetan Patel Y G, Kiran Kuldeep K N "The Study on Behaviour of Outriggers for Tall Buildings Subjected to Lateral Load". International research journal of engineering and technology, Volume 04, Issue 07, July 2017.
7. Daril John Prasad, Srinidhilakshmish Kumar "Comparison of Seismic Performance of Outrigger and Belt Truss System in A RCC Building with Vertical Irregularity". International Journal of Research in Engineering and Technology, Volume: 05, Issue: 20, Nov-2016.
8. IqraBano Ayaz Ahmad Khan, Prof. N. G. Gore "Effect of Outrigger Structural System on High-Rise Structures, Subjected to Lateral Loads" IOSR Journal of Mechanical and Civil Engineering, Volume 15, Issue 6, Nov. - Dec. 2018.
9. Kasi Venkatesh, B.Ajitha "Behaviour of a Building with Outrigger Structure". National Institute of Technical Teachers Training & Research. May 2017.
10. Komal Jain. J, Mr. G. Senthil Kumar "An Analytical Study on Outrigger Structure Using Non- Linear Dynamic Time History Analysis". International Research Journal of Engineering and Technology, Volume: 03, Issue: 04, Apr-2016.
11. Krutagn Patel, Prof.Vishalkumar Patel, Dr. SnehalMevada "Design and Analysis of Core and Outrigger Structural System". International Research Journal of Engineering and Technology. Volume 7, Issue: 06, June 2020.
12. KushagraAshara, Keval Patel, Abbas Jamani "Comparative Study on Performance of RC Building with Outrigger System Incorporating Buckling Restrained Bracings". International Research Journal of Engineering and Technology, Volume: 07, Issue: 06, June 2020.
13. Mohd. Imran Mohd. Azahar, Hemant B. Dahake "Effective Position of Shear Walls and Braces as an Outrigger Systems in Tall Building". International Journal of Scientific Development and Research, Volume 4, Issue 5, May 2019.
14. Mr. Raeed Aslam Bhatkar, Prof. Narayan Gorakh Gore "Comparative Study of the Two Most Effective & Popular Structural System Viz. Outrigger and Diagrid Structural System". International Research Journal of Engineering and Technology, Volume 06, Issue 07, July 2019.