*IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)*
*e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 19, Issue 2 Ser. III (Mar. – Apr. 2022), PP 28-36*
*www.iosrjournals.org*

# Dynamic Analysis of Outrigger Systems in High Rise Building against Lateral Loading

Vandana Kushwaha[1], Neeti Mishra[2]
*[1]M.Tech 2nd Year (SE), Babu Banarasi Das University*
*[2]Assistant Professor, Department Of Civil Engineering*
*Babu Banarasi Das University*

***Abstract***
*In this research dynamic analysis of outrigger system was carried out for a 60-storey building having an overall height of 180 m. First of all, comparison of performance between single and multi-outrigger was drawn, then analysis was carried out on different outriggers such as X, V, Inverted V and shear wall. Outriggers were placed according to Taranto theory i.e. (1/n+1), (2/n+1), (3/n+1), (4/n+1) … (n/n+1) of height [30]. Frame with only shear wall core and other outrigger models were analysed in ETABS software and different parameters as Maximum Story Displacement, Maximum Story Drift and Story Shears was compared. By analysing all the models by dynamic analysis for Earthquake Load (Response Spectrum) and static analysis for Wind Load it was concluded that structure becomes more resistive to lateral load with increase in no. of outriggers. Between X, V and inverted V type steel outrigger, inverted V is most effective but when shear wall was used as an outrigger, it gave better results than steel outriggers. Also belt trusses or shear bands increases the effect of outriggers even more.*

***Keywords:*** *Outrigger System, ETABS, Dynamic Analysis, Static Analysis, Lateral Load*

---

Date of Submission: 25-03-2022 Date of Acceptance: 05-04-2022

---

## I. Introduction

From the early days of the human civilization migration has been a common part of day-to-day life. Early people travelled thousands of miles in search of food, water and safety. In the modern era people still migrate from one place to other for better job opportunities and lifestyle. As we know big cities and metropolis provides a great deal of life to human these days hence a lot of people are attracted toward the big cities. Due to which the population of these cities are raising ten folds. Supporting a large amount of population in a limited area of land has been a challenge to the society. Different types of land utilization techniques were evolved in the past years, one of these techniques is high rise buildings. High rise building is best land utilization technique in present time it can save a lot of land as the plan of high-rise buildings are very less as compare to the elevation.

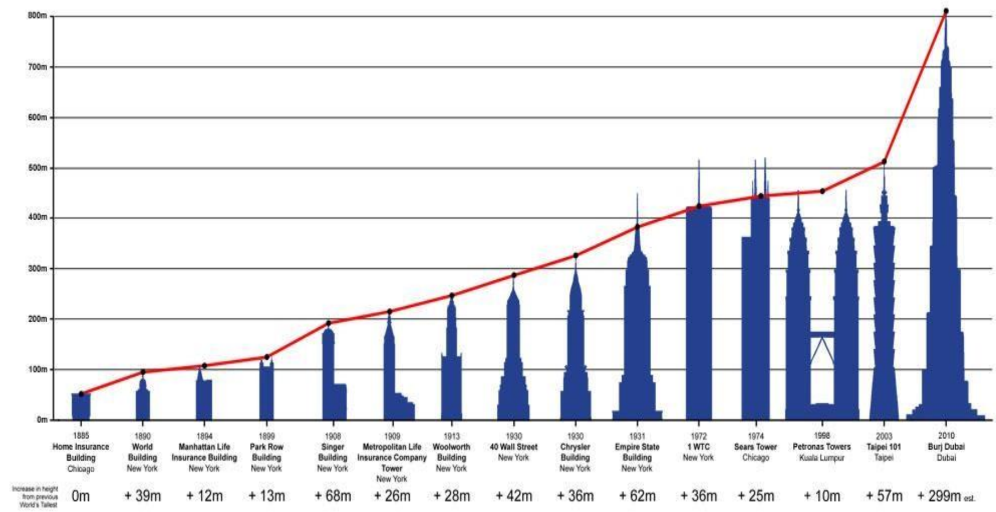


**Figure:1** History of High-Rise Buildings
Source: www.ctbuh.org

With less plan area and more elevation, it has no limitations in vertical direction till sky. A high-rise building is a building having height more than 35 meters. High rise buildings that are taller than 150m are termed as “skyscrapers”, buildings taller than 300m are termed as “Supertall” and buildings taller than 600m are termed as “Megamall”.

But with great advantages there are some great challenges which are faced by engineer daily to make these buildings into reality. One of these challenges is lateral forces i.e., earthquake and wind forces. High rise building consists of a large elevation area than plan which makes them easy target for lateral forces. Hence, they are very venerable to earthquake and wind loads on regular basis. Hence to make high rise buildings safe against lateral loads different types of structural systems are used.

**Description of the model**

In this research a 60-storey building was considered having 3 m of storey height. Plan dimension was of 38 × 38 m with five bays of 8 × 6 × 10 × 6 × 8 m in both directions. Total height of the building was 180 m. M30 grade of concrete and Fe345 steel was used in different members of structures. Size of the column was taken as 0.8 × 0.8 m and beam of size 0.5 × 0.8 m and for the outrigger beams ISMB250 was used. Slab thickness was kept 0.2 m. Vertical and horizontal loads were calculated as per recommendations of IS 456 [10], IS1893 (Part1) [9] and IS-875 (Part 3) [14]. First of all, comparison of performance between single and multi-outrigger was drawn, then analysis was carried out on different outriggers such as X, V, Inverted V and shear wall. ETABS software was used for modelling and analysis purpose, two type of analysis was done i.e., Response Spectrum and Static Wind Analysis.

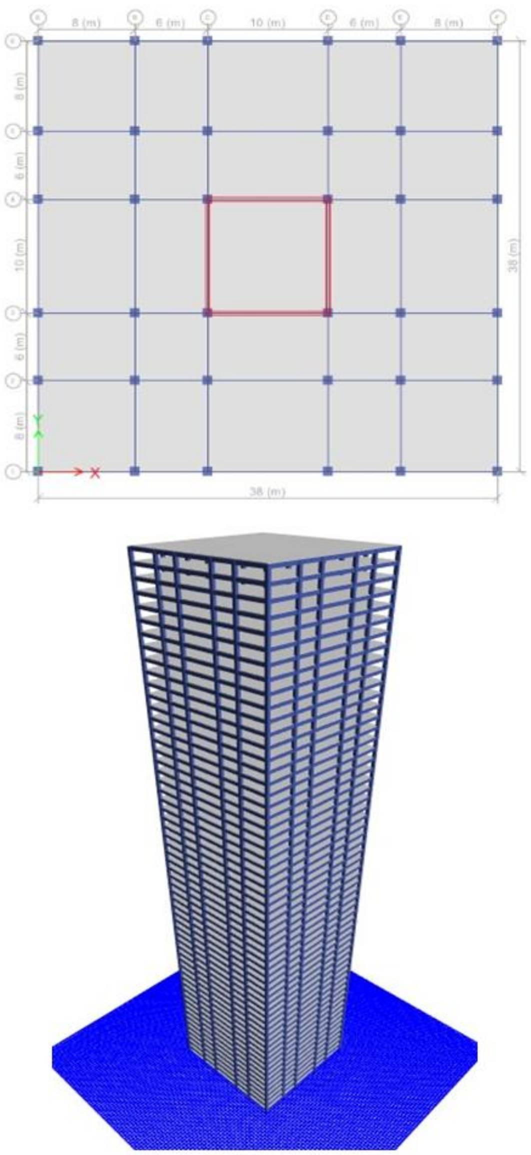


**Figure: 2** Plan and Elevation of the Model

**Table: 1** Model Data

| Sr. No. | Title | Details |
|---|---|---|
| 1. | **Type of Structure** | RC frame with Steel Outrigger Bracing |
| 2. | **Grid Data** | Plan regular - Rectangle geometric shape |
| | Grid Spacing | X and Y direction - 8 x 6 x 10 x 6 x 8 m |
| | Total Dimension | 38m x 38m Base dimension |
| | Storey Height | Uniform – 3 m |
| | No. of Stories | 60 |
| 3. | **Material Properties** | **Standard Values input in N-mm** |
| | Grade of Structural Steel | FE 345 |
| | Grade of Concrete Deck | M30 |
| 4. | **Frame Section Properties** | |
| | Column | RC 0.8 x 0.8 m |
| | Beams | RC 0.5 x 0.8 m |
| | Outrigger | ISMB250 |
| | Slab | 0.2 m |
| 5. | **Static Loads** | **$kN/m^2$** |
| | Self-weight | Considered |
| | Dead load (DL) | 1 |
| | Live load (LL) | 3 |
| | Masonry load (kN/m) | Considered |
| 6. | **Seismic Data** | **Values as per IS 1893** |
| | Response Reduction Factor (R) | 5 |
| | Importance Factor (I) | 1.5 |
| | Zone(z) | 0.36 (V) |
| | Soil type | II |
| 7. | **Type of Analysis** | |
| | Dynamic Analysis | Response spectrum |
| | Static analysis | Wind analysis |

## II. Literature Review

Outrigger is a very old concept but still a lot of things in it are not very clear, this chapter consists of some past researches on outriggers by different authors.

**Akbar A. et al. (2016):** In this paper 40 storey cored shear wall irregular building was analysed with the help of ETABS software. ISMB150 was used for outriggers and belt truss, size of which was 0.2 x 0.6 m for beam and 0.75 x 0.75 m for column. Storey height was kept constant at 3 m. Outriggers were placed at top, bottom and ¾ height of the building [1]. It was found that the lateral displacement and storey drift values was lowered with the use of outriggers in the structure. Also, the value of overturning and storey storey shear was reduced which increases the stiffness and stability of the building.

**Bayati Z. et al. (2008):** In this study an 80-storey steel framed building was investigated for the performance of belt trusses as virtual outriggers comparison was drawn between conventional and virtual outriggers systems in ETABS software. Building consists of a storey height of 4m and has three, four storied deep outriggers at floors 77 to 73, 46 to 50, and 21 to 25 storeys. The plan of the building was 45 x 45 m with a central core of 15 x 15 m. 3 bays of each 15 m were there in both directions. It was found that structure without outriggers have a displacement of 2.75 m, by using belt trusses as virtual outrigger displacement was reduced to 0.95 m and displacement in structure with conventional outrigger was 0.7 m. then structure with belt truss as virtual outrigger was again analysed with increasing the stiffness 10 times with this displacement was reduced to 0.8 m and when in addiction the belt truss size was increased by 10 times the displacement further reduced to 0.65 m with these conclusion effectiveness of virtual outrigger was found.

**Chen Y. et al. (2018):** In this study multi objective genetic algorithm (MGA) was used on a mathematical model of outrigger braced structure and practical model to get an optimum solution. MATLAB software was used to determine optimum number and optimum location of outriggers against wind load. It was found that MGA provide great advantages to the designer as it become easy to get the optimum location as well as optimum numbers of outriggers in the structure.

**Taholah A. et al. (2012):** In this study two steel framed models having 20 and 25 storeys with outriggers and belt truss were analysed. The storey height was kept constant at 3.2m throughout the building. Frame space was 5 m in x direction and 5.5 m in y direction also Xshaped bracing was used. SAP2000 was used for two types of analysis i.e., response spectrum and time history analysis. It was found that the optimum location of outrigger according to response spectrum was 10 and 14 storeys for 20 and 25 storey models respectively and in case of time history it was 14 and 16 storeys for 20 and 25 storey models respectively.

**Hasan R. (2016):** In this study a 30-storey building was analysed in ETABS with beam and wall outriggers. Three types of models were analysed, first one without outrigger, second with beam outrigger and belt truss and last one with wall outrigger and belt wall. Position of outrigger was obtained by Taranto theory i.e. (1/n+1), (2/n+1), (3/n+1), (4/n+1) … (n/n+1) of height. With this conclusion was drawn that the wall outrigger behaves better than beam outrigger to lower the value of displacement and drift of the building.

**Herath N. et al. (2009):** In this study a 50-storey building was analysed to find the optimum location of outriggers. Storey height of building was kept 3.75 m. Size of the outer column was 2 x 1.2 m, beam of 0.45 x 1 m, shear wall thickness of 0.45 m and outrigger beam of 0.25 x 3.75 m. STRAND7 and SpaceGass frame analysis package was used for modelling and analysis purpose. Firstly, one outrigger was used than for 2nd outrigger location 1st outrigger was fixed at top and 2nd outrigger was varied under earthquake action. Response spectrum analysis was conducted and it was found that optimum location for outrigger is 0.44 to 0.48 of height of the structure form bottom.

## III. Research Methodology

Research mythology is techniques for finding problem, selection, processing and analysing information about a given problem.

### 3.1 Research Process

Research process is a group of different activities which are interrelated to find a proper solution for a research problem. There are steps in research process which are given as

**i) Identifying research problem:** First of all, a researcher selects a topic of his interest, or sometime a trending topic that will benefit some institute or identity for some extent. Then the research title and statements are found that makes the whole after process easier, after the research problem have been found it is discussed with teachers and friends.

Research problem should be practical, ethical and have relative importance.

**ii) Literature review:** After the problem has been found literature review is carried out. Literature is mainly of the selected topic but sometime it can be of a problem as a whole e.g., to study a specific structural member, researcher must have a knowledge of structural frame. To study the literature thoroughly different journals, books and reports are very important and can be found on suitable: places.

**iii) Making hypothesis:** Making hypothesis is a technical work. Hypothesis is made to find out the advantages and disadvantages and effects of the research topic. Hypothesis helps to make researcher on the correct path for finding the solution of that particular problem.

**iv) Research design:** Research design is mainly the whole structure of the problem in which the research will take place. Research design helps researcher to find the necessary data with less efforts and more accuracy. A good research design is one which has fewer problems for researchers and gives accuracy in data collected and data analysed.

**v) Sampling:** Sampling is the process of taking the testers from a whole area. Sample is generally of two types Probability sampling and Non probability sampling

**vi) Data collection:** Data collection is also an important job for the researchers. Data collection is a fact-based process and should be in a symmetric order. There are two types of data collection. Primary data collection which involves experiments, questionnaires, observations and interview and in secondary data collection literature, reports and books are used

**vii) Data analysis:** After the collection of the data, data analysis takes place. This step mainly depends upon the objective of the study and data collected. Also, data analysis can be qualitative or quantitative.

**viii) Testing of hypothesis:** After the above steps testing of hypothesis is carried out. In this it is checked as either the facts are true or false. Various tests are used for this purpose as chi square test, t test, f test which are based on statistics. One or more tests can be used to test the hypothesis and it is found that either hypothesis is accepted or rejected. If there is no hypothesis then facts or previous knowledge can be stated as hypothesis. **ix) Generalizations and Interpretation:** When hypothesis testing is done then the researcher finds a generalization of his work, it is completely based upon the researcher if there is no hypothesis what so ever than previous facts are taken as hypothesis this is then known as interpretation. Interpretation sometimes leads to new questions and hence new scopes for future studies.

**Model Analysis**
ETABS software was used for the modelling and analysis, where two types of analysis were carried out static and dynamic analysis for earthquake zone V i.e., Response Spectrum Analysis and Static Wind Analysis. Analysis was carried out for Frame with shear wall core structure, frame with x, v, inverted v and shear wall outrigger w and w/o belt truss/ shear band. Results were studied on the basis of different parameters such as max storey displacement, story drift and max story shears.

**Methods of analysis**
In this research two methods of analysis are used one is response spectrum method and other is static wind analysis. For this purpose, different assumptions were taken in case of outriggers as

i) Core and outriggers have a rigid connection.
ii) Core and foundation have a rigid connection.
iii) Sectional properties of different members such as shear wall, beam column is constant throughout the height of the building.
iv) Material is behaving as linearly elastic.
v) Outrigger generated only axial forces in the columns.
vi) The rotation in the core generated by shear deformation is considered as negligible

**Response Spectrum Method**
This is a linear dynamic analysis for earthquakes, the different values for the analysis purpose are already available in ETABS and some of them are provided by Indian Standards.

**Natural Time Period**
Natural time period is the time taken to complete the one cycle at a given point. According to clause 7.6.2. of IS 1893:2002 (Part 1) it can be calculated as

$$T_a = 0.075\, H^{0.75}$$

Where H = Height of the building
Buildings with outriggers show less natural time period than buildings without outriggers

**Lateral Story Displacement**
Lateral story displacement is the lateral movement of the stories from its original position according IS 456:2000 its value can be calculated as

$$D = \frac{H}{500}$$

Where H = Height of the building
This equation shows the maximum value of lateral displacement that can be allowed in a building.

**Seismic Base Shear**
Base shear is the maximum lateral force that is induced at the base of the structure in case of earthquake motion. It is a very important factor for designing earthquake resistant buildings.
Static base shear is taken as design base shear because it is always more than dynamic base shear. Hence static Base shear can be calculated according to the IS 1893:2002 (Part 1) as

$$V_b = A_h \times W$$

Where
$V_b$= Static Base Shear
$A_h$= Horizontal seismic coefficient
$W$= Weight of the building
The design horizontal seismic coefficient can be found by the equation

$$A_h = \frac{Z\, I\, S_g}{2\, R\, g}$$

For any structure with $T \leq 0.1$s, the value of $A_h$will not be taken less than $\frac{Z}{2}$ whatever be the value of $\frac{I}{R}$
Where
$Z$ = Zone Factor, according to Code, for Zone V its value is 0.36
$I$ = Importance factor, its value is taken as 1.5
$R$ = Response reduction factor, taken as 5
$\frac{S_g}{g}$ = Average coefficient acceleration coefficient

The distribution of the base shear through the height of the building can be shown by the equation

$$Q_i \quad = \quad V_B \ \frac{W_i h_i^2}{\sum_{j=1}^{n} W_j h_j^2}$$

Where
$Q_i$ = Design lateral force at floor $i$
$V_B$ = Base shear
$W_i$ = Seismic weight of floor $i$ $h_i$ = Height of floor $i$ from base.
$n$ = Number of storeys in the structure at which the masses are located.

**Static Wind Analysis**

Static wind analysis was carried by ETABS with the IS codes recommendations. From IS 875:1987 (Part 3) clause 5.3, the design wind speed at a height for any building can be calculated as

$$Vz = Vbk1k2k3$$

Where
$V_z$ – Design wind speed at any height z in m/sec,
$k_1$ – Risk coefficient (or probability factor), $k_2$ – Terrain, height and structure size factor, $k_3$ – Topography factor.
From clause 5.4 of IS 875:1987 (Part 3), the wind pressure at any height from the ground level can be calculated as

$$p_z = 0.6\, V_z^2$$

Where
$p_z$ – Design wind pressure at any height z in N/mm$^2$, $V_z$ – Design wind velocity at height z in m/s.
From clause 6.3 of IS 875:1987 (Part 3), the total wind load on a building as a whole can be calculated as

$$F = C_f\, A_e p_d$$

Where
$F$ – The force acting on a building,
$C_f$ – Force coefficient for the building.
For this research the building was assumed to be structure of class B. Basic wind speed, $V_b$ = 50 m/sec $k_1$ = 1.08 $k_3$ = 1
Terrain Category = 3
Class of Structure = B
Windward coefficient, $C_p$ = 0.8
Leeward Coefficient, $C_p$ = 0.5
Windward and Leeward coefficient values are adopted from the Table 3 of IS 875:1987 (Part 3).

## IV. Results and Discussion

### Results for Earthquake load

**Table: 1** Maximum Story Displacement variation using one Outrigger

| Type of Outrigger | Maximum Story Displacement (mm) | |
|---|---|---|
| | w/o Belt | w Belt |
| X | 392.06 | 390.27 |
| V | 391.83 | 389.66 |
| Inverted V | 391.68 | 389.44 |
| Shear Wall | 363.52 | 360.60 |

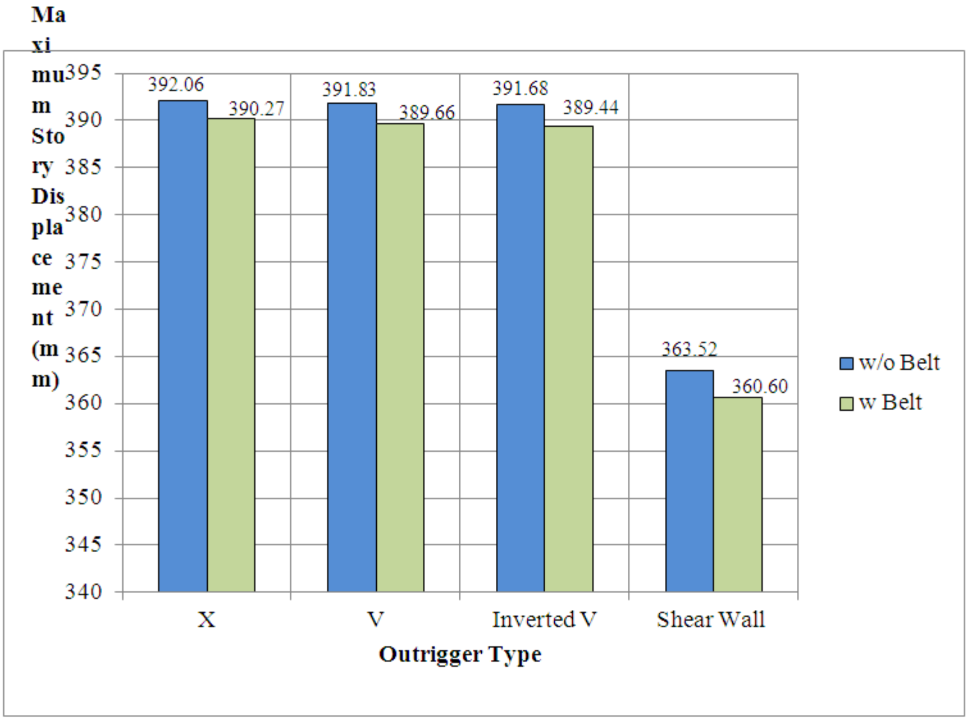


**Figure: 2** Maximum Story Displacement variation using one Outrigger

**2** Maximum Story Drift variation using one Outrigger

| Type of Outrigger | Maximum Story Drift | |
|---|---|---|
| | w/o Belt | w Belt |
| X | 0.002651 | 0.002634 |
| V | 0.002648 | 0.002628 |
| Inverted V | 0.002648 | 0.002628 |
| Shear Wall | 0.002447 | 0.002427 |
| | | |

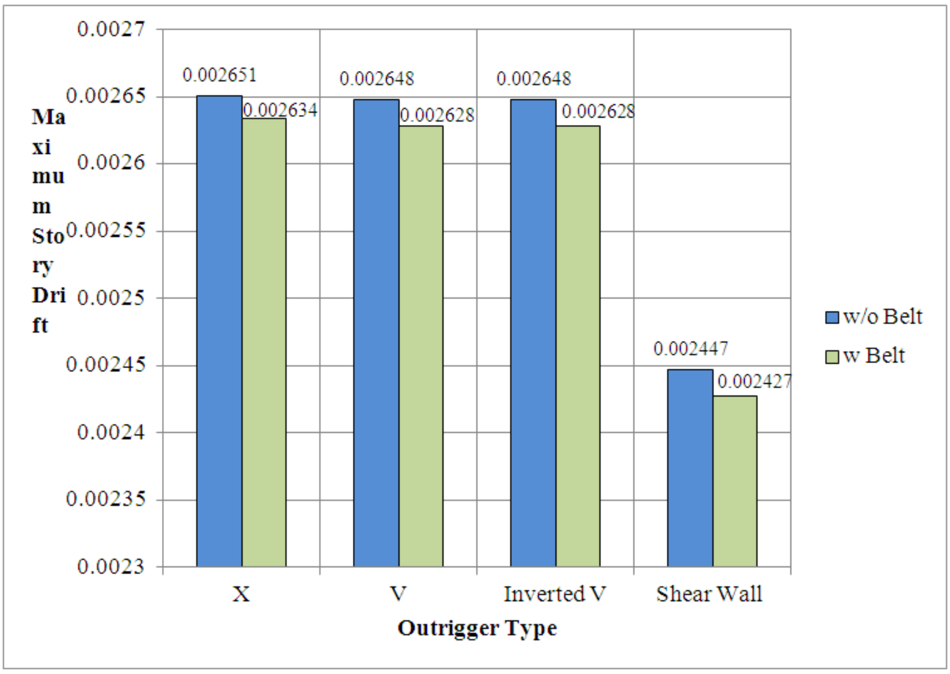


**Figure: 2** Maximum Story Drift variation using one Outrigger

## V. Conclusion

This study compares the behaviour of multi outriggers, effect of belt truss (shear band) on outriggers and effect of different bracings as outriggers. The results of parameters such as maximum story displacement, maximum story drift and story shears are drawn. Hence the conclusions are made as follows

With the increase in the no. of outriggers performance of the building also increases and use of belt trusses and shear band with outriggers is more effective than only outriggers. Between X, V and Inverted V type steel outrigger bracing beams, inverted V combined with 4 outriggers is most effective but shear walls are far better than steel bracings.

**Maximum Story Displacement conclusion**

For Earthquake Load Inverted V combined with 4 outriggers is most effective as maximum story displacement decreases by 14.43 mm (3.64%) without belt truss and 21.77 mm (5.5%) with belt truss. In case of shear wall outriggers, the displacement decreases by 87.34 mm (22.06%) without shear band and 98 mm (24.75%) with shear band.

For Wind Load Inverted V combined with 4 outriggers is most effective as maximum story displacement decreases by 11.04 mm (3.71%) without belt truss and 16.72 mm (5.61%) with belt truss. In case of shear wall outriggers, the displacement decreases by 68.29 mm (22.92%) without shear band and 79.22 mm (26.59%) with shear band.

**Maximum Story Drift conclusion**

For Earthquake Load Inverted V combined with 4 outriggers is most effective as maximum story displacement decreases by 3.48% without belt truss and 5.12% with belt truss. In case of shear wall outriggers, the displacement decreases by 19.87% without shear band and
22.14% with shear band.

For Wind Load Inverted V combined with 4 outriggers is most effective as maximum story displacement decreases by 3.95% without belt truss and 5.7% with belt truss. In case of shear wall outriggers, the displacement decreases by 22.89% without shear band and 26.14% with shear band.

**Story Shears conclusion**

For Earthquake Load Inverted V combined with 4 outriggers is most effective as Story Shears increases by 100 kN (0.38%) without belt truss and 157 kN (0.59%) with belt truss. In case of shear wall outriggers, the Story Shears increases by 1465 kN (5.49%) without shear band and 1895 kN (7.11%) with shear band.

For Wind Load Inverted V combined with 4 outriggers is most effective as Story Shears decreases by 54 kN (0.26%) without belt truss and 81 kN (0.39%) with belt truss. In case of shear wall outriggers, the Story Shears decreases by 333 kN (1.58%) without shear band and 363 kN (1.73%) with shear band.

It is observed that story shears increase in case of earthquake loads but decreases in case of wind load.

## References


[1]. Akbar, A., & Azeez, S. (2016). “EFFECT OF OUTRIGGER SYSTEM IN A MULTISTORIED IRREGULAR BUILDING,” 197–203.

[2]. Bayati, Z., M. Mahdikhani, and A. Rahaei. "Optimized use of multi-outriggers system to stiffen tall buildings." *The 14th World Conference on Earthquake Engineering, Beijing, China.* 2008.

[3]. Chen, Yue, and Zhenya Zhang. "Analysis of outrigger numbers and locations in outrigger braced structures using a multi objective genetic algorithm." *The Structural Design of Tall and Special Buildings 27.1* (2018).

[4]. Haghollahi, Abbas, Mohsen BesharatFerdous, and Mehdi Kasiri. "Optimization of outrigger locations in steel tall buildings subjected to earthquake loads." *The 15th World Conference on Earthquake Engineering*, LISBOA. 2012.

[5]. Hasan, R. A. A. J. Behavior Of beam and wall outrigger in high –rise building and their comparison.

[6]. Herath, N., et al. "Behaviour of outrigger beams in high rise buildings under earthquake loads." *Australian Earthquake Engineering Society Conference. 2009*.

[7]. Ho, G. W. M. (2016). The Evolution of Outrigger System in Tall Buildings. *International Journal of High-Rise Buildings*, *5*(1), 21–30.

[8]. https://doi.org/10.21022/IJHRB.2016.5.1.21

[9]. IS:16700-2016. “Criteria for Structural Safety of Tall Concrete Buildings.” New Delhi: *Bureau of Indian Standard*; 2016.

[10]. IS:1893 (Part 1)-2002.” Criteria for Earthquake Resistant Design of Structures Part 1 General Provisions and Buildings (Fifth Revision).” New Delhi: *Bureau of Indian Standard*; 2002.

[11]. IS:456-2000. “Plain and Reinforced Concrete – Code of practice (Fourth Revision).” New Delhi: *Bureau of Indian Standard*; 2000.

[12]. IS:800-2007. “General Construction in Steel – Code of Practice (Third Revision).” New Delhi: *Bureau of Indian Standard*; 2007.

[13]. IS:875 (Part 1)-1987. “Code of Practice for Design Loads (Other than Earthquake) for Buildings and Structures Part 1 Dead Loads – Unit weights of building materials and stored materials (Second Revision).” New Delhi: *Bureau of Indian Standard*; 1987.

[14]. IS:875 (Part 2)-1987. “Code of Practice for Design Loads (Other than Earthquake) for Buildings and Structures Part 2 Imposed Loads (Second Revision).” New Delhi: *Bureau of Indian Standard*; 1987.

[15]. IS:875 (Part 3)-1987. “Code of Practice for Design Loads (Other than Earthquake) for Buildings and Structures Part 3 Wind Loads (Second Revision).” New Delhi: *Bureau of Indian Standard*; 1987.

[16]. Jagadheeswari, A. S., and C. Freda Christy. "Optimum Position of Multi Outrigger Belt Truss in Tall Buildings Subjected to Earthquake and Wind Load." *International Journal of Earth Sciences and Engineering*, ISSN (2016): 0974-5904.

[17]. Jagadish, J. S., and Teja’s D. Doshi. "A Study on Bracing Systems on High Rise Steel Structures." *International Journal of Engineering Research and Technology 2.7 (2013):* 1672-1676.

[18]. Jayaram, N. "OPTIMUM POSITION OF OUTRIGGER SYSTEM FOR HIGH

[19]. RAISED RC BUILDINGS USING ETABS 2013.1. 5 (PUSH OVER ANALYSIS)."

[20]. Kamath, Kiran, N. Diva, and Asha U. Rao. "A study on static and dynamic behaviour of outrigger structural system for tall buildings." *Boning international journal of industrial Engineering and Management Science 2.4 (2012)*: 15.
[21]. Kiran Kamath, Avinashi AR, and K. Sandesh Upadhyay. "A Study on the performance of multi-outrigger structure subjected to seismic loads." *IOSR Journal of Mechanical and Civil Engineering e-ISSN (2013):* 2278-1684.
[22]. Kogilgeri, Srinivas Suresh, and Beryl Shanthapriya. "A study on behaviour of outrigger system on high rise steel structure by varying outrigger depth." *IJRET: International Journal of Research in Engineering and Technology 4.07 (2015)*: 434438.
[23]. Mistry, Krunal Z., and Dhruti J. Dhyani. "Optimum Outrigger Location In Outrigger Structural System For High Rise Building." *International Journal of Advance Engineering and Research Development (IJAERD) Volume 2* (2015).
[24]. Mulla, Abdul Karim, and B. N. Srinivas. "A study on outrigger system in a tall RC structure with steel bracing." *International Journal of Engineering Research & Technology (IJERT) Vol 4* (2015).
[25]. Nanduri, PMB Raj Kiran, B. Suresh, and MD Ihtesham Hussain. "Optimum position of outrigger system for high-rise reinforced concrete buildings under wind and earthquake loadings." *American Journal of Engineering Research 2.08 (2013).*
[26]. Patil, Dhanaraj M., and Keshav K. Sangle. "Seismic Behaviour of Outrigger Braced Systems in High Rise 2-D Steel Buildings." *Structures. Vol. 8*. Elsevier, 2016.
[27]. Safari Gorji, M., & Cheng, J. J. R. (2017). Steel plate shear walls with outriggers. Part
[28]. I: Plastic analysis and behavior. *Journal of Constructional Steel Research*, *134*, 148– 159. https://doi.org/10.1016/j.jcsr.2017.02.033
[29]. Shetty, Anitha Ganesh, and G. Narayan. "EVALUATION OF SEISMIC RESPONSE
[30]. OF STRUCTURAL SYSTEMS IN HIGH. RISE BUILDING WITH DIFFERENT
[31]. CONFIGARATION USING ETABS."
[32]. Shivacharan, K., et al. "Analysis of outrigger system for tall vertical irregularities structures subjected to lateral loads." *IJRET 4.05 (2015)*: 84-88.
[33]. Sukesh, H. S., Chandra, H. S. S., Lakshmi, P. S., Student, P. G., Engineering, C., Mandya, P. E. S. E., … Mandya, P. E. S. E. (2017). Influence of Outrigger system in RC Structures for Different Seismic Zones. *International Research Journal of Engineering and Technology (IRJET)*, *4*(6), 1749–1752. Retrieved from https://irjet.net/archives/V4/i6/IRJET-V4I6566.pdf
[34]. Sukhdev, Shruti B. "Optimum Position of Outrigger in G+ 40 RC Building." IJSTE-
[35]. *International Journal of Science Technology & Engineering 2.10 (2016)*: 1051-1055. 30. Taranto, Bungle S. "Reinforced concrete design of tall building." *CRC press*, 2009.

Vandana Kushwaha. "Dynamic Analysis of Outrigger Systems in High Rise Building against Lateral Loading". *IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)*, 19(2), 2022, pp. 28-36.