Optimum Location of Outrigger Structural System in Tall Vertical Irregular RC Building Subjected to Lateral Loads

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Abstract

The development of tall buildings has been rapidly increasing worldwide, introducing new challenges that need to be met through engineering judgment. One effective structural system used to control excessive drift due to lateral loads is the outrigger system. This system minimizes the risk of structural and non-structural damage during small or medium lateral loads caused by wind or earthquakes. Particularly for high-rise buildings in seismically active zones, the outrigger system is a suitable structural choice. This thesis employs ETABS 21.0.0 software to analyze the performance of vertical irregularities in outrigger structures through Response Spectrum Analysis. The objective of this study is to investigate the behavior of outriggers under lateral loads, optimize outrigger location, and evaluate the efficiency of each outrigger when outriggers are used at different story heights. 30-storey three-dimensional models, with and without outrigger and belt truss systems are used subjected to wind and earthquake loads. These models are analyzed and compared to determine the story drift, story displacement, and base shear reduction associated with different outrigger and belt truss system locations. The study includes a comprehensive analysis of story displacement, story drift, and base shear of the structure.
Keywords: E-tabs, Lateral loads, Story drift, Story displacement, Base shear.

1. Introduction

There has long been a competitive drive among humans to claim the title of having the tallest building in the world. This relentless pursuit of height has created remarkable opportunities within the building profession. The design of skyscrapers is predominantly influenced by the lateral loads imposed on the structure.There are various structural lateral systems used in the design of high-rise buildings, including shear frames, shear trusses, frames with shear cores, framed tubes, trussed tubes, and super frames. Among these, the outrigger and belt truss system are particularly effective for controlling building drift. This system connects the perimeter columns of the building to the central core using structural elements known as outriggers. These outriggers can be horizontal beams, trusses, or walls. Classified as interior structural systems, outriggers are highly efficient and can be effective for buildings up to 150 floors. This configuration is widely recognized for its success and stability in high-rise construction. The outrigger system is commonly employed as an effective structural solution for controlling lateral loads in buildings. When a structure is subjected to small or medium lateral forces, such as those from wind or earthquakes, the outrigger system helps prevent both structural and non-structural damage. Engineers can use this system to predict and mitigate the impact of these forces. This system is particularly beneficial for high-rise buildings located in earthquake-prone areas or regions with significant wind loads. It effectively reduces drift, lateral deflection, and base shear, enhancing the building's overall stability and performance Analysis of bare frame with outrigger system at to begin with optimum location and Analysis of Bare Frame with outrigger system for Second position keeping to begin with position common at 0.67. and the analysis of the trigger in outrigger systems under wind or seismic loading shown in Figure 1[1]
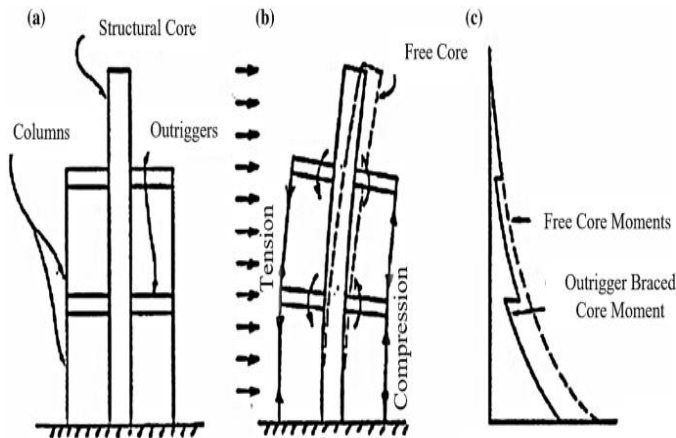
Figure 1   Outrigger Systems Under Wind or Seismic Loading

1.1. Vertical irregularities

I must apply an outrigger structural system in vertical irregular structure. Figure 2 shows the vertical irregularities. Some dissimilar categories of vertical irregularities are:
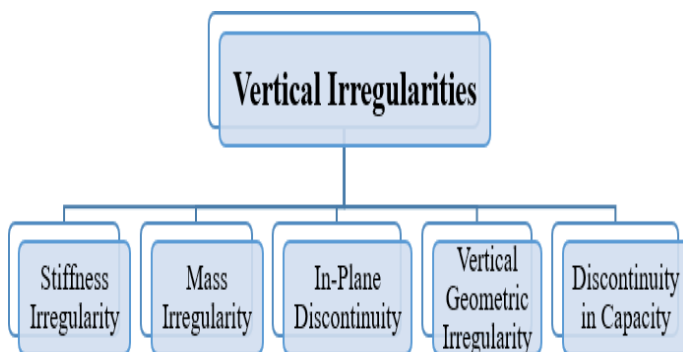

Figure 2 Vertical Irregularities

1.2. Objective of the Study

1) The primary objective of this study is to explore the implementation of core walls integrated with an outrigger and belt truss system. [2]
2) To study the performance of RC high rise building with and without outrigger structural system.
3) To analyze & evaluate performance of RC high rise buildings in terms of storey displacement, storey drift, base shear subjected to dynamic earthquake load.
4) To find out the best configuration of outrigger structural system at different location along height subjected to dynamic seismic load.

5) To determine the responses of Structures by varying positions of outriggers in high rise buildings. [3]
6) The location of outrigger and belt truss for reducing lateral displacement, building drift and base shear can be obtained.

2. Methodology

The finite element analysis program Etabs21 is used to form different models for investigation of response spectrum analysis and wind load calculated using IS 875 [p-3-2015]. The software can figure the geometric linear behavior of frames under static and dynamic loadings. Vertical irregular building comprises of G+29 story and numbers of demonstrate arranged at that point analysis using Response Spectrum Analysis in Etabs21. Analysis of bare frame without outrigger, Analysis of bare frame with outrigger system at to begin with optimum location and Analysis of Bare Frame with outrigger system for Second position keeping to begin with position common at 0.67. and to learn the software and to know the concept of Response Spectrum Analysis. Table 1 shows the details of model [4]

Table 1   Details of Model

Story	Description
1-10	7x7 Spacing
11-15	5x5 Spacing
21-30	3x3 Spacing

2.1   Seismic Parameters

- Earthquake Load: (1893(Part 1): 2016)
- Bhuj Zone V – 0.36
- Importance factor – 1
- Type of soil – Medium Soil
- Response Reduction Factor – 5
- Mass Source Definition
- Dead Load – 1
- Floor Finish- 1
- Live Load- 0.25

2.2 Section Properties

Table 2 Properties of Building

Building	G+29
Floor Height	3 m
Beam size	450 mm x 600mm
Slab thickness	150 mm
Shear wall thickness	300 mm
Column size [1st and 2nd storey] [3rd to 5th storey] [6th to 10th storey] [11th to 15thstorey] [16th to 30th storey]	900mm x 900mm 800mm x 800mm 750mm x 750mm 600mm x 600mm 550mm x 550mm
Outrigger properties	375mm x 375mm
Concrete grade	M40
Steel grade	Fe500
Floor finish load	2.5 KN/m^2
Live load	3 KN/m2
Wall load	5.8 KN/m

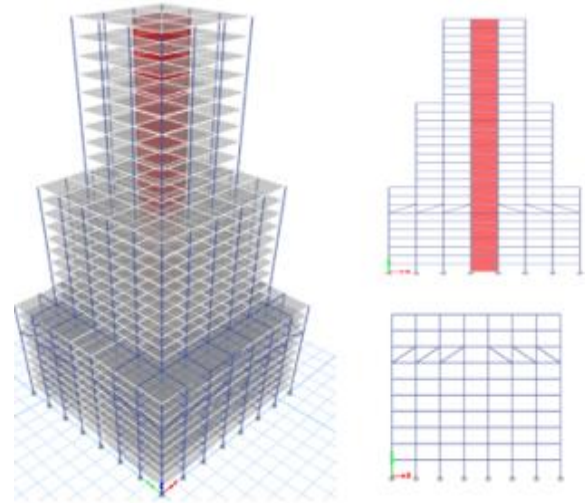**Figure 3 3d and Plan View of G+29 Story Bare Frame**

Figure 4 Elevation and 3d View of G+29 Story with Outrigger and Belt Truss
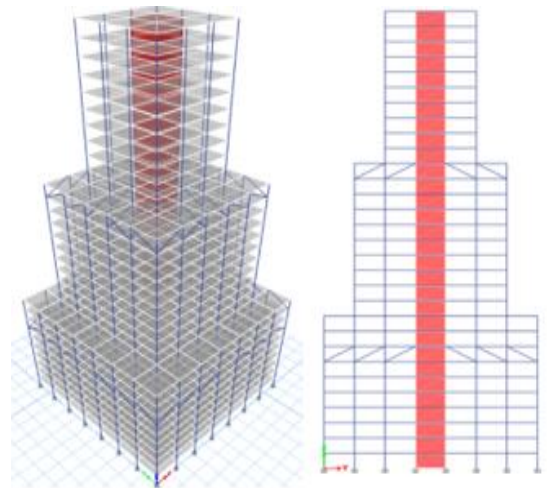
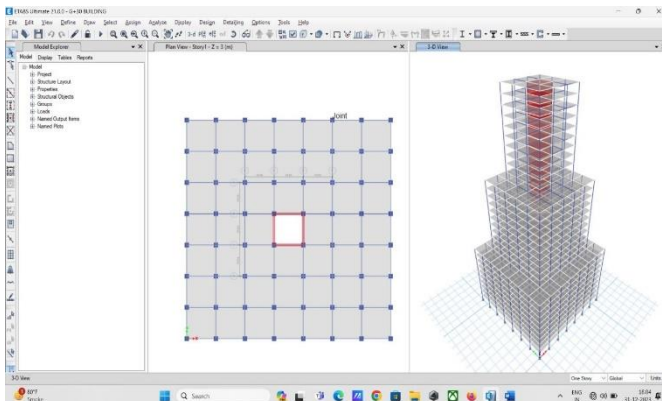**Figure 5 Elevation and 3d View of G+29 Story with Outrigger and Belt Truss at Two Position**

3. Results and Discussion

Three parameters are compared in this study. Mainly story drift, Story Displacement and Base shear are compared for all the models. [5] Figure to 11 shows Base Shear for Case1 and Case2, Base Shear for Case1 and Case3, Variation of displacement for models at optimum position of outrigger, Variation of displacement for models at two optimum positions of outrigger first at 0.67 Height, Storey drift for models at optimum position of outrigger, Storey drift for models at two optimum positions of outrigger First at 0.67 Height.

Case 1: Bare Frame Analysis and Design [9]

Case2: Analysis of Bare Frame with outrigger system for the first optimum location.

- Outrigger with Belt truss at 0.25 Position
- Outrigger with Belt truss at 0.33 Position
- Outrigger with Belt truss at 0.5 Position
- Outrigger with Belt truss at 0.67 Position
- Outrigger with Belt truss at 0.75 Position
- Outrigger with Belt truss at top Position
- **Case 3:** Analysis of Bare Frame with outrigger system for Second position keeping first position common at 0.67.
- Outrigger with Belt truss at 0.25 Position
- Outrigger with Belt truss at 0.33 Position
- Outrigger with Belt truss at 0.5 Position
- Outrigger with Belt truss at 0.75 Position
- Outrigger with Belt truss at top Position

Table 2 shows the properties of building, Figure 3 3d and plan view of G+29 story bare frame, Figure 4 shows the elevation and 3d view if G+29 story with outrigger and belt truss, Figure 5 elevation and 3d view of G+29 story with outrigger and belt truss at two position
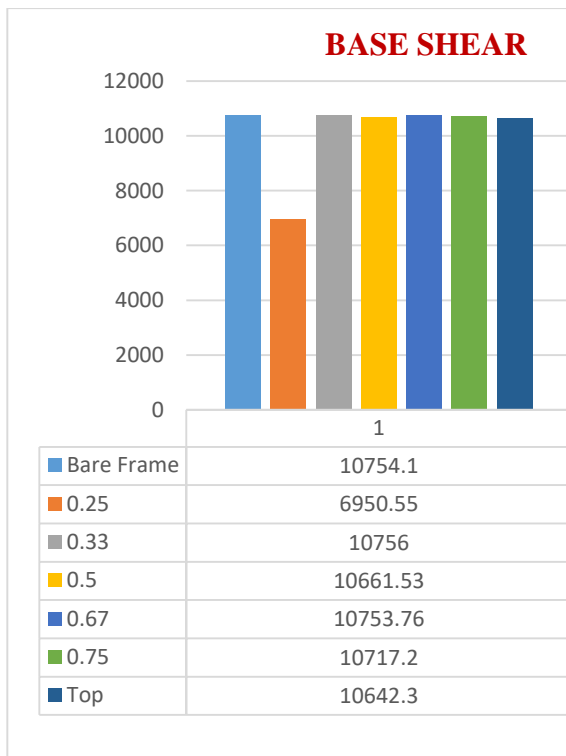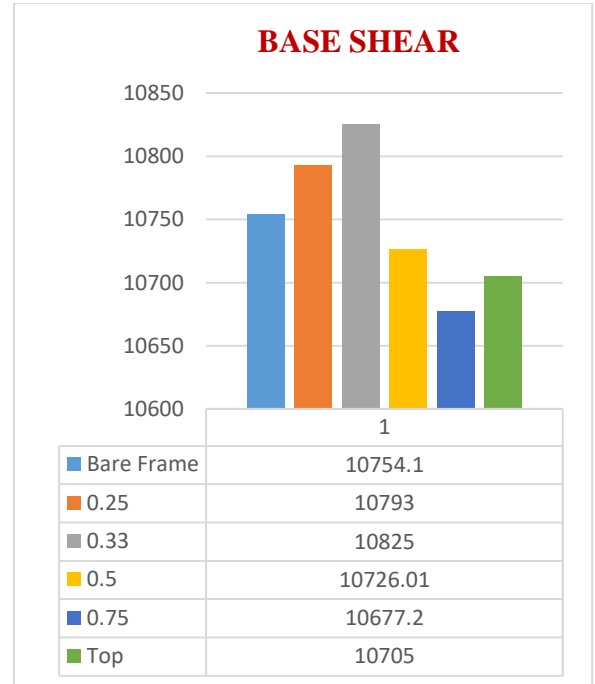
3.1 Base Shear

BASE SHEAR

	1
Bare Frame	10754.1
0.25	6950.55
0.33	10756
0.5	10661.53
0.67	10753.76
0.75	10717.2
Top	10642.3

Figure 6   Base Shear for Case1 and Case2

BASE SHEAR

	1
Bare Frame	10754.1
0.25	10793
0.33	10825
0.5	10726.01
0.75	10677.2
Top	10705

Figure 7   Base Shear for Case1 and Case3

3.2 Story Displacement

DEFLECTION

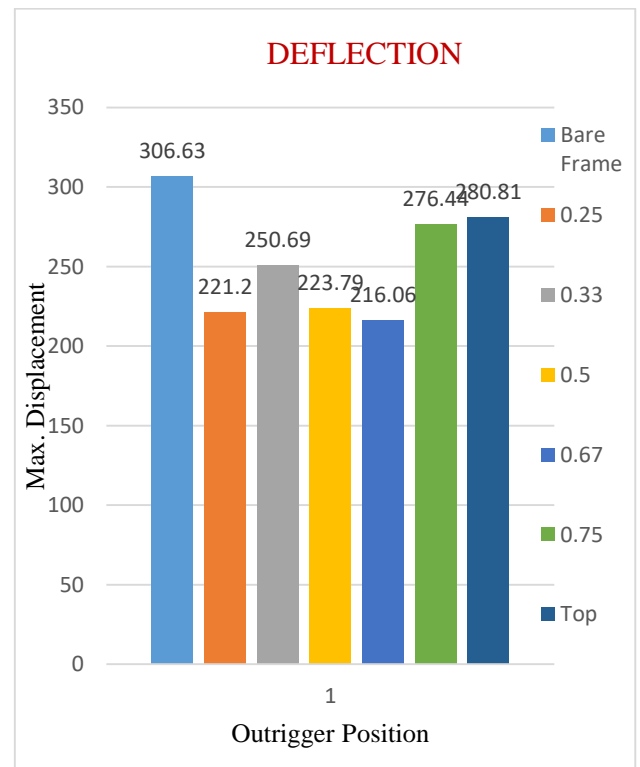306.63 221.2 250.69 223.79 216.06 276.44 280.81

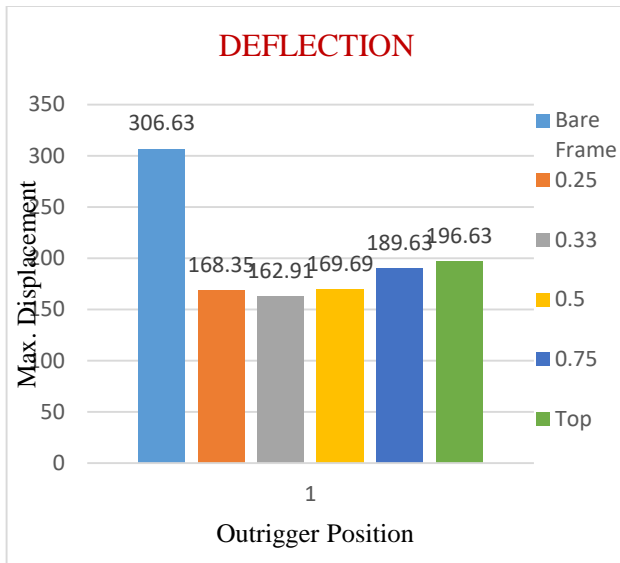**Figure 8   Variation of Displacement for Models at Optimum Position of Outrigger**

Figure 9   Variation of Displacement for Models at Two Optimum Positions of Outrigger First at 0.67 Height
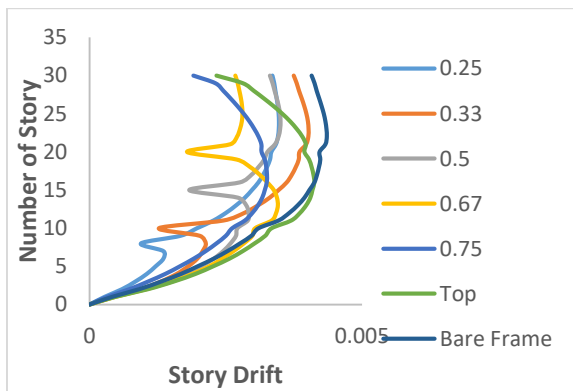
3.3 Story Drift

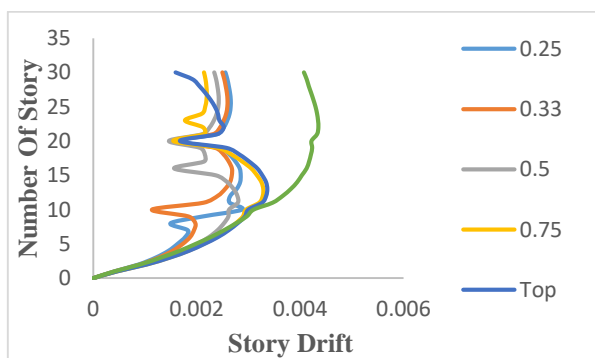**Figure 10 Storey Drift for Models at Optimum Position of Outrigger**

Figure 11 Storey Drift for Models at Two Optimum Positions of Outrigger First at 0.67 Height

Conclusion and Discussion

Throughout the analysis, the primary focus was on examining the drift and deflection of the building. Graphs 3.1, 3.2, 3.3, 3.4, 3.5 and 3.6 illustrate the variations in story drift and story displacement. [6] The study revealed several key findings. Implementing a single outrigger at 0.67 times the building height results in a reduction of story displacement and drift by 29.53% and 24.85%, respectively, when compared to a structure lacking outriggers. Installing an outrigger with a belt truss at heights of 0.67 and 0.33 times the building height achieves significantly better control, resulting in reductions of 46.87% in story displacement and 46.93% in drift compared to the bare frame. Comparing the effects of the first and [7] second outrigger positions within the building, decreases of 17.34% in story displacement and 22.05% in drift were observed. These findings highlight the effectiveness of outrigger systems, particularly when paired with belt trusses, in enhancing structural stability and reducing drift and displacement under lateral loads in tall buildings. The study concludes that integrating outrigger and belt truss systems in high-rise reinforced concrete (RC) buildings enhances structural stiffness and efficiency under lateral loads. This method effectively supports the stability and performance of tall buildings subjected to dynamic forces such as wind and seismic activity. [8] Therefore, choosing these systems is a viable strategy to optimize structural integrity and flexibility in high-rise construction. The maximum drift observed at the top of the structure when only the core is used amounts to approximately 306.63 mm. However, this drift can be significantly reduced by implementing an outrigger structural system. Specifically, placing an outrigger at 0.67 times the building height reduces the drift to 216.06 mm. This reduction highlights the effectiveness of outriggers in minimizing lateral movement and enhancing the overall stability of tall buildings under dynamic loads. Using a second outrigger at 0.67 times the building height results in reductions of 17.34% in story drift and 22.05% in displacement. The

optimal location for the second outrigger is at 0.33 times the building height. The optimal placement of an outrigger in a high-rise building is generally found to be between 0.33 and 0.5 times the building's height. [10]

References

[1]. Shivacharan K, Chandrakala S and Karthik N M (2015) "Optimum Position of Outrigger System for tall vertical irregularities" IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN: 2278-1684, p-ISSN: 2320-334X, Volume 12, Issue 2 Ver. II (Mar - Apr. 2015), PP 54-63 www.iosrjournals.org.

[2]. Reddy, S. P. S., & Ali, M. A. (2022). Analysis of vertically irregular R.C structure using outrigger system. International Journal of Health Sciences, 6(S2), 11029–11042. https://doi.org/10.53730/ijhs.v6nS2.7957

[3]. P.M.B. Raj Kiran Nanduri, B. Suresh, MD. Ihtesham Hussain (2013) "Optimum Position of Outrigger System for High-Rise Reinforced Concrete Buildings Under Wind and Earthquake Loadings" American Journal of Engineering Research (AJER) e-ISSN: 2320-0847 p-ISSN: 2320-0936 Volume-02, Issue-08, pp-76-89

[4]. Shivacharan k, Chandrakala S, Narayana G, Karthik N M (2015) "Analysis of outrigger system for tall vertical irregularities structures subjected to lateral loads" IJRET: International Journal of Research in Engineering and Technology eISSN: 2319-1163 | pISSN: 2321-7308

[5]. N. Herath, N. Haritos, T. Ngo & P. Mendis (2009) "Behaviour of Outrigger Beams in High rise Buildings under Earthquake Loads".

[6]. Nm, K., & Jayaramappa, N. Optimum Position of Outrigger System for High Raised Rc Buildings Using Etabs 2013.1. 5 (Push Over Analysis).

[7]. Shinde, B. H. Seismic Analysis of RCC Multistoried Building by IS 1893: 2016 and it's Comparison with IS 1893: 2002.

[8]. Bhandari, N. M., Krishna, P., Kumar, K., & Gupta, A. An Explanatory Handbook on IS 875 (Part3): 1987 Wind Loads on Buildings and Structures.

[9]. IS, B. (2000). Plain and reinforced concrete-code of practice.

[10]. IS: 875 (Part2) - 2015 Code of Practice for Design Loads (Other Than Earthquake) For Buildings and Structures (Imposed Loads)