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Study of High Rise Building with Outrigger System subjected to Transverse Loading

Mr. Rushikesh Rajendra Hedgire[1], Mr. R. R. Badeghar [2]

[1]*P.G. Student, Department of Civil Engineering, N.B. Navale Sinhgad College of Engineering, Solapur*
[2]*Assistant Professor, Department of Civil Engineering, N.B. Navale Sinhgad College of Engineering, Solapur*

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Abstract - Accumulation of growing population especially in developing countries has resulted in an increased height of buildings, this need creating impact on structural development of tall building. And hence tall building construction has been rapidly increasing worldwide. The development in concrete technology over the twentieth century covering materials, structural systems, analysis and construction techniques, made it possible to build concrete tall buildings. The primary function of a structure is achieved through the utilization of various structural systems. These systems include bracing systems, moment-resisting frames, and shear walls. When aiming to control the horizontal displacement of a structure, it is crucial to prioritize the lateral forces as the most significant factors. Over the years, a variety of mechanisms have been developed to resist lateral loads. The utilization of outrigger-belt truss systems is widespread globally due to their exceptional efficiency. The outrigger with belt truss is a structural solution that effectively regulates excessive deviation caused by lateral tension. The implementation of this solution will lead to an improvement in the performance of the building. It will effectively protect the building from potential damage caused by both seismic and atmospheric stresses, including both structural and non-structural harm. The current study utilized the Etabs 2018 software to simulate a multi-story R.C.C. building consisting of 40, 45, and 50 floors. The research on response spectrum is conducted specifically on structures that are situated in zone III. The Etabs 2018 software is designed to analyze building models and investigate the effects of various parameters. These parameters include maximal displacement, time period, base shear, storey shear, and base moments.

Key Words: Outrigger-belt truss system, tall building, Response spectrum analysis, Etabs software.

1.INTRODUCTION

An outrigger system is a horizontal component that resembles a deep beam. It is used to increase the rigidity and strength of a structure against overturning by connecting the building core or spine to the farthest or exteriormost columns and maintaining the columns in place. The lateral movement is reduced by implementing this solution. The utilization of core outrigger systems is a common practice in high-rise structures with a slender profile when the primary cause of the building's sideways movement is the overall bending deformation, such as story drifts, and the force causing the building to tip over exceeds the force causing it to shear. These core outrigger systems serve as the lateral load resisting systems in such cases. The utilization of outriggers is implemented to create a tension-compression pair in the perimeter columns in situations where the central core of a structure endeavors to tilt. The aforementioned process facilitates the reversion of the core to its initial position and augments its ability to resist overturning by amplifying its rigidity. The outrigger beams or cross bracing supports, which are attached to the external columns and shear wall, exhibit a certain level of complexity. However, it is widely acknowledged that the key factors that impact the performance of linked wall systems are the proper rigidity and strength of the outrigger beams. In order to minimize lateral deflection and inter-story drift, it is crucial to uphold a high level of overall rigidity in tall structures. The performance of the outrigger system is affected by the outrigger locations along the height of the building, the number of level of outriggers provided, their plan locations, presence of the belt trusses, outrigger truss depth and primary structural materials used in our study, braced core frame i.e. reinforced concrete shear wall core acting in conjunction with the concrete. belt truss and outrigger struts are provided which resist the earthquake loads by stiffening the whole structure.

2. LITERATURE REVIEW

Komal et. al. [1] The primary factors that contribute to the susceptibility of a high-rise structure's performance are storey displacement and storey drift. These two phenomena are primarily caused by seismic forces in regions with high seismic activity. Several methodologies have been employed to improve the efficiency of tall structures in various research projects. The utilization of core shear walls, bracing systems, dampers, and other comparable measures are encompassed by these methods. Although these methods can partially reduce storey displacement, the overall performance degradation of the building is ultimately limited by storey drift. The study project is utilizing the outrigger technique, which is considered outdated, to minimize the disturbance of the structure during seismic tremors. The reason for this is the presence of a constraint. The purpose of this investigation is to evaluate the performance of the cantilever structural system in high-rise structures located in seismic zones. This evaluation will be conducted by analyzing the existing literature on the subject. The performance of the structure is greatly impacted by the specific placement and depth of the outriggers. Additionally, studies have shown that the outrigger structural system and core system have the ability to effectively decrease storey drift to an acceptable level. However, it should be noted that these systems only provide partial mitigation of storey displacement.

Anju et. al. [2] The outrigger system effectively reduces the seismic reactivity of tall core-tube constructions by utilizing the axial rigidity of the perimeter columns. A damped-outrigger system has been proposed for the purpose of reducing seismic energy. This system involves integrating dampers into the outrigger mechanism. The objective of this study is to analyze and evaluate the seismic performance of a damped-outrigger system that incorporates a buckling-restrained brace (BRB-outrigger). The seismic response of the structure is significantly mitigated through the utilization of the buckling-restrained brace (BRB) and the outrigger effect, which effectively dissipate energy. This study proposes a methodology for evaluating the inelastic seismic response of structures equipped with multiple damped outriggers using a spectral analysis (SA) approach. The main goals of this study are to identify the most effective heights for placing outriggers in a structure that is equipped with BRB-outriggers. Additionally, the study aims to establish the relationships between the axial stiffness of the BRB, the axial stiffness of the perimeter column, and the flexural rigidity of the core structure. These correlations are important for minimizing the seismic response of the structure. Analytical models are utilized to conduct nonlinear response history analysis and spectral acceleration (SA) for structures with heights of 64 m, 128 m, 256 m, and 384 m. At the conclusion of this investigation, a design recommendation is provided for the purpose of initial design. This study aimed to assess the seismic behavior of structures equipped with multiple buckling-restrained brace (BRB) outrigger systems. The assessment was conducted using a simplified model and sensitivity analysis approach. The seismic response of the dual BRB-outrigger system can be reduced by analyzing the optimal relationships between the axial stiffness of the two BRBs, axial stiffness of the perimeter columns, flexural rigidity of the core structure, and the most effective outrigger heights.

Abeena et. al. [3] The structural efficiency of lofty structures is significantly influenced by their lateral rigidity and resistance capabilities. Outrigger systems are commonly used as structural systems in tall buildings, especially those with consistently designed floors. The utilization of outriggers in construction was first observed in the early 1950s, which coincided with the development of the concept of deep beams. As the height of a structure increases, deep beams undergo a transformation, leading to the construction of either concrete walls or, more recently, steel truss outriggers that have a minimum height of one story. The form and intended function of outriggers have been modified due to the increased variety of materials that can now be utilized in their construction. The analysis is closely connected to the design and construction challenges associated with the outriggers. The process of compression will inevitably impact the dimensions of both the central and outer components. This article presents a comprehensive analysis of the outrigger system, a structural component used in tall buildings. It covers the historical evolution of this system and explores its various applications in different contexts. In this section, we will present and discuss the outrigger concept, which is considered the most efficient arrangement, as well as the factors that need to be considered in its design and construction.

Sreelekshmi et. al. [4] The rise in the number of high-rise buildings in metropolitan areas can be attributed to the increasing demand for accommodation. The probability of oscillation in tall structures is heightened by the tendency towards slimmer constructions when they experience lateral forces. Shear walls are suitable for structures with a height of 20 stories. However, to reduce the impact of these pressures, it is essential to incorporate additional lateral load resisting devices in taller structures. The outrigger system is widely recognized as a highly efficient and popular system due to its resilient lateral rigidity, cost-effectiveness, and straightforward construction. The outrigger braced structure is a structural design known for its high efficiency in connecting the central core to the outside columns. The construction of these systems is designed to prevent tilting by creating a tension-compression pair in the surrounding columns when the central core rotates at the outrigger level. The data collected in this study allow us to draw conclusions about the overall behavior of outrigger braced structures when subjected to lateral loads. The response spectrum technique was utilized to conduct an analysis on the chosen models. The focus of the investigation was to compare the seismic performance of outrigger placements in a typical reinforced concrete structure, with a specific emphasis on the utilization of a braced frame core and a shear core.

Daril et. al. [5] The purpose of this study is to present a new design that utilizes energy-dissipation outriggers constructed with buckling restrained braces (BRBs) instead of conventional diagonal reinforcement. The objective of this study is to improve the seismic performance of high-rise building structures that are equipped with outriggers. A case study was conducted to assess the seismic performance of the newly constructed structure. Two tall structures were planned for construction: one utilizing conventional outriggers, while the other incorporating outriggers specifically engineered for energy dissipation. The following article presents a succinct overview of the outrigger system concept, encompassing its benefits and structural composition. The investigation provides a comprehensive analysis of different types of outriggers, including conventional, offset, and virtual. The purpose of this document is to demonstrate the advantages of the virtual system compared to other systems. The structural system, while conceptual in nature, has the capability to satisfy the technical and financial requirements of a tall skyscraper. The research study not only compares the virtual system with the classic outrigger system, but also offers a comprehensive analysis of various lateral load resisting systems.

Roy et. al. [6] The objective of this study is to assess the feasibility of utilizing a high-rise outrigger structural system for withstanding seismic activity in areas prone to earthquakes. This will be achieved by conducting an analysis on a tall building. The purpose of this article is to provide a concise introduction to supplementary structural systems and offer a comprehensive overview of the Outrigger System. The optimal position for an outrigger in a grid frame, in order to sustain seismic stresses, is determined to be between 0.4-0.48 times the height of the structure. The height is measured from the base of the building. Outriggers are installed at mid-height to minimize storey displacement. The optimal reduction in displacement is attained by setting the height ratios of the two outriggers to 1.5 and ensuring that the relative axial rigidity of a multi-outrigger system is 0.75. The relationship between the displacements of the outriggers and their depth is inversely proportional.

Bishal et. al. [7] The objective of this study is to propose a design strategy that effectively reduces the size of the primary structural components, including the core wall, outrigger, and external columns. This is achieved by utilizing a genetic algorithm to determine the optimal positions for outriggers. The objective of this study is to develop an effective method for regulating the lateral displacement of a high-rise building. The optimal design of the primary structural elements, including the core wall, outriggers, and outside columns, in an outrigger system, is determined by considering various design criteria. These criteria include the installation location of the outrigger and the sections of the main structural members. The solutions were optimized through the utilization of a genetic algorithm (GA) that aimed to minimize the total volume of the principal structural elements. The implementation of two additional constraint criteria was completed. These criteria include the measurement of horizontal displacement at the upper level and the determination of the maximum bending tension at the base of the core wall.The total capacity of the building's core wall, outrigger, and external columns is observed to decrease as the number of stories with outriggers increases. In addition, the installation of additional outriggers led to an enlargement of the external column and a reduction in the dimensions of the core wall and outrigger. The observed outcome is a direct consequence of the correlation between the rising count of outrigger installations and the corresponding increase in the moment exerted on the outer columns that are linked to these outriggers. Simultaneously, there is a decrease in the moment resisted by the core wall. The reduction in question exhibited the highest magnitude when one to two outriggers were integrated, while it demonstrated the lowest magnitude when three to four outriggers were integrated. The determination of the optimal solutions for the outrigger system was based on the maximum displacement constraint, irrespective of the number of stories where the outriggers were installed. The volume of the system was minimized by implementing these solutions. However, it is important to note that the flexural bending moment at the base of the core wall decreased when the number of vertically mounted outriggers increased. This is in contrast to the fact that the maximal bending stresses increased due to the decrease in the core wall's second moment of inertia.

Kasi et. al. [8] The study aimed to determine the most effective positioning for steel outrigger systems and assess the vulnerability of high-rise steel composite structures to wind loading. An analysis is conducted to determine the optimal location for the steel belt and outrigger systems. The study involves testing different configurations of single and double level outriggers for composite structures with varying sizes, forms, and heights. A finite element analysis is performed to evaluate different building configurations, such as rectangular, octagonal, and L-shaped structures, each consisting of 28, 42, and 57 storeys. The 28-story model demonstrated superior performance across all three design configurations as a result of the inclusion of upper-level bracings. To optimize the reduction in lateral deflection, it may be required to install an additional set of outriggers at the midpoint of structures with 42 stories. The 57-story model featuring a double belt-truss and outrigger levels should be outfitted with a secondary outrigger positioned at a height equivalent to two-thirds of the total height, as determined from ground level.

Chetan et. al. [9] An analysis was conducted by the author on a tall steel structure in order to investigate the impact of adjusting the depth of the outrigger on the behavior of the system. The research study focuses on analyzing both static and dynamic effects resulting from reducing the depth of the outrigger. In this analysis, a comparison is conducted between the structural system of outriggers and the central core at different depths. The outrigger depth is reduced to two-thirds and one-third of the story height, in accordance with the building's overall height. The belt-truss depth of each structure is uniform and matches the height of a standard storey. The outrigger structural system is utilized to establish a connection between the building core and a remote column, resulting in an enhanced rigidity of the structure. When the outrigger depth is decreased to two-thirds of the story height instead of the full story height, the lateral displacement and story drift are reduced by approximately 4% to 5% in the case of variable depth. Upon conducting a comparison between the outrigger's performance when operating at full story height and when operating at a reduced depth, it was observed that there is no noticeable difference in performance.

Alok et. al. [10] The main purpose of this article is to assess the effectiveness of each outrigger, optimize the placement of outrigger sites, and examine the use of outriggers in a construction project involving three outriggers. An analysis was conducted on nine three-dimensional models of the system, with each model representing a thirty-story structure. The purpose of the analysis was to evaluate the reduction in lateral displacement caused by the placement of the outrigger and belt truss system, under wind and seismic loading conditions. The displacement of the 30-story model can be decreased by up to 23% by strategically placing the first outrigger at the highest point and the second outrigger at the structural height. The utilization of belt truss and outrigger systems in high-rise buildings has been shown to enhance structural efficiency and increase rigidity when exposed to lateral forces, as evidenced by the findings of the aforementioned experiment. The effectiveness of deviation reduction is not significantly improved when using an outrigger as a cap truss on the uppermost level, as compared to a belt truss. Based on the available information, it can be deduced that the optimal range of the outrigger is equal to half the height of the structure.

3. OBJECTIVES

The objective of current research is to evaluate the structural behavior of RC framed building subjected to lateral loads. The structural and dynamic analysis of building is conducted using ETABS simulation software. The analysis of building is conducted with and without outrigger structural system.

4. METHODOLOGY

The primary objective of this research is to investigate the behavior of G+40 story reinforced concrete frame structures that possess a square or rectangular geometry and a regular arrangement. The floor height is specified as 3.2 meters. Additionally, the frame structure's specific characteristics are specified. The Etabs software is employed to generate models by strategically positioning rigid outrigger structures at various locations on the buildings. Diverse categories of burdens are assessed. Numerous variables influence the structure's static behavior. The live load is determined in accordance with IS 875 Part III, the dead load is computed in accordance with the specifications of IS 875 Part I, and the lateral load is determined in accordance with the guidelines of IS 1893 (part 1) 2016. The response spectrum analysis of three-dimensional reinforced concrete structures with a height of 40 storeys was performed using the Etabs program. The outrigger belt truss system's efficacy in relation to base moments, base shear, base displacement, time period, and storey shear, among other aspects, will be demonstrated by the analysis's conclusions.

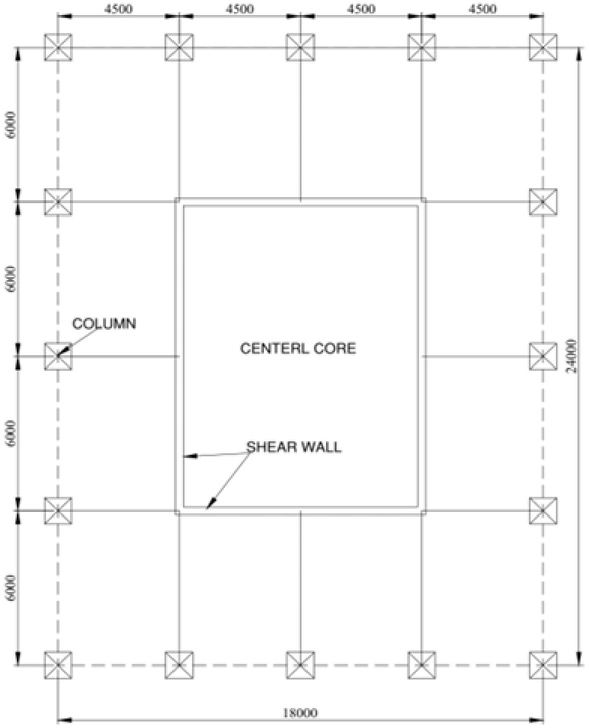


Figure 1: Plan of rectangular geometry without outrigger belt truss system for zone III

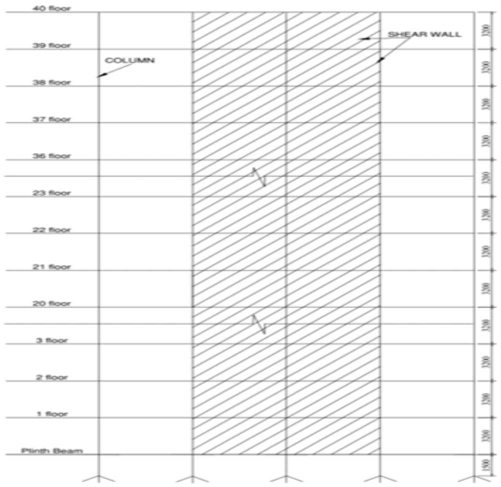


Figure 2: Elevation of rectangular geometry without outrigger belt truss system for zone III

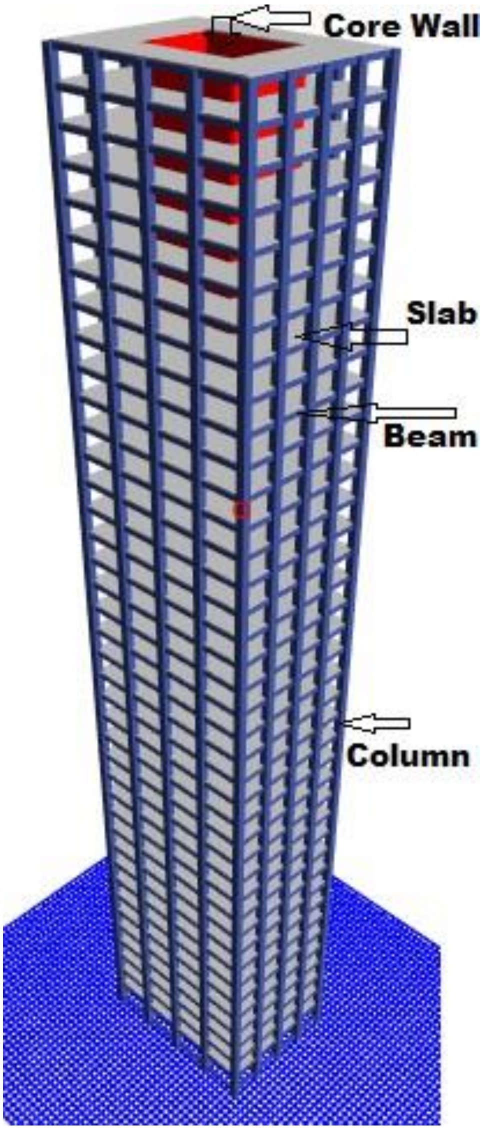
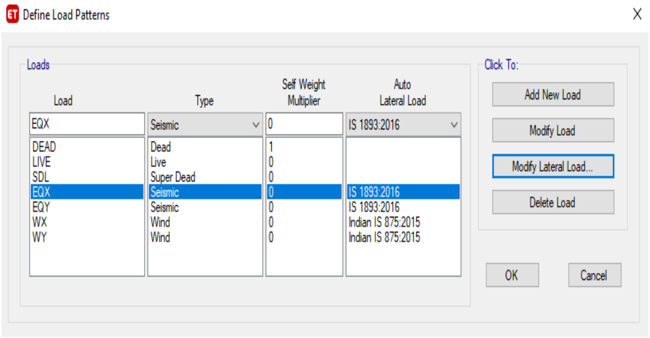


Figure 3: 3D View of rectangular geometry without outrigger belt truss system for zone III


Define Load Patterns

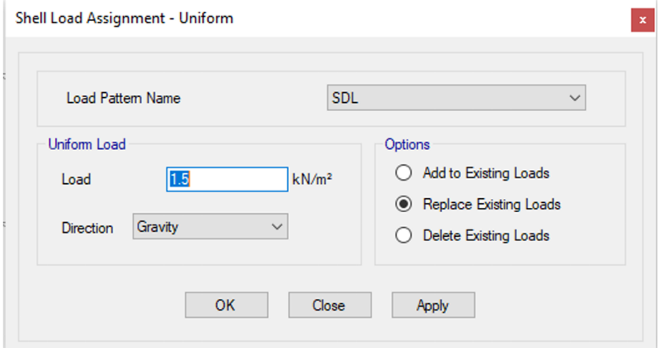
Loads

Load	Type	Self Weight Multiplier	Auto Lateral Load
EQX	Seismic	0	IS 1893:2016
DEAD	Dead	1	
LIVE	Live	0	
SDL	Super Dead	0	
EQX	Seismic	0	IS 1893:2016
EQY	Seismic	0	IS 1893:2016
WX	Wind	0	Indian IS 875:2015
WY	Wind	0	Indian IS 875:2015

Figure 4: Load pattern definition

Gravity pressures refer to the downward forces exerted due to the acceleration caused by gravity. The internship program was primarily structured into three distinct categories: The self-weight of structural elements is determined by their dimensions and composition.

Overlapped dead loads refer to the loads that are produced by permanent fixtures and fittings, such as ceilings, air conditioning ducts, floor treatments, and dividers. The expected inert load value to be applied to this model is 1.5 kN/m².


Shell Load Assignment - Uniform

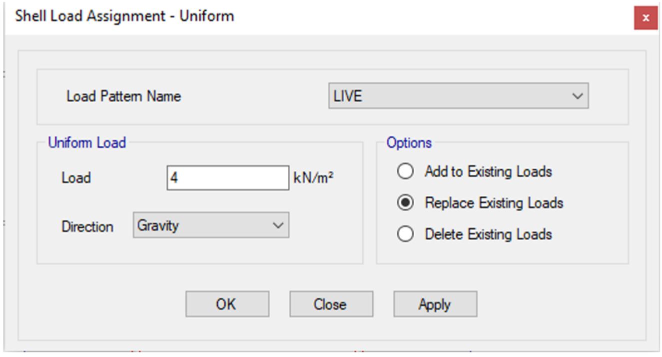
Load Pattern Name: SDL

Uniform Load
Load: 1.5 kN/m²
Direction: Gravity

Options
○ Add to Existing Loads
● Replace Existing Loads
○ Delete Existing Loads

Figure 5: Superimposed dead loads

Live Load Intensity specified (Public building) = 4 kN/m²

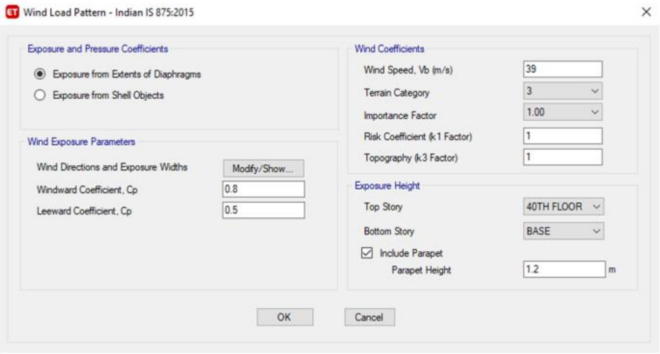

Shell Load Assignment - Uniform

Load Pattern Name: LIVE

Uniform Load
Load: 4 kN/m²
Direction: Gravity

Options
○ Add to Existing Loads
● Replace Existing Loads
○ Delete Existing Loads

Figure 6: Live loads


Wind Load Pattern - Indian IS 875:2015

Exposure and Pressure Coefficients
● Exposure from Extents of Diaphragms
○ Exposure from Shell Objects

Wind Exposure Parameters
Wind Directions and Exposure Widths: Modify/Show...
Windward Coefficient, Cp: 0.8
Leeward Coefficient, Cp: 0.5

Wind Coefficients
Wind Speed, Vb (m/s): 39
Terrain Category: 3
Importance Factor: 1.00
Risk Coefficient (k1 Factor): 1
Topography (k3 Factor): 1

Exposure Height
Top Story: 40TH FLOOR
Bottom Story: BASE
☑ Include Parapet
Parapet Height: 1.2 m

Figure 7: Wind Loads

5. RESULTS AND DISCUSSION

Storey shear values for rectangular geometry with and without outrigger belt truss system for zone III models are obtained using Response spectrum analysis from the Etabs software.

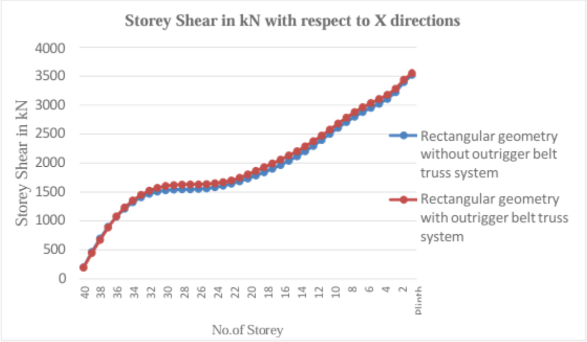


Figure 8: Storey Shear in kN with respect to X

Storey shear values for rectangular geometry with and without outrigger belt truss system for zone III models are obtained using Response spectrum analysis from the ETABS software

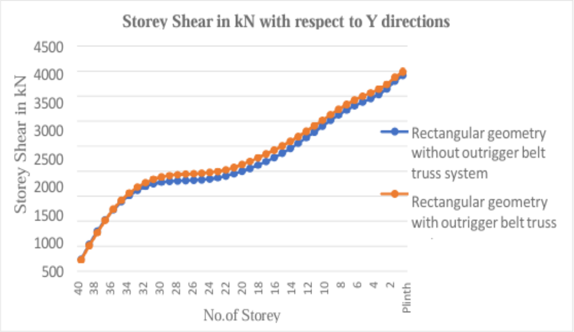


Figure 9: Storey Shear in kN with respect to Y

Base shear values for rectangular geometry with and without outrigger belt truss system for zone III models are obtained using Response spectrum analysis from the Etabs software

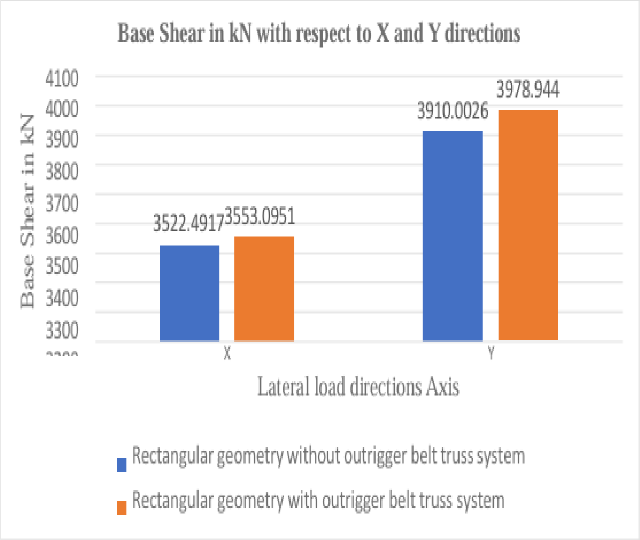


Figure 10: Base shear with respect to x and y directions

The base moment of Spec1 (Y) for rectangular geometry with outrigger belt truss system is 4.58 % more than that of rectangular geometry without outrigger belt truss system. 2. The base moment of Spec2 (X) for rectangular geometry with outrigger belt truss system is 4.53 % more than that of rectangular geometry without outrigger belt truss system.

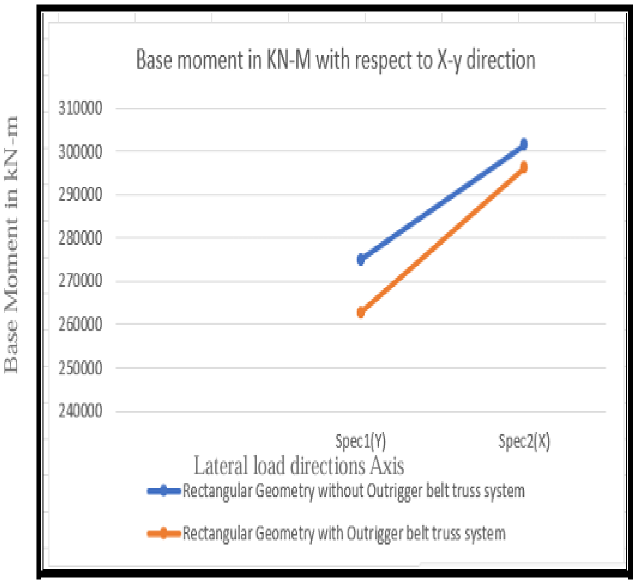


Figure 11: Base moment in kN-m with respect to X and Y-directions for 50 storey

Maximum Displacement values for rectangular geometry with and without outrigger belt truss system for zone III models are obtained using Response spectrum analysis from the ETABS software zones III for terrace levels.

Table 1 Maximum Displacements for rectangular geometry with and without outrigger belt truss system for Earthquake Load Case for 40 storey

	Maximum Displacements in mm for Terrace Floor	
	Rectangular geometry without outrigger belt truss system	Rectangular geometry with outrigger belt truss system
X	38.102	36.482
Y	32.486	30.03

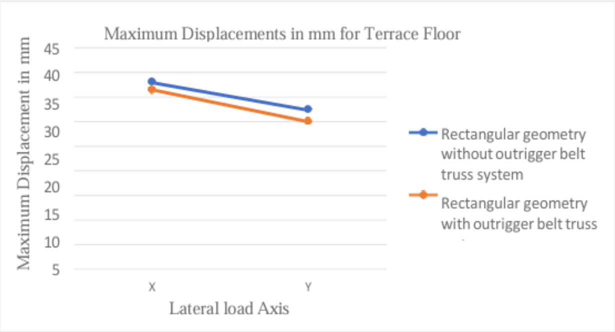


Figure 12: Maximum Displacements for rectangular geometry with and without outrigger belt truss system for Earthquake Load Case for 40 storey

1. The X Axis of Maximum displacements for rectangular geometry without outrigger belt truss system for zone III is 4.25 % more than rectangular geometry with outrigger belt truss system for zone III

2. The Y Axis of Maximum displacements for rectangular geometry without outrigger belt truss system for zone III is 7.56 % more than rectangular geometry with outrigger belt truss system for zone III

6. CONCLUSIONS

The performance and execution of the outrigger structural system are significantly impacted by several factors, including the location, cost, duration, type, and material of bracing. The positioning of the outrigger beam has a substantial influence on the manner in which a building reacts to horizontal forces. In a typical single outrigger construction, it is common practice to position the outrigger beam at the midpoint of the height.

1. The utilization of a belt truss system, perimeter columns, outriggers, and core structural walls in a building results in improved resistance to lateral forces, in accordance with the specifications outlined in IS 1893-2016 (part 1). The outriggers serve to enhance the coordination between the perimeter columns and core structural walls, while the belt truss acts as a conduit for the perimeter columns. The global lateral stiffness is influenced by several factors, including the flexural stiffness of the outrigger components, the axial stiffness of the outrigged columns, and the flexural stiffness of the outrigger elements that connect the perimeter columns to the core structural walls.

2. The recommended positioning for outriggers in a system with two outriggers is as follows: the first outrigger should be positioned at a distance of 0.9H from the bottom of the structure, while the second outrigger should be positioned at a distance of 0.5H from the bottom.

3. The outrigger structural technique enhances the structural stiffness of the building by linking the building core to a remote column. This connection enables the entire structure to act as a cohesive unit in withstanding lateral loads.

4. The utilization of an outrigger structural system is known for its exceptional efficacy in mitigating the adverse effects of wind and seismic forces. This is achieved by imparting a high degree of rigidity to the overall structure.

5. Earthquake load cases: The X-Axis of Maximum displacements for rectangular geometry without outrigger belt truss system for zone III is 4.25 % more than rectangular geometry with outrigger belt truss system for zone III

6. Earthquake load cases: The Y Axis of Maximum displacements for rectangular geometry without outrigger belt truss system for zone III is 7.56 % more than rectangular geometry with outrigger belt truss system for zone III.

7. Wind load cases: The X-Axis of Maximum displacements for rectangular geometry without outrigger belt truss system for zone III is 9.23 % more than rectangular geometry with outrigger belt truss system for zone III

REFERENCES

[1] 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.

[2] 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.

[3] 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.

[4] Sreelekshmi. S 1, Shilpa Sara Kurian “Study of Outrigger Systems for High Rise Buildings”. International Journal of Innovative Research in Science, Engineering and Technology, Volume 5, Issue 8, August 2016.

[5] 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.

[6] Roy Shyam Sundar, Gore. N. G "A Study on Tall RC Structure with Outrigger System Subjected to Seismic and Wind Loading". International Journal of Engineering Research & Technology. Volume 6, Issue 02, February-2017.

[7] 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.

[8] Prakarsh Sangave, Nikhil Madur, Sagar Waghmare, Rakesh Shete, Vinayak Mankondi, Vinayak Gundla. February, 2015. "Comparative study of Analysis and Design of RC and steel structure". ISSN: 2229-5518, Volume 6, Issue 2, IJSER

[9] Sattainathan.A, Nagarajan.N. March, 2015 "Comparative study on the behavior of RCC steel and composite structure (B+G+20 storeys)". ISSN: 2395-3837, Volume 1, Issue 3, IJACEE, Pg.no:21-26.

[10] Zaveri, Bhavin H., Bhargav K. Panchotiya, Smit U. Patel, and Pratik A. Bilimoria. 2016. "Parametric Study of RCC, Steel and Composite Structures under Seismic Loading." International Journal of Civil Engineering and Technology 7 (4): 127–47

[8] Kasi Venkatesh, B.Ajitha "Behaviour of a Building with Outrigger Structure". National Institute of Technical Teachers Training & Research. May 2017.

[9] 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.

[10] 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.

[11] Premalatha J, Mrinalini M "Seismic Behaviour of a Multi-Storeyed Reinforced Concrete Irregular Building with Outrigger Belt Truss System". International Journal of Engineering and Advanced Technology, Volume-8, Issue-2S, December 2018.

[12] Iqra Bano 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.