Comparative Analysis of Different Outrigger System At Different Height And Belt-Truss Systems

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Abstract- *Tall buildings are necessary in cities due to the rapid expansion of infrastructure to support contemporary civilisation. The issue of the buildings' lateral stability and sway must be addressed by engineering judgment as they go taller. The outrigger and belt truss structural systems are two examples of structural systems that have developed continually to address issues with lateral stability and sway. To reduce the danger of both structural and non-structural damage during small or medium lateral loads caused by wind or earthquakes, the outrigger system is one of the most effective ways to efficiently control excessive drift caused by lateral load. Strong-rise structures can use this system as a suitable structure, especially in areas with strong seismic activity or wind load. This study examines the effective usage of belt truss and outrigger systems for high-rise concrete buildings that are subjected to seismic or wind loads. To determine the lateral displacement reduction associated with the various types of outrigger and belt systems in different forms at varying heights, 26-story two-dimensional models of outrigger and belt truss systems are subjected to seismic load, analysed, and compared. The purpose of the analysis was to examine the impact and functionality of the outrigger system in a 26-story building. As the building rises in height, the outrigger system is installed at various levels. The outrigger and belt truss depths are maintained constant throughout all models and are equivalent to the normal story's height.*

Keywords- outrigger, belt truss, shear wall, lateral stability, sway, storey drift, storey displacement, base shear, wind.

I. INTRODUCTION

Structural engineering has advanced as a result of the fast urbanisation and the need for larger, more efficient structures. Among the many difficulties faced by tall buildings are lateral stresses brought on by seismic and wind forces. Unwanted structural vibrations and excessive lateral deflections may arise from these loads. In order to address these problems, engineers have created novel structural solutions, like outrigger systems, which have been successful in raising tall buildings' overall performance. Tall structures frequently use the outrigger system, a lateral load-resisting mechanism, to improve structural stability and lessen excessive lateral displacements. In order to connect the building's core or perimeter columns to the external columns, it uses horizontal components called outriggers. The structural design effectively redistributes the lateral forces and lowers the overall strain on the building's core and perimeter columns by strategically placing outriggers. A comparative research to examine and assess various outrigger structural systems is essential given the importance of outrigger systems in tall structure design. By evaluating the performance, effectiveness, and behaviour of several outrigger configurations, this study seeks to improve the overall structural integrity of tall buildings by lowering lateral deflections and managing interstory drifts. Analysing various outrigger configurations, such as belt truss, diagrid, and external bracing systems, will be part of the comparative study. Advanced structural analysis methods, including numerical simulations and finite element modelling, will be used to assess each system. A number of variables, including lateral stiffness, strength, dynamic properties, construction complexity, and economic viability, will be taken into account in this study. The study will also investigate how tall buildings' structural behaviour is affected by the size, placement, and material characteristics of outriggers. This study intends to offer important insights into the benefits, drawbacks, and applicability of various outrigger systems for various building kinds and locations by comparing their performance under various loading scenarios. For structural engineers, architects, and developers working on the design and construction of tall structures, the results of this comparison study can be used as a guide. Future tall structures will be safer and more effective because to the knowledge gathered from this research, which can help construct outrigger systems that are optimised.

II. OUTRIGGER SYSTEM

The outrigger structural system is a widely adopted engineering solution in the design of high-rise buildings, primarily employed to enhance lateral stiffness and stability. As building heights increase, their susceptibility to lateral loads such as wind and seismic forces becomes a critical design consideration. The outrigger system effectively addresses this issue by integrating structural elements that tie the building's central core to the perimeter columns, enabling a more efficient transfer and resistance of lateral forces.

In essence, an outrigger system comprises a central core—typically made of reinforced concrete or steel—which acts as the primary vertical and lateral load-resisting element. Outriggers are horizontal structural members, often designed as trusses or deep beams, which extend from the core to the outer columns, typically at one or more intermediate levels of the structure. These outrigger elements restrain the rotation of the core under lateral loads by engaging the perimeter columns, thereby creating a wider moment-resisting base and significantly reducing overturning moments.

One of the key advantages of the outrigger system is its ability to control building drift and enhance the overall stiffness without significantly increasing the weight or material usage. This makes it both structurally efficient and economically viable. The integration of outrigger systems also facilitates architectural flexibility, as the core can be centralized to free up surrounding floor space, enabling more efficient spatial planning for commercial or residential use.

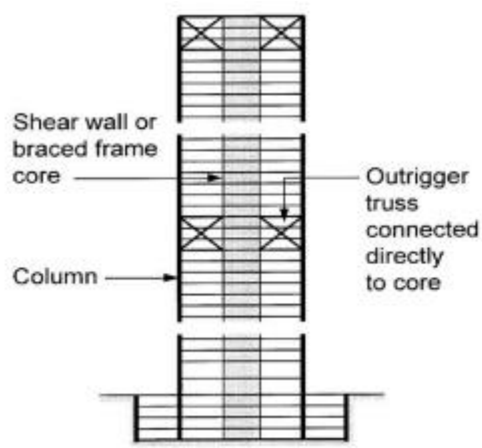

Fig Outrigger Structure System

III. OBJECTIVES OF THE RESEARCH

The main aim of this study is to examine and contrast the structural effectiveness of tall steel buildings that have traditional outriggers with those that have virtual outriggers.

- The performance evaluation will prioritize the examination of critical parameters, including lateral displacements, story drifts, and member forces, specifically when subjected to seismic loading conditions.
- To study the performance of RC high rise building with and without outrigger structural system.
- The study intends to gain a thorough understanding of how different types of outrigger systems effect the stability and efficiency of high-rise structures by performing response spectrum analysis in ETABS Software.
- The location of outrigger and belt truss for reducing lateral displacement, building drift and base shear can be obtained.
- Present comparative analysis of different outrigger system at different storeyheight.

IV. LITERATURE REVIEW

The research papers from authors who have researched different outrigger systems were summarized in this section, primarily focusing on the structure when subjected to lateral loads. The structures can be designed using analytical applications such as STAAD.Pro, ETABS and other modelling and analysis software and the analytical reports were presented below.

Giulia Angelucci et.al (2025) The structural reaction was assessed and contrasted with that of a regular geometry, both with and without outriggers. To give a thorough evaluation, the quantity, position, and relative stiffness of outriggers about the inner core are also systematically changed. Simplified analytical models are used to make the comprehensive parametric analysis easier to understand.

The findings show that the morphology of the building has a large impact on the structural reaction, with regular and slanted layouts showing the most benefits. On the other hand, depending on the degree of twist, twisted geometries might significantly change the behaviour of the global structure, which could reduce the outrigger's ability to reduce lateral displacement and core base moment demands. Using an effective, simplified modelling framework for preliminary design, this research informs a more integrated architectural and structural approach in modern high-rise construction by offering measurable insights on outrigger performance in complex-shaped structures.

V. METHODOLOGY

This section presented the methodology adopted for the modelling and analysis of G+25 high rise structure with outrigger system at different height with various shapes, considering similar loading conditions.

STEPS INVOLVED IN THE METHODOLOGY

Step-1 First step is collection of data related to outrigger structures considering software implementation.

The use of computers in the analysis of structure enable the rapid calculation of forces and moments within a complex frame, by the rigorous application of proven theory and mathematics. Analysis by computer offers advantages to the structure designer in speed and in accuracy of the arithmetic. there is, however a growing concern that reliance of computer analysis can seriously reduce the structural designer's ability to understand inutility the real behaviour of a structure.

Basic investigation is the way toward figuring the forces, moment and deflection to which the membranes in a structure are to be oppressed. There is an immense scope of investigation instruments offering velocity, exactness and economy of plan; 3-D, FE demonstrating, bespoke entry outline, cell shaft or plate support structure programming are currently broadly accessible. Demonstrating catenary activities, cold framed part execution or grillage investigation - all these are currently ordinary for structures, where hand examination is unimaginable. Progressively modern examination techniques keep on improving the exactness with which the conduct of structures can be anticipated.

Step-2 Modelling of Structure using ETABS

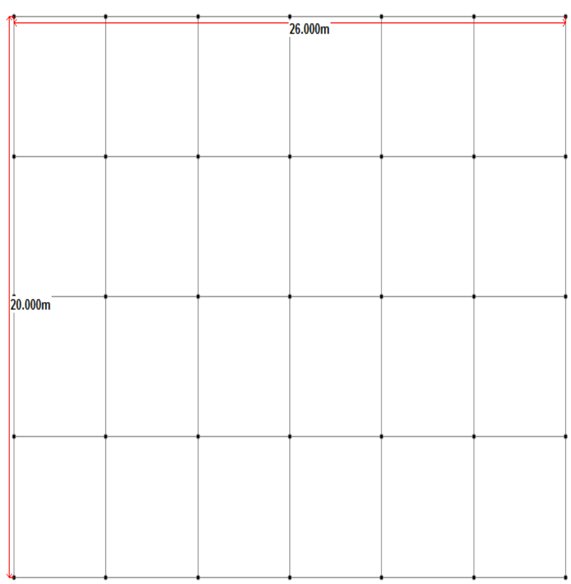

Fig 1: Modelling of Structure using ETABS

The dimensions of the structure were designed in both the cases.

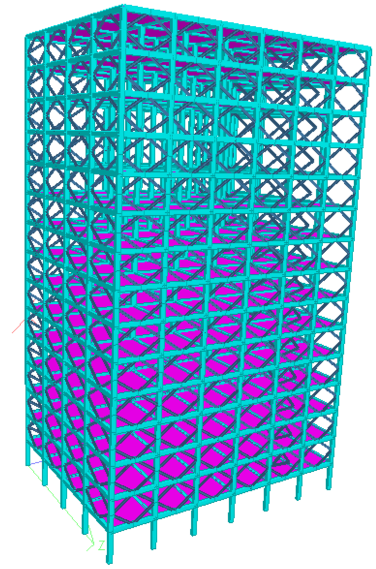

Fig 2: Modelling of Octagrid

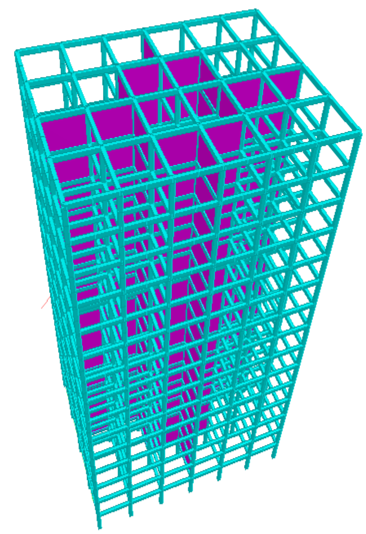

Fig 3: Modelling of Outrigger

Step-3 To assign sectional data and properties
Step-4 To Assign support conditions**.**
Step-5 Formation of load combination (8 load combinations in x & z-direction) and Time History Plot.
Step-6 To perform finite element analysis and design as per I.S. 456:2000
The Finite Element Analysis (FEA) is the reproduction of some random physical marvel utilizing the numerical procedure called Finite Element Method (FEM). Architects use it to lessen the number of physical models and tries and enhance parts in their structure stage to grow better items, quicker.

It is important to utilize arithmetic to thoroughly comprehend and evaluate any physical wonders, for example, auxiliary or liquid conduct, warm vehicle, wave engendering, the development of natural cells, and so forth. A large portion of these procedures are portrayed utilizing Partial Differential Equations (PDEs). Nonetheless, for a PC to settle these PDEs, numerical procedures have been created throughout the most recent couple of decades and one of the noticeable ones, today, is the Finite Element Analysis.

Step-7 To prepare comparative result in M.S. excel
Step-8 To provide conclusion as per results.

RESULTS AND DISCUSSION

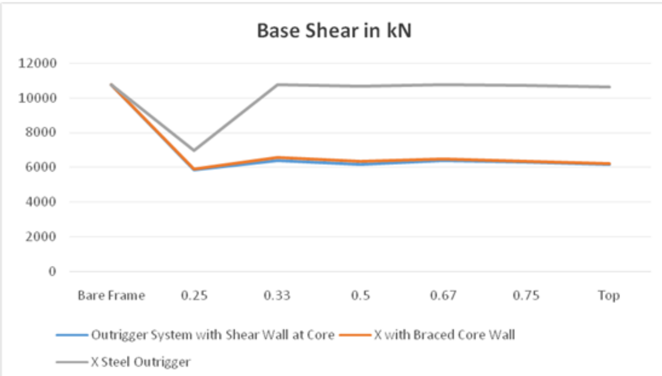

Fig Base Shear in kN

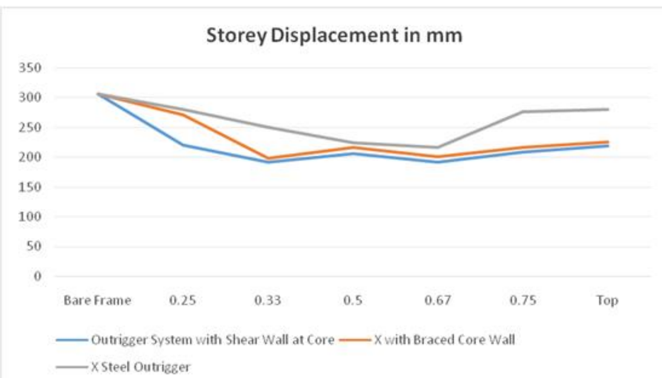

Fig Storey Displacement in mm

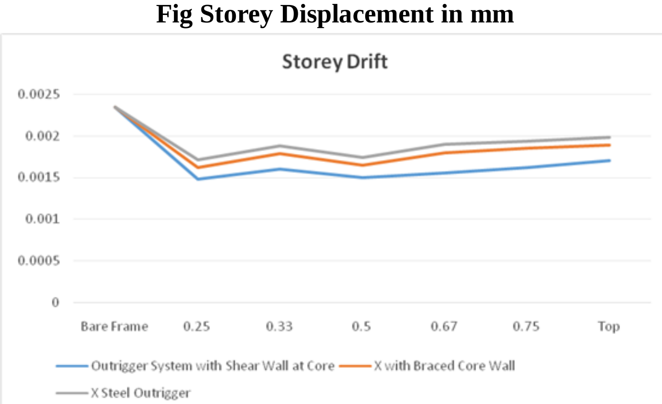

Fig Storey Drift

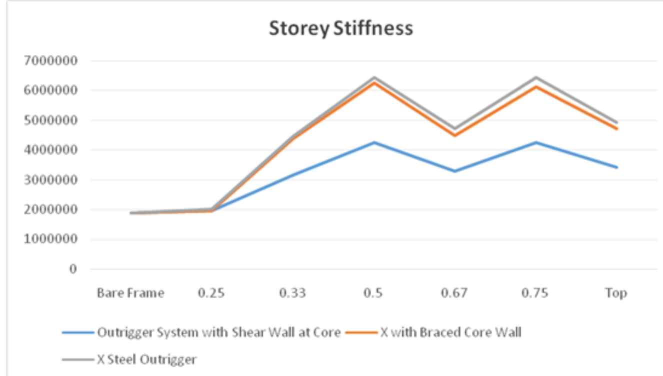

Fig Storey Stiffness in kN

VI. CONCLUSION AND FUTURE SCOPE

- The analysis shows that outrigger systems with shear walls and braced core walls consistently reduce base shear across all height ratios, demonstrating superior lateral load performance. In contrast, the steel outrigger system is less effective, especially at higher elevations, where its base shear values nearly equal the bare frame configuration.
- Outrigger systems incorporating a shear wall at the core consistently outperform both braced core and steel outrigger systems in minimizing lateral storey displacement across all height ratios. The braced core wall configuration shows moderate effectiveness, while the steel outrigger system exhibits comparatively high displacements, particularly at lower and upper height levels. These findings highlight the importance of selecting appropriate core structural systems and outrigger placement to optimize deformation control in high-rise building design.
- Outrigger systems contribute to improved drift performance in high-rise structures, with the shear wall core configuration consistently delivering superior performance. The braced core wall also shows notable improvement but is moderately less effective, while the steel outrigger system, despite offering improvements over the bare frame, exhibits the least efficiency in controlling storey drift. These findings are crucial for informed decision-making in the structural design of tall buildings subject to lateral loads.
- The data demonstrate that outrigger systems significantly enhance storey stiffness compared to the bare frame model, particularly when placed at mid-to-upper heights. Among the systems, the steel outrigger consistently achieves the highest stiffness values, followed closely by the braced core wall system, while the shear wall system, although effective, shows relatively lower gains in stiffness. These findings underscore the critical role of

outrigger type and elevation in optimizing the stiffness characteristics of high-rise structural systems.

VII. SCOPE OF FUTURE STUDY

- Examine the performance for outriggers and belt trusses in composite structures in order to improve performance by minimising material usage and decreasing total weight.
- Perform comprehensive parametric analyses to optimise the positioning and arrangement of outriggers and belt trusses at various elevations and configurations for buildings with irregular geometries.
- Study the design of high rise steel structures with different outrigger systems.
- Analysis of outrigger systems with different type of bracings such as X,V ,knee bracings .

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