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Comparative Study of Tube-In-Tube and Bundled Tube System in High Rise Buildings

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Abstract
This study evaluates the seismic performance of Tube-in-Tube and Bundled Tube structural systems for high-rise buildings, following IS 1893 standards. Key parameters, including storey displacement, drift, and shear, were assessed in Seismic Zones 3 and 5. In Seismic Zone 5, the Bundled Tube system reduces storey displacement by about 33% compared to the Tube-in-Tube system. Similarly, in Seismic Zone 3, displacements are lowered by 21-24%. The Tube-in-Tube system exhibits higher storey drift, particularly in Seismic Zone 5, where the Bundled Tube system offers a remarkable 85% reduction. In Seismic Zone 3, this reduction ranges from 45-50%. In terms of storey shear, the Bundled Tube system consistently outperforms the Tube-in-Tube system, reducing shear forces by 24-30% across both seismic zones. Overall, the Bundled Tube system proves to be more effective under seismic conditions, minimizing displacements, drifts, and shear forces, making it the superior choice for high-rise structures in earthquake-prone regions. This improvement in performance contributes to safer structural designs in compliance with IS 1893 standards.
Keywords: *Tube in Tube, Bundled Tube, Storey Displacement, Storey Drift, Storey Shear, Mode Shapes.*

1. Introduction
In structural engineering and architecture, the design of tall buildings has evolved significantly, driven by the need for innovative and efficient structural systems. Among these, Tube-in-Tube and Bundled Tube systems have gained prominence as essential solutions for high-rise construction, providing stability and support in urban environments where space is limited and resilience is crucial. The Tube-in-Tube system features an inner core surrounded by an outer tube, enhancing stiffness and efficiently distributing vertical and lateral loads. In contrast, the Bundled Tube system comprises multiple interconnected tubes, offering robust resistance to lateral forces and greater architectural flexibility. (Oduor, 2023) (Y Hao, 2024) As cities grow vertically, understanding the differences between these systems becomes vital for optimizing structural performance and cost-effectiveness. This research project aims to thoroughly examine Tube-in-Tube and Bundled Tube systems, focusing on their structural behavior, construction complexity, cost-effectiveness, and adaptability. By analyzing existing literature and empirical case studies, along with advanced computational techniques, this study seeks to uncover the intricate differences between the two systems.The objectives of this study are to analyze the behavior of Tube-in-Tube and Bundled Tube systems under combined wind and seismic loads, perform a response spectrum analysis for both systems in seismic zones 3 and 5 using ETABS, and compare storey displacements, drifts, and shears between the two systems to recommend the more suitable option. Ultimately, this research aims to enhance the efficiency, resilience, and sustainability of built environments, providing valuable insights for practitioners and researchers in the field. [1-5]

1.1. Tube System
In architectural and structural engineering, the development of tube systems has significantly advanced tall building design, offering efficient

solutions to challenges like height, wind loads, and seismic forces. Tube systems utilize interconnected vertical and horizontal elements, effectively distributing loads and providing both vertical and lateral support. Pioneered by Fazlur Rahman Khan, these systems enable taller buildings with slender profiles, exceptional resistance to lateral forces, and architectural flexibility. Advantages of tube systems include structural stability, height achievement, cost-effectiveness, and sustainable design. However, they also present disadvantages, such as limited floor layout flexibility, construction complexity, and potential architectural constraints. Moreover, the reliance on the integrity of the building's core raises concerns about structural redundancy and retrofitting challenges. While tube systems can be cost-effective in the long run, initial investments may be higher due to specialized techniques and materials. Overall, tube systems play a crucial role in shaping modern skyscrapers and advancing sustainable architecture. [6-10]

1.2. Types of Tube System

Two prominent types of tube systems used in high-rise buildings are the Tube-in-Tube and Bundled Tube systems. The Tube-in-Tube system features a central core surrounded by an outer tube, enhancing stiffness and efficiently distributing loads. This design improves structural stability while reducing material usage. Conversely, the Bundled Tube system comprises multiple interconnected tubes that provide superior resistance to lateral forces. This configuration not only enhances stability but also allows for greater architectural flexibility, minimizing the need for internal supports and enabling open floor plans, making it ideal for iconic skyscraper designs.

2. Methodology

The methodology section of the research study outlines a structured approach to achieving the research objectives and answering key questions. Initially, a comprehensive literature review is conducted to summarize existing research, identify gaps, and set clear objectives. This is followed by selecting the appropriate building type (such as steel or RCC) and the analysis software best suited for the study, which in this case is ETABS. The selected building type is modeled in ETABS according to the dimensions specified in relevant IS codes. Material properties, including the grade of concrete and steel, are defined, and loads such as dead and live loads are calculated and applied as per code provisions. The model is then subjected to seismic analysis across various scenarios outlined in the objectives. Errors identified during the analysis phase are corrected, and the process is repeated to ensure accuracy. Results such as storey displacements, drifts, and shear forces are then obtained and compared. Finally, the study involves comparing these results across different cases, plotting relevant graphs, and discussing the findings to draw meaningful conclusions about structural performance. Figure 1 shows Flow Chart of Methodology

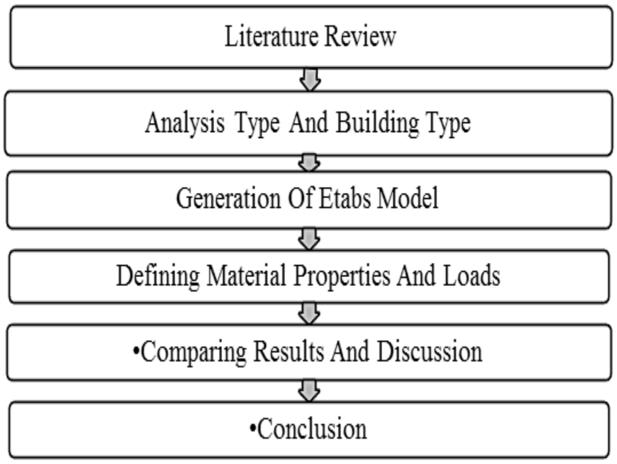

Figure 1 **Flow Chart of Methodology**

2.1. Modeling and Building Information

In analyzing a 36-storey RCC building with ETABS, both tube-in-tube and bundled tube systems are modeled. The building, standing 126 meters tall with 3.5-meter storeys, features columns of 800 mm by 800 mm, beams of 300 mm by 600 mm, and 250 mm thick slabs. Constructed with high-strength M40 concrete and Fe550 steel, it is designed to handle substantial loads. ETABS models incorporate all relevant loads and perform seismic analysis according to IS 1893:2016 for Zones 3 and 5, evaluating storey shear, drift, and displacement. This ensures compliance with seismic safety standards and aids in optimizing the design for stability and regulatory adherence.

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Table 1 Building Information

Particulars	RCC Structure
Plan Dimension	48 *48m
Height of Each Storey	3.50m
Number of Storeys	G+35
Type of Building	RCC Building
Grade of Concrete	M55 (Beam, Column) M40 (Slab)
Grade of Reinforcing Steel	Fe-550
Column Dimension	800*800 Mm
Beam Dimension	300*600 Mm
Slab Thickness	200mm

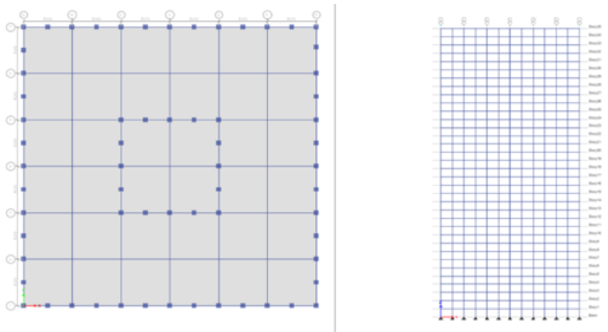

Figure 2 Model-1-Plan and Elevation of Tube in Tube System

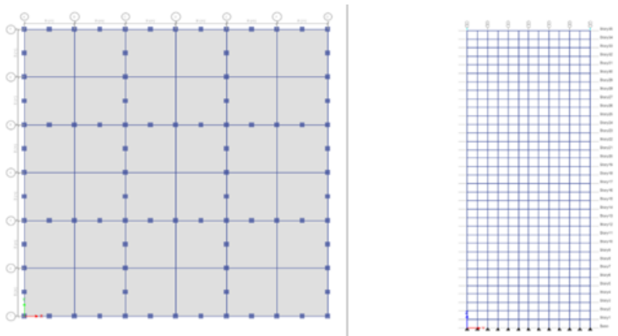

Figure 3 Model-2-Plan and Elevation of Bundled Tube System

To model a G+35 story RCC building in ETABS, first select the metric SI system and apply the Indian standard codes IS 800 for steel and IS 456:2000 for concrete design. Set up a grid system with a 48-meter length in both X and Y directions and a story height of 3.5 meters. Define material properties with concrete grade M40 and steel grade Fe550. Create sections for beams (300 mm x 600 mm), columns (800 mm x 800 mm), and slabs (200 mm thick). Consider two main types of loads: gravity loads (dead and live loads) and lateral loads (wind and seismic). Dead loads include the weight of cladding and concrete, with a density of 25 kN/m³, while live loads are 3.0 kN/m² as per IS: 456 for residential and office buildings. Lateral loads include wind and earthquake forces, analyzed using the Equivalent Static Method and the Response Spectrum Method according to IS 1893:2002. Load definitions follow IS 875 (Part I and Part II) for dead and live loads and IS 1893:2016 for seismic loads. Live loads are applied as 3.0 kN/m², and wall loads are set as 16.1 kN/m for main walls and 3.0 kN/m for parapet walls, with the wall density based on IS 875- Part 1. Table 1 shows Building Information, Figure 2 shows Model-1-Plan and Elevation of Tube in Tube System and Figure 3 shows Model-2-Plan and Elevation of Bundled Tube System.

3. Results and Discussion

The analysis of the G+35 multi-storey building under gravity and seismic loads using the static method provides insights into the building's behaviour under seismic forces. This analysis compares the performance of Tube-in-Tube and Bundled Tube systems, focusing on storey displacement**,** storey drift**,** and storey shear**.**

3.1. Storey Displacement

Storey displacement in high-rise buildings refers to the misalignment of actual floor numbers with the traditional numbering sequence. This can occur due to cultural preferences, superstitions, or architectural design choices, such as skipping certain numbers or including mechanical floors. Such decisions, made during the design phase, can lead to confusion for occupants and visitors unfamiliar with the building's numbering system. According to IS 1893 (Part 1), the maximum allowable lateral displacement for high-rise buildings is generally limited to a certain percentage of the building height.

1. Using H/300: Δ=122.5/300=408mm
2. Using H/500: Δ=122.5/500=245mm

Thus, according to IS 1893, the maximum lateral displacement for a 122.5 m high building would typically range between 245 mm and 408 mm. Always refer to the latest code provisions for the most accurate limits.

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3.2. Storey Drift

Storey drift refers to the horizontal displacement of floors due to external forces, such as wind and seismic activity, causing the building to stretch or compress. Engineers design structures with flexibility to accommodate this movement, ensuring stability and occupant safety. Special materials and design techniques are employed to minimize storey drift. According to IS 1893 (Part 1), the maximum allowable lateral displacement for high-rise buildings is limited to 0.004 times the storey height. For a typical storey height of 3.5 meters, this results in a permissible limit of 14 mm, ensuring the building remains strong and stable under challenging conditions.

3.3. Comparison Story Displacement of Tube in Tube and Bundled Tube System at (Zone 5)

The Tube-in-Tube system exhibits significant storey displacements, particularly in Seismic Zone 5, with maximum displacements increasing from 9.07 mm at the first storey to 356.42 mm at the top storey (storey 35). In contrast, the Bundled Tube system demonstrates considerably smaller displacements, ranging from 6.05 mm at storey 1 to 237.61 mm at storey 35. This comparison highlights that the Bundled Tube system offers superior stiffness, resulting in notably reduced lateral movement when compared to the Tube-in-Tube system. (Refer Figure 4)

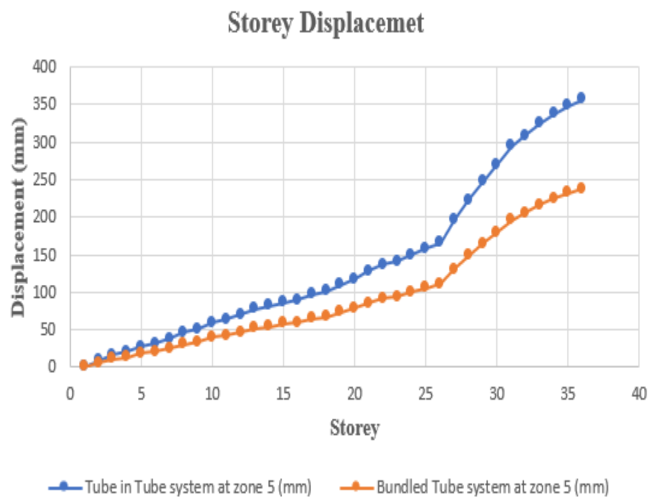

Figure 4 Maximum Story Displacement of Tube in Tube Building at Zone V

3.4. Comparison Story Displacement of Tube in Tube and Bundled Tube System at (Zone3)

In comparing the displacement values between the Tube-in-Tube and Bundled Tube systems, the Tube-in-Tube system exhibits higher overall displacements within acceptable limits. In Seismic Zone 3, displacements range from 1.13 mm at storey 1 to 72.85 mm at storey 35 for the Tube-in-Tube system. Conversely, the Bundled Tube system shows reduced displacements, with values from 0.741 mm at storey 1 to 59.408 mm at storey 35. This indicates the Bundled Tube system's superior performance in minimizing lateral displacement, crucial for enhancing both the stability and comfort of the building under seismic loads.(Refer Figure 5)

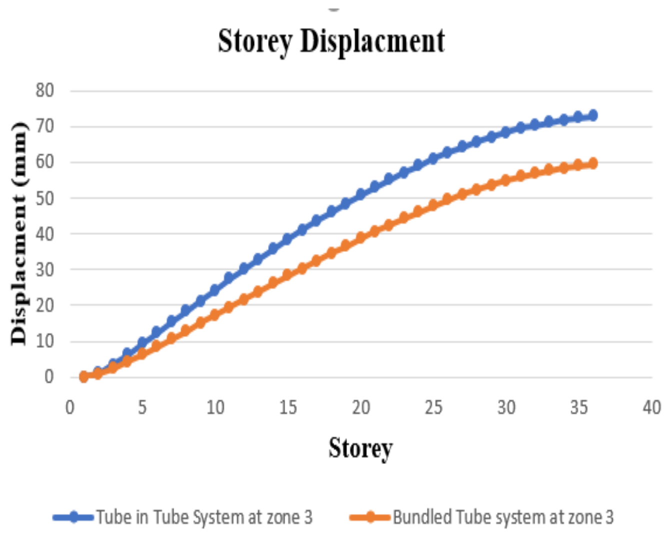

Figure 5 Maximum Story Displacement of Tube in Tube and Bundled Tube System at Zone III

3.5. Stroey Drift of Tube in Tube and Bundled Tube at Zone 5

The Tube-in-Tube system exhibits significantly higher storey drifts compared to the Bundled Tube system. For the Tube-in-Tube system, the drift is 0.032038 mm at storey 1, gradually decreasing to 0.027175 mm at storey 35. In contrast, the Bundled Tube system demonstrates much lower drift values, with a drift of 0.00469 mm at storey 1, reducing to 0.0026 mm at storey 35. Overall, the Bundled Tube system provides better control over storey drift, making it a more stable option under seismic loads compared to the Tube-in-Tube system. (Refer Figure 6)

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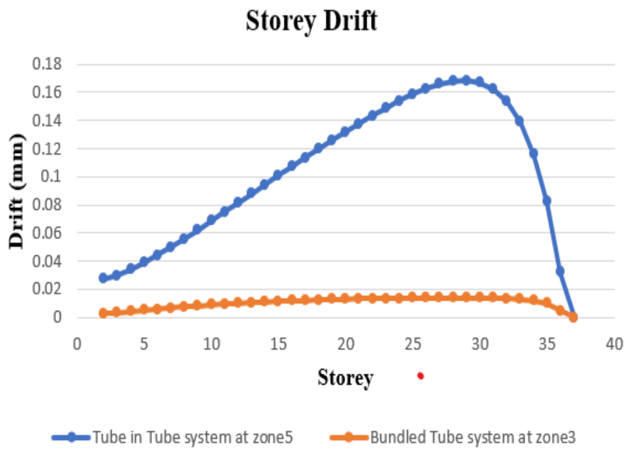

Figure 6 **Storey Drift of Tube in Tube and Bundled Tube System at Zone V**

3.6. Storey Drift of Tube in Tube and Bundled Tube Zone 3

The storey drift in the Tube-in-Tube system ranges from 0.000422 mm at storey 1 to 0.000234 mm at storey 35. In comparison, the Bundled Tube system shows even lower drifts, decreasing from 0.000212 mm to 0.000125 mm over the same height. This highlights the Bundled Tube system's superior lateral stiffness and better control of building sway under seismic loads. (Refer Figure 7)

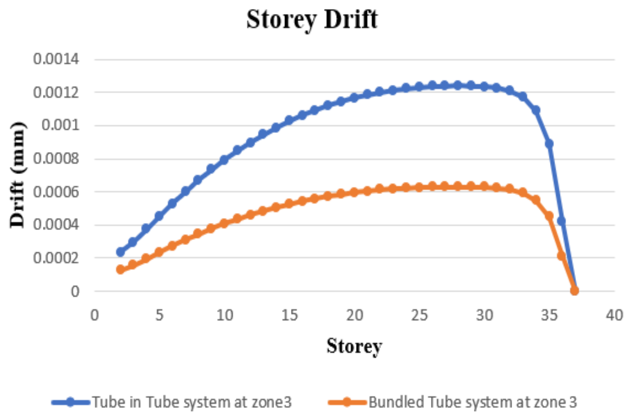

Figure 7 **Storey Drift of Tube in Tube and Bundled Tube System at Zone III**

Conclusion

The comparison between the Tube-in-Tube and Bundled Tube systems reveals that the Bundled Tube system offers superior performance in seismic conditions, particularly in Seismic Zones 3 and 5.

Storey Displacement

- **Tube-in-Tube System**: In Seismic Zone 5, displacements increase from 9.07 mm at storey 1 to 356.42 mm at storey 35, while in Zone 3, displacements range from 1.13 mm to 72.85 mm.
- **Bundled Tube System**: Zone 5 displacements range from 6.05 mm to 237.61 mm, and in Zone 3, they range from 0.741 mm to 59.408 mm, demonstrating the Bundled Tube system's superior stiffness and reduced lateral movement.

Storey Drift

- **Tube-in-Tube System**: Drift in Zone 5 starts at 0.032 mm at storey 1, reducing to 0.027 mm at storey 35. In Zone 3, drift ranges from 0.000422 mm to 0.000234 mm.
- **Bundled Tube System**: Zone 5 drift starts at 0.00469 mm and decreases to 0.0026 mm at storey 35, while Zone 3 drift ranges from 0.000212 mm to 0.000125 mm. This demonstrates better control over building sway.

Overall, the Bundled Tube system demonstrates lower displacements, drifts, and shear forces, making it the preferred option for stability and seismic performance, especially at higher levels.

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References

[1]. Hao, Y., Chen, F., Han, Y.H., Hao, X.Q., Du, C.H. and Ding, Q.Y., 2024. Study on the Seismic Optimization Scheme of Steel Bundled-Tube Structure with Vertical Setback. KSCE Journal of Civil Engineering, 28(2), pp.732-743.

[2]. Oduor, G., Abuodha, S. and Mumenya, S., 2023. A comparative study of the dynamic earthquake behaviour of braced tube, diagrid, tube-in-tube, and shear wall-frame structures. Andalasian International Journal of

Applied Science, Engineering and Technology, 3(1), pp.67-79.

[3]. Roshani, M., Meshkat-Dini, A. and Massumi, A., 2023. Evaluation of the Robustness of Tall Buildings with Bundled Tube Resistant Skeleton using Fragility Curves. Amirkabir Journal of Civil Engineering, 55(6), pp.1137-1158.

[4]. Nathan, C.S. and Preethi, P., 2023, August. Comparative analysis of behavior of various tube structures under earthquake loading using E-tabs software. In AIP Conference Proceedings (Vol. 2861, No. 1). AIP Publishing.s

[5]. Rajappa, K. and Ravindra, P.M., 2022. Comparative Analysis of Tube in Tube Structure and Conventional Moment Resisting Frame with and Without Single Diagonal Bracing Subjected to Lateral Loads. Journal of Engineering Analysis and Design, 3(3), pp.14-21.

[6]. Bore, M.S. and Desai, R.M., Wind Analysis of RCC Tube in Tube Structure.

[7]. Ussher, E., Aloisio, A. and Rathy, S., 2023. Effect of lateral resisting systems on the wind-induced serviceability response of tall timber buildings. Case Studies in Construction Materials, 19, p.e02540.

[8]. Babaei, M., Mohammadi, Y. and Ghannadiasl, A., 2021. Calculation of vibration period of tall pyramidal buildings structures with tube systems, tube-in-tube, bundled tube and hybrid tube systems with shear wall. Iranian Journal of Science and Technology, Transactions of Civil Engineering, pp.1-15.

[9]. Kawade, M.P., Bangde, V.S. and Sawai, G.H., 2020. Seismic analysis of tall building with central core as tube structure. Int. Res. J. Mod. Eng. Technol. Sci, 2, pp.300-310.

[10]. Balakrishnan, S. and James, R.M., 2019. Comparative study on tube in tube and tubed mega frames on different building geometry using ETABS. International Journal of Applied Engineering Research.