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An In-Depth Study Of Outrıgger And Belt-Truss Systems

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Abstract. The outrigger and belt-truss system is widely used in tall and super-tall structures to effectively counteract lateral stresses, primarily because of its proven effectiveness. The effectiveness of this structural system has been supported by a comprehensive range of research studies investigating many aspects of its performance. Therefore, the primary objective of this extensive literature analysis is to consolidate and integrate the significant discoveries and research approaches obtained from previous studies. The main objective of this resource is to provide important information to designers and researchers, especially those who are inexperienced in this particular area of study. This paper aims to provide a comprehensive analysis of the components, configurations, and diverse types of outrigger systems within the context of extensive research conducted on this subject matter. The study will also explore the aspects that impact system performance, clarify the structural response under various loading circumstances, and elaborate on the pros and cons of utilizing outrigger systems. Furthermore, this paper will provide a succinct overview of essential design factors as an introduction to upcoming evaluations. This article aims to function as a central resource for academics and designers, enabling them to get a comprehensive understanding of the outrigger and belt-truss system by integrating a significant amount of material. In addition, the objective is to provide individuals with knowledge and understanding that can help reduce any potential limitations linked to the system. This, in turn, will enable a smoother incorporation of the system into design provisions and guidelines, resulting in improved efficiency.

Keywords: Outrigger systems, Belt-truss systems, Lateral load resistance, Research synthesis, Loading conditions, Design factors.

1 INTRODUCTİON

1.1 The Significance of Tall Structures

High-rise buildings have become crucial architectural elements in modern urban areas, playing a substantial role in promoting social, economic, and ecological sustainability [1, 2]. In comparison to low-rise buildings, high-rise constructions exhibit increased intricacy as a result of their extensive structural elements and heightened vulnerability to a range of events, which have more significant effects on tall edifices. Significantly, the considerable gravitational pressures encountered in tall structures result in adverse consequences, including differential axial contraction of columns, distortion of the core, and large foundation settlements. Furthermore, the impact of horizontal forces, such as seismic and wind loads, becomes increasingly significant as the structure's height increases. This phenomenon has been referred to as the "Premium for height" concept, as proposed by Fazlur Khan. Therefore, the prioritization of stability and rigidity standards over strength concerns significantly influences the final architectural design of skyscrapers [3, 4, 5]. In addition, the swift progress in technology across various domains, including building materials, dampening systems, construction technologies, and advanced structural analysis and design facilitated by computer software, has facilitated the widespread construction of tall buildings. Emerging economies have adopted this tendency for several compelling reasons [2, 6, 7, 8], as they grapple with the necessity of implementing such arrangements. The shortage of urban land has been brought about by the increasing urbanization, which is primarily fueled by population expansion and the migration of individuals from rural to urban areas. High-rise structures present a viable resolution to the predicament of land utilization.

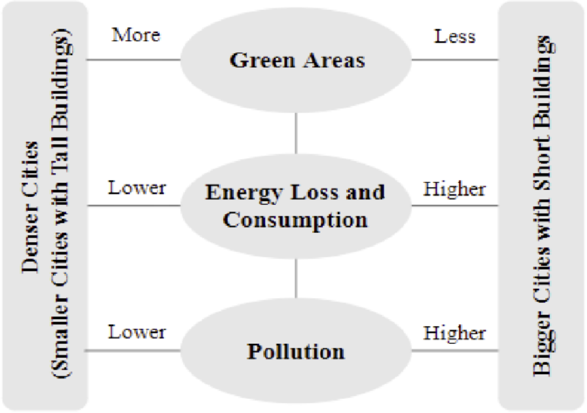


Fig. 1 presents a comparative environmental analysis conducted to examine the differences between tall and short buildings.

The pursuit of erecting the most towering and distinguished structures on a global, regional, national, or urban scale has engendered the emergence of intricate architectural configurations, encompassing twisted, slanted, tapered, and aerodynamic designs. Urban areas with higher population densities, which are defined by the presence of megastructures, have certain environmental benefits such as enhanced land utilization and decreased energy consumption. The implementation of smaller power grids within compact urban areas enables the effective transmission of electrical energy, reduces dependence on automobiles, mitigates pollution, and promotes energy conservation. Moreover, the construction of high-rise structures offers prospects for the establishment of vertical ecosystems and the integration of green spaces, so fostering the development of sustainable and intelligent urban areas while safeguarding natural habitats. In light of these factors, it is crucial to do extensive study on high-rise structures across diverse disciplines. The presence of tall structures holds significant importance in the realm of modern and prospective architectural development, exerting profound influence on both human society and the delicate balance of the Earth's biosphere.

1.2 The Significance of Outrigger & Belt-Truss Systems in Structural Engineering

The economic feasibility of classic lateral load-resisting technologies, such as moment-resisting frames and shear walls, has been compromised due to the increasing vertical size of buildings. The terrorist events that took place on September 11th in the United States had a significant impact on the feasibility of structural systems, particularly the frame-tube system. The primary reason for this phenomenon can be attributed to the heightened susceptibility of structures to progressive collapse, as well as their significant influence on the aesthetic aspect of buildings [11, 12]. Over the past five decades, engineers have endeavored to tackle these challenges through the development and integration of innovative structural frameworks, including bundled-tube, diagrid, and outrigger systems, in numerous high-rise buildings. The primary goal of these systems is to meet safety, serviceability, and aesthetic criteria, while also minimizing material usage [13, 14]. The selection of the most suitable structural system, from the available choices, depends on the specific construction materials used and the vertical height of the building. The assessment of lateral loads and their consequential effects are contingent upon a range of factors, which subsequently dictate the most appropriate structural framework for efficiently withstanding these stresses [15]. Previous research has extensively examined the bulk of these systems [16-19]; however, this current analysis primarily focuses on the outrigger system. The decision to utilize this option is driven by its efficacy in fulfilling design criteria, not just in typical high-rise buildings but also in extraordinarily tall ones. Therefore, it is imperative to possess a thorough understanding of this system, a goal that can be accomplished by integrating prior research and studies.

2 COMPREHENDİNG THE OUTRİGGER AND BELT-TRUSS SYSTEM

The hybrid lateral load-resisting system, including of the outrigger and belt-truss system, integrates both exterior and interior structural systems. The process of integration is facilitated by the utilization of inflexible horizontal beams referred to as outriggers, as well as a horizontal beam termed a belt-truss. These components serve to connect the perimeter columns of the outer structural system [20-22]. The integration of these two components boosts the structural depth, enabling it to function as a cantilever and effectively combine the deformed configurations of both systems in response to lateral forces. As a result, this methodology enhances the efficiency of these systems and functions as the principal technique for managing narrative deviations [25]. The outrigger and belt-truss system is widely utilized in tall buildings worldwide, with numerous tall buildings in China, for instance, embracing its structural methodology. The presented data in Table 1 showcases a curated collection of tall structures across the globe that utilize the outrigger and belt-truss structural system.

3 COMPONENTS OF THE OUTRİGGER AND BELT-TRUSS SYSTEM

The outrigger and belt-truss system consists of four essential components:

The interior structural system refers to the framework or support system that is responsible for maintaining the stability and integrity of a building's interior. The aforementioned component has the potential to manifest in various configurations, namely a steel braced core, concrete core, or composite core. The exterior structural system refers to the framework or support system that is located on the outer surface of a building or structure. The structural composition of a building can encompass several elements such as a frame tube system, moment-resisting frame, or mega-frame. Outriggers refer to stiff connections that serve to link the interior and outside structural systems. These connections can encompass a variety of features such as walls, trusses with different topologies, deep beams, or combinations of wall and truss components [5, 25, 28, 29]. The perimeter belt is a structural element that serves to connect either all or a portion of the perimeter columns. It can manifest in various forms such as a wall, truss, or deep beam, as documented in sources [30-34].

4 CONFİGURATİONS OF THE OUTRİGGER AND BELT-TRUSS SYSTEM

The structural behavior and performance of the Outrigger and Belt-Truss System can be comprehensively studied and evaluated through the examination and analysis of their configurations. The adaptability of the outrigger and belt-truss system can be modified to accommodate various configurations, taking into account factors such as prevalent loads (such as wind or earthquake), spatial limitations, and the desired structural behavior. The determination of these configurations is accomplished by modifying exterior and internal system types, selecting materials, arranging components, and including or excluding specific aspects. As a result, the resulting structural system possesses the capability to adopt many configurations, including a broad spectrum of possibilities that may encompass, but are not limited to:

- The integrated system is comprised of a singular tube, shear core, outriggers, and belt-trusses, rendering it highly suitable for efficiently withstanding lateral loads, including wind and seismic forces [3, 20].
- A proposed composite system has been suggested, which comprises various tube configurations such as tube-in-tube and multi-level outrigger-belt truss systems [35].
- A comprehensive structural system known as a mega-frame consists of many components, such as mega-columns, belt trusses, a con-centrically braced frame core tube, and outrigger trusses [36, 37].
- The integrated system being proposed consists of modern high-rise moment-resisting frames (MRFs), shear cores, outriggers, and belt-trusses [37].
- The system proposed comprises a central core, perimeter columns, and either rigid shear walls or deep beams functioning as outriggers [5, 38].
- The aforementioned configurations, distinguished by varying numbers of outrigger and belt-truss levels, are exemplified by the Jamsil Lotte World Tower (Seoul, Korea) in its original design. The tower in question consists of three sets of outriggers and six sets of belt trusses [39].

5 Outrigger and Belt-Truss Systems Types

Within the field of structural engineering, outrigger and belt-truss systems exhibit a range of layouts and utilize different structural materials. These systems are specifically designed to offer resilient responses to a wide array of load circumstances. This section classifies these systems based on various perspectives.

5.1 Structural Material Perspective:

- Steel outriggers are commonly employed in tall buildings, particularly in composite or steel structural systems. Traditional designs utilize outriggers that are constructed as trusses, extending across the entire height of a single story [41].
- Concrete outriggers are notable for their cost-effectiveness and exceptional rigidity. They are particularly prominent in situations involving wind loads, where rigidity is of utmost importance. This particular form of prevalence is observed to be more pronounced in concrete structures as opposed to steel structures [41].
- Hybrid or composite outriggers pertain to sophisticated structural systems that combine the favourable characteristics of steel and concrete outriggers, while mitigating their respective limits. Examples that can be used to illustrate this concept include the steel-concrete hybrid outriggers found in the Raffles City Chongqing towers, as well as outriggers that have slender steel cores wrapped in concrete casings, such as buckling restrained braces (BRBs) [29, 41].

5.2 Response Perspective (Behaviour)

- Rigid outriggers, also known as traditional outriggers, are designed to function as rigid, linear elastic structures that have the ability to sustain calculated and service wind loads, as well as occasional seismic loads. As a result, they experience the highest magnitudes of forces when subjected to the greatest lateral deflections (29).
- The category of flexible outriggers involves the utilization of outrigger trusses that have been specifically adjusted to minimize the negative impacts associated with the transfer of gravity forces resulting from differential shortening. Despite this focus on reducing these undesired effects, these outrigger trusses nonetheless offer notable benefits in terms of drift resistance and overall structural stability. Prominent instances encompass the implementation of Vierendeel trusses in architectural structures such as the China World Tower in Beijing and the Petronas Towers in Kuala Lumpur [29].

- Damped outriggers, also known as mechanically damped outriggers, utilize rigid outrigger arms to activate nonlinear damping mechanisms. This implementation successfully mitigates dynamic reactions, including stresses, deformations, and accelerations, experienced by tall structures when exposed to crosswind and seismic pressures. Vortex-induced oscillations (VIO) caused by wind can be effectively mitigated through their application [29]. Diverse damping technologies, such as viscous dampers, viscoelastic dampers, magnetorheological (MR) dampers, and friction dampers, have the potential to be integrated into damped outrigger systems [29].
- The category of yielding outriggers encompasses the utilization of yielding materials in order to reduce the force requirements at connections and members, absorb seismic energy, and uphold structural robustness. Illustrative instances encompass Buckling Restrained Braces (BRBs) and concrete outrigger systems featuring structural fuses, such as shear link connections. Buckling-restrained braces (BRBs) exhibit linear-elastic response under wind loading, demonstrate stable hysteretic behaviour during seismic events, and possess dependable connection requirements [29]. The utilization of steel plate "shear links" in concrete outrigger systems with structural fuses is a method employed to maintain elasticity under wind loads and yield under intense seismic events. This design approach guarantees resistance against overturning and provides the necessary lateral stiffness [29, 41].

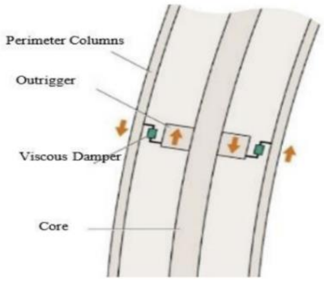


Fig. 2 displays the Innovative Damped Outrigger Concept [40].

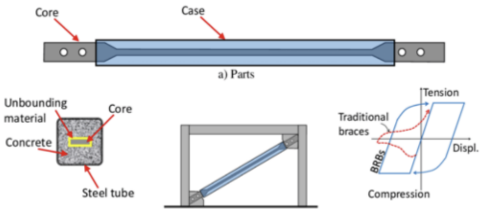


Fig. 3 illustrates the application and implementation of Buckling Restrained Braces (BRBs).

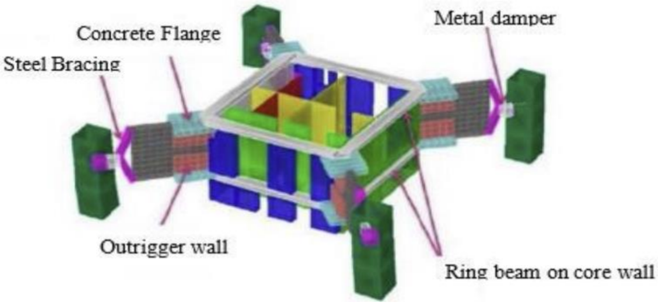


Fig. 4 illustrates the practical application of a concrete outrigger system incorporating a structural fuse (Source: [41])

5.3 Linking Approach Between External and Internal Structural Systems:

- The initial category of outriggers, referred to as direct or conventional outriggers, entails a direct linkage between the central structure of the building and the outer columns by means of rigid outrigger trusses or walls. The primary function of the belt truss is to make a structural connection between the perimeter columns, so facilitating a direct conduit for the transmission of loads from the core to the columns through the outriggers. The aforementioned configuration significantly enhances the overall efficiency of the system [29].

- Indirect or virtual outriggers, which are alternatively referred to as offset outriggers, are a form of support mechanism employed across many applications. This technology, sometimes known as the belt-truss system, shares similar qualities with the direct system. However, it does not involve direct vertical-plane links between core walls and perimeter columns. On the other hand, belt trusses are employed to encircle the periphery of the structure and form a linkage with the columns located along the perimeter. The efficacy of this system is contingent upon the strength and stiffness of the diaphragm, which are critical components. The lack of enough stiffness in the diaphragm results in the independent reaction of the perimeter frame and core to lateral loads, rather than operating as an integrated system. The virtual outrigger is widely recognized for its cost-effectiveness and is frequently employed in high-rise structures due to its manifold advantages, such as the provision of additional space and the mitigation of gravitational forces transmitted through conventional outriggers during differential shortening [22, 29].

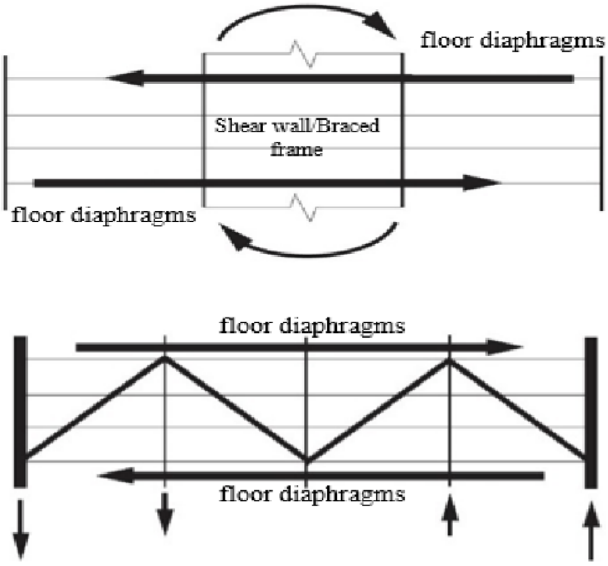


Fig. 5 illustrates the examination of the Virtual Outrigger or Belt Wall System, as sourced from reference [41].

6 Understanding the Function and Load Paths in Outrigger and Belt-Truss Systems

The comprehension of the operational mechanisms and load distribution pathways in outrigger and belt-truss systems. In this section, we will discuss the response of structures to lateral loads. In the context of lateral loads exerted on an outrigger-braced building, two basic techniques are utilized to augment the stability of the structure:

6.1 Stabilizing Lateral Load Effects

6.1.1 Outrigger System: Direct or Conventional

The application of lateral forces results in the building's core being exposed to overturning moments and rotations. Moreover, the application of lateral loads results in the vertical displacement of the points of outrigger trusses. In response, outriggers equipped with columns effectively mitigate these motions by generating counteracting forces. The aforementioned conflicting forces then act as a counterbalance to the original movements, so instigating a reversal in the narrative shear forces present within the core. The reversal of the core's deflection curve results in the establishment of an inflection point, leading to a decrease in overturning moments, rotations, and lateral displacement experienced at the uppermost part of the structure. Significantly, this measure successfully enhances the structural depth of the building when it undergoes deflection as a cantilever. This phenomenon is accomplished through the implementation of compression in the leeward columns and tension in the windward columns, as depicted in Figure 6 [23, 29, 45].

6.1.2 Implementation of an Indirect or Virtual Outrigger System

When subjected to lateral loads, such as those that cause rotation and overturning moments in the core, the floor diaphragms located at belt-truss levels on various floors undergo lateral displacements. The belt-truss, which extends across both levels, endeavors to mimic this motion by rotating and displacing one side downward while elevating the other. The motion of these entities is constrained by the presence of perimeter columns, resulting in the generation of counteracting forces. In general, the corner columns are subjected to the greatest magnitudes of forces. The vertical forces are conveyed by the belt truss, resulting in the generation of opposing horizontal forces inside the floor diaphragms. Consequently, this phenomenon results in the generation of a counteracting tale shear within the central region, leading to a notable decrease in rotational effects and overturning forces [29]. The corner columns are of utmost importance in this design owing to their capacity to withstand the most significant forces.

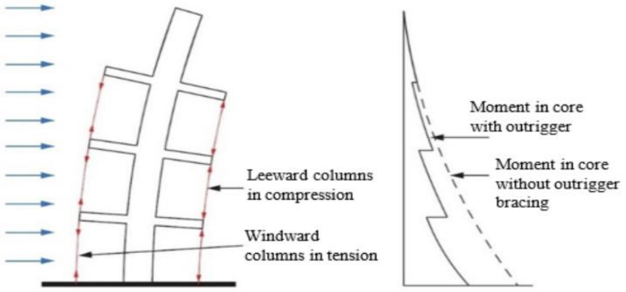


Fig. 6 illustrates the interaction between the building core and outriggers, as sourced from reference [32].

6.2 Analysis of the Effects of Gravity Loads

The fundamental objective of the outrigger system is to augment the lateral stiffness in response to lateral loads. Nevertheless, tall structures are susceptible to a range of phenomena such as differential axial shortening, foundation settling, and the potential for abrupt failure of a specific component or connection capability. These factors can exert gravitational stresses on the outriggers and belt-trusses.

6.2.1 Load Path in the Differential Axial Shortening Phenomenon

The present section discusses the load path associated with the phenomenon of differential axial shortening.
In high-rise structures, minor discrepancies in strain levels within and between columns, as well as between columns and the central core, gradually amass as a result of several variables such as time-dependent deformations encompassing elastic deformation, creep, shrinkage, and thermal deformation. Over the course of time, these disparities result in notable fluctuations in the degree of axial contraction over the vertical extent of the structure. This phenomenon exhibits two primary effects: (i) The displacement of outriggers due to differential movements can lead to the generation of significant forces within the outriggers. These forces facilitate the transfer of a portion of the gravity loads from columns to the core through the outriggers [29]. (ii) The differential movements experienced by belt-trusses connecting adjacent columns can result in strains that generate significant forces within the belt-trusses. These forces enable the transfer of a portion of the gravity loads between adjacent columns through the belt-truss [29].

6.2.2 Load Path in the Foundation Dishing Phenomenon:

Foundation settlement, a common occurrence in tall buildings, is generally caused by variables such as concentrated loads beneath the central core. This leads to differential vertical displacements, creating variations in the vertical positions of the perimeter columns and the core. The observed difference results in the production of significant forces within the outriggers, which subsequently transmit a fraction of the gravitational loads from the central structure to the columns via the outriggers [29].

6.2.3 Load Path in the Event of an Abrupt Reduction in Local Member or Connection Capacity

Another situation in which outriggers assume a critical function is when there is an abrupt decrease in connection capacity or a failure of a local member within the structure. In instances of this nature, outriggers can serve as a viable alternate means of load redistribution in order to mitigate the risk of increasing collapse. Table 2 presents an overview of the potential load pathways.

7 Pros & Cons of Outrigger Systems

7.1 Advantages of Outrigger Systems

The utilization of outrigger systems in high-rise buildings offers several notable advantages:

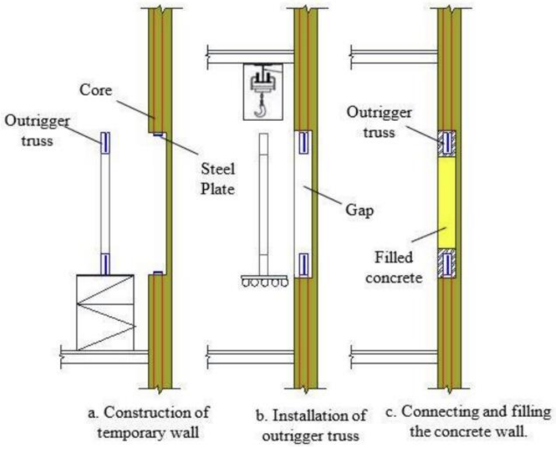
1. High-rise buildings can easily integrate outrigger systems with tube-in-tube, single-frame tube, stand-alone cores with mega columns, and other structural systems.
2. Outriggers are essential for cost-effective and efficient tall building architecture. Integrating the perimeter frame and core's shear wall increases structural system depth and overturning resistance. This reduces structural response to seismic or wind loads, reducing building deformations, lateral displacements at higher levels, core overturning moments, and drift.
3. Outrigger systems reduce structural damage and protect acceleration-sensitive non-structural elements, which can increase floor accelerations.
4. Outriggers improve tall building flexural behavior, improving dynamic stability. This improvement reduces dynamic instability's seismic effects on diagonal bracing and perimeter columns.
5. Conventional outriggers reduce differential shortening and foundation effects. These systems reduce shortening differences between core walls and columns, preventing heat, creep, and shrinkage-induced floor slopes.
6. Outriggers and belt-trusses introduce an alternate load route, increasing structural redundancy and reducing the risk of progressive collapse. The elements' location depends on bending moment, base shear, roof displacement, and strain energy.

7. Material Flexibility: Outrigger systems can be used with concrete, steel, or composite materials, allowing for many design and construction options.
8. Outrigger systems reduce net tension and uplift forces on foundations and columns, reducing mat shear demands in high-rise structures.
9. Outrigger systems allow functional and aesthetic preferences in addition to structural considerations, allowing greater flexibility in determining outside column spacing.
10. Outside framing with simple beam-column connections eliminates the need for rigid-frame connections, saving money. In addition, outrigger systems can integrate gravity columns into the lateral load-resisting system, saving construction costs.
11. Integrated structural configurations like tube-in-tube and multi-level outrigger-belt truss systems improve axial stress distribution. These systems increase column stiffness and uniformly distribute axial stress, reducing shear lag.
12. Outrigger system design must optimize strength and stiffness. These systems can improve acceleration and inter-story drift performance by balancing their configuration.
13. Mechanically damped outrigger systems outperform tuned mass and liquid column dampers in situations requiring additional damping. Both options provide comparable damping without weight, space, or tuning requirements.
14. Torsional stiffness enhancement: Belt-trusses increase the torsional rigidity of outrigger systems, offsetting the lower stiffness of structures with only a core configuration.

7.2 Disadvantages of Outrigger Systems and Solutions

While outrigger systems offer numerous advantages, they also present certain challenges:

1. Occupancy and Space Obstruction: One significant drawback is the potential obstruction of occupancy and rentable space. This issue can be mitigated by various methods, such as placing outriggers in interstitial and mechanical levels, aligning them with the structural profile's natural slopes, using multilevel single diagonal outriggers, offsetting and skewing outriggers to match floor layouts, or adopting virtual outrigger systems.
2. Limited Shear Resistance: Outrigger systems primarily enhance the flexural stiffness of structures but do not significantly contribute to shear resistance, which is mainly borne by the core.
3. Stiffness Irregularities: Outrigger floors can introduce stiffness irregularities, potentially leading to weak stories near outrigger levels under seismic or wind action. However, these issues can be addressed through performance-based analysis and design, ensuring satisfactory behaviour.
4. Construction Impact: The installation of outriggers can impact the construction process, leading to longer construction times for outrigger levels. Techniques like retro-casting, where the core is backfilled with concrete after outrigger installation, can mitigate delays.
5. Shortening Effects: Differential shortening can induce significant axial forces in outrigger elements due to their high stiffness. This issue can be managed by delaying outrigger connection until the building is topped out or by using adjustable outriggers that accommodate shortening effects.
6. Code Limitations: Outrigger systems often exceed the limitations and provisions of building codes not designed for high-rise applications. Performance-based design approaches are recommended by organizations like the Council on Tall Buildings and Urban Habitat (CTBUH) to address these challenges, considering factors like seismic response, ductility, and shear demand.



a. Construction of temporary wall
b. Installation of outrigger truss
c. Connecting and filling the concrete wall.

Fig. 7 displays the construction sequence for the outrigger component, as depicted in reference [39].

8 FACTORS IMPACT OUTRİGGER SYSTEM PERFORMANCE

The performance of outrigger systems is subject to a multitude of influential factors, as identified within the scope of the reviewed literature [20, 22, 24, 28]. These factors encompass:

1. Outrigger Configuration: The location and quantity of outriggers, in conjunction with the structural robustness of the outrigger beams, play a pivotal role.
2. Relative Stiffness Among Components: The relative stiffness between core and outrigger components, as well as between core and perimeter columns, involves several facts:
   i. Flexural and shear stiffness of outriggers and belt-trusses.
   ii. Flexural and axial rigidity of perimeter columns.
   iii. Flexural stiffness of the core.
3. Building Geometry Complexity: Contemporary tall building designs frequently feature intricate architectural forms, including twisted, tilted, and tapered profiles, deviating from simpler architectural paradigms. These complex forms exert a significant influence on the outrigger system's contribution to overall structural stiffness. For instance:

- Twisted shapes may introduce sloping "corkscrew" columns following slab edges, resulting in reduced lateral stiffness, with an escalated stiffness reduction rate corresponding to increased twisting angles. This phenomenon is attributable to the adverse impact of column slopes on their vertical stiffness and the conflicting nature of outrigger action at varying twisting angles.
- Vertical columns, set back from slab edges to accommodate building envelope requirements, also diminish lateral stiffness due to the reduced structural depth of the outrigger lever arm.

4. Diaphragm Stiffness: The stiffness of diaphragms, particularly within virtual outriggers, emerges as a critical determinant.
5. Gravity Force Limits: The permissible limits of gravity forces, arising from differential shortening, transmitted via outriggers must be considered.
6. Building Parameters: Parameters encompassing building height, floor-to-floor height, plan dimensions between core-and-outrigger centroids, and lateral load patterns significantly impact outrigger system performance.
7. Outrigger System Selection: The choice of an appropriate outrigger system hinges upon the prevailing dominant lateral loads and architectural plans. For instance:
   i. Rigid outrigger systems prove advantageous when wind loads predominate.
   ii. Flexible outrigger systems find utility in cases where seismic loads prevail.
   iii. Virtual outrigger systems become preferable when the need for increased free space or the alleviation of gravity forces transferred by conventional outriggers arises.
   iv. Damped outrigger systems are deployed in scenarios where both wind and seismic loads exert influence.

9 TECHNİCAL ADVANCEMENTS İN OUTRİGGER AND BELT TRUSS SYSTEMS RESEARCH

Over the past few decades, the outrigger system has emerged as a prominent lateral load resisting system (LLRS) for high-rise buildings. Its numerous advantages over alternative LLRS solutions have spurred extensive research efforts. These investigations aim to elucidate critical design aspects, enhance system performance, mitigate disadvantages, and facilitate its incorporation into design standards and guidelines. In this review paper, we delve into the primary research domains of outrigger and belt truss systems:

1. Optimal System Topology and Sizing: Numerous studies have focused on determining the optimal configuration and dimensions of outrigger systems. These investigations encompass considerations such as the ideal number and placement of outrigger trusses, the preferred truss forms (outrigger or belt truss), optimal member dimensions, and the configuration of other system constituents, including the core and exterior structural system. Subsequent sections provide an in-depth exploration of these studies.
2. Energy Dissipation Mechanisms: The role of energy dissipation mechanisms in bolstering structural performance against lateral loads, such as wind and seismic forces, has been a key area of research interest. Scholars and designers have examined the damping properties of outrigger systems, investigating both self-damping and supplementary damping devices activated by outrigger arms. Subsequent reviews will expound upon the types, sizes, ideal locations of these damping devices, and their impact on system behaviour.
3. Gravity Load Effects: As previously mentioned, outriggers play a critical role in mitigating the effects of gravity loads caused by differential shortening and foundation settling, as well as preventing progressive collapse following column loss. Research endeavours in this domain have aimed to diminish and control these effects on outrigger systems.
4. Connection Systems: Studies have also scrutinized the influence of connection types between various outrigger system components (e.g., core to outrigger or outrigger to column) under diverse loading conditions.
5. Additional Design Considerations: Numerous studies have delved into other design-related aspects, including the effects of fire and explosions on system behaviour, the impact of diaphragm stiffness on structural performance, and more.

10 CONCLUSİON:

This review serves as a pivotal reference, shedding light on numerous critical facets encompassing the behaviour, constituent elements, and merits and demerits of the outrigger and belt truss structural system. It stands as an indispensable resource for

designers and researchers, especially those venturing into the realm of this specialized field, enabling them to attain a comprehensive and imperative comprehension of this intricate system and its fundamental design principles.
The primary contributions of this paper can be succinctly summarized as follows:

1. Introduction of a pragmatic definition for the outrigger and belt truss system, along with an exploration of diverse system configurations.
2. Deliberation on the varied configurations and structural material options for the outrigger system, coupled with an examination of its requisite response under different load conditions. This culminates in the delineation of several typologies from multiple perspectives, offering designers valuable guidance in making judicious choices.
3. Establishment of a profound understanding of the behavioural dynamics of the outrigger system, accompanied by a lucid exposition of the parameters exerting influence on its performance.
4. Presentation of an exhaustive exposition on the advantages and disadvantages inherent to the outrigger system, along with potential solutions to address its challenges.

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