

# A Comprehensive Review of Vierendeel Column Systems for Multi-Storey Buildings

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**Abstract**—Vierendeel column systems constitute a distinctive class of rigid-frame structures that feature rectangular or square openings without any diagonal bracing. Conceptually, they form an intermediate or hybrid structural typology between beam-column moment-resisting frames and trussed systems, effectively transmitting loads through a combination of bending moments and shear forces, rather than through direct axial tension and compression. This departure from traditional triangulated frameworks allows for rigid joint action, leading to continuous moment distribution and enhanced architectural versatility. The Vierendeel system is fundamentally defined by its aesthetic openness and structural clarity. The absence of diagonal members creates unobstructed architectural spaces and enables the seamless integration of glazed façades, open-plan interiors, and service penetrations, which are highly desirable features in contemporary multi-storey and high-rise buildings. Despite being less material-efficient compared to conventional trusses, the system compensates through its ability to balance engineering efficiency, architectural elegance, and functional adaptability.

Over the years, the concept originating from the pioneering work of Arthur Vierendeel (1896) has evolved significantly, supported by advancements in material science and computational analysis. The integration of finite element modeling (FEM) and nonlinear numerical simulations has allowed engineers to capture complex behaviors such as moment redistribution, shear lag effects, and joint flexibility with high accuracy. Furthermore, innovations in composite construction techniques, involving the use of steel concrete or FRP concrete hybrid members, have enhanced both stiffness and ductility, making Vierendeel columns viable even in tall buildings subjected to substantial lateral forces.

The present paper provides a comprehensive review of the conceptual framework, historical development,

analytical modeling, design methodologies, and performance behavior of Vierendeel column systems. It also examines recent advancements in computational design, parametric optimization, and sustainable materials that have contributed to the system's renewed relevance in modern construction practice. In addition, the paper highlights key advantages and challenges, identifies existing research gaps, and proposes future directions for enhancing the structural and architectural integration of Vierendeel columns in multi-storey and composite buildings. Through this review, it is evident that the Vierendeel column approach represents a fusion of structural engineering and architectural expression, offering a forward-looking paradigm for the design of open, efficient, and visually striking building systems in the 21st century.

**Index Terms**—Vierendeel column, rigid frame, bending moment, shear transfer, multi-storey building, composite system, finite element analysis, architectural transparency.

## I. INTRODUCTION

### 1.1 Background

Structural design in modern architecture has evolved into a multidisciplinary pursuit that must balance engineering performance, architectural freedom, and aesthetic sophistication. The rapid pace of urbanization and vertical expansion in cities across the world has driven the need for multi-storey and high-rise buildings capable of accommodating larger populations and diverse functions within limited urban spaces. These tall structures are subjected to significant gravity and lateral loads—primarily from wind and seismic forces which necessitate efficient

and stable structural systems. Consequently, engineers have long sought configurations that not only ensure safety and serviceability but also allow for functional flexibility and visual openness in architectural design. Traditional braced and trussed systems have been widely adopted in building design due to their proven efficiency in resisting lateral loads through axial force transfer. However, these systems often impose architectural constraints by introducing diagonal bracing members that obstruct openings such as windows, doors, and service ducts. Such constraints hinder open-plan concepts, façade transparency, and aesthetic continuity, particularly in modern architecture where form and function are intended to coexist harmoniously. To overcome these limitations, Belgian engineer Arthur Vierendeel introduced, in 1896, a revolutionary alternative known as the Vierendeel frame.

Vierendeel girder, by definition involves connecting two or more parallel beams connected by members normal to the axis of beams.

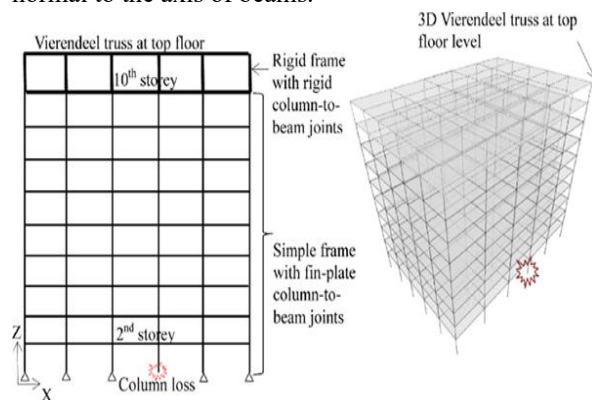


Fig. 1.1: Vierendeel column and truss

The Vierendeel frame departs from the conventional truss concept by eliminating diagonal members altogether and instead relies on rigid joints between horizontal and vertical members to maintain equilibrium. The structure comprises rectangular openings, with loads transmitted primarily through bending moments and shear forces rather than direct axial tension or compression. Each rectangular bay behaves as a miniature portal frame, capable of transferring vertical and lateral loads via flexural action. This design allows for large unobstructed spaces and a clean architectural appearance while maintaining adequate stiffness and strength.

Over the years, the basic concept of the Vierendeel frame has been refined and adapted to meet contemporary engineering challenges. One notable adaptation is the Vierendeel column system, in which multiple Vierendeel frames are stacked vertically to act as primary load-carrying elements in multi-storey structures. These columns not only resist gravity loads but also contribute to the global lateral stability of the building. With the development of finite element modeling techniques, nonlinear analysis methods, and advanced materials such as high-strength steel and composite sections, the Vierendeel concept has regained relevance as a viable system for the structural and architectural integration of modern buildings.

### 1.2 Significance in Modern Construction

In contemporary construction, the Vierendeel column approach holds growing significance due to the increasing demand for transparent façades, large column-free interiors, and integrated structural–architectural solutions. The 21st-century skyline is dominated by buildings that emphasize lightness, openness, and visual continuity, attributes that align closely with the characteristics of the Vierendeel system. The absence of diagonal bracing allows for continuous glazing and curtain wall systems, enabling architects to achieve sleek façades and natural daylighting without structural obstructions.

Moreover, advancements in computational tools such as finite element analysis (FEA) and parametric design optimization have made it possible to model and evaluate the complex bending and shear behavior of Vierendeel systems with high precision. Similarly, the use of composite materials particularly steel–concrete hybrid systems has improved the load-carrying capacity, stiffness, and ductility of Vierendeel columns, addressing earlier concerns about material inefficiency and excessive deflection. These innovations have expanded the applicability of the Vierendeel concept to a range of modern structural typologies, including:

1. Façade frames for commercial and office towers, offering structural support with architectural transparency;
2. Transfer girders at podium or parking levels, enabling redistribution of loads and open lower spaces;
3. Sky bridges, atriums, and long span connectors, where unobstructed circulation and aesthetic appeal are essential; and

4. Composite building frames, integrating steel and reinforced concrete to optimize both stiffness and weight.

The growing interest in parametric and performance-based design approaches has further strengthened the role of the Vierendeel column in architectural engineering. By allowing flexible geometry and load-path control, these systems enable designers to explore innovative façade morphologies and nonlinear performance optimization, ensuring that both structural integrity and aesthetic vision are achieved simultaneously.

### 1.3 Objectives of the Review

The primary objective of this review is to provide a comprehensive understanding of the Vierendeel column system and its role in the structural design of modern multi-storey buildings. Specifically, the paper aims to:

1. Explain the fundamental behavior of Vierendeel column systems, focusing on their load transfer mechanisms, moment–shear interactions, and overall structural response under vertical and lateral loads.
2. Review and summarize existing literature, tracing the evolution of the Vierendeel concept from its historical origins to its modern applications in composite and high-rise structures.
3. Highlight analytical, experimental, and numerical methods used in the performance evaluation and design of Vierendeel systems, including finite element and parametric modeling techniques.
4. Identify the key advantages, challenges, and research gaps associated with the application of Vierendeel columns in multi-storey buildings, emphasizing opportunities for future innovation in materials, design optimization, and sustainability.

Through these objectives, the study aims to bridge the gap between architectural aspirations and structural realities, showcasing the Vierendeel column approach as a holistic design solution that merges functionality, strength, and elegance within the evolving framework of modern construction technology

## II. REVIE OF LITERATURE

A considerable amount of research has been conducted over the past century on the behavior, analysis, and design of Vierendeel structures, from their conceptual inception in the late 19th century to their modern

computational and composite applications. The following section presents a chronological and thematic review, focusing on major milestones in theoretical development, experimental validation, numerical modeling, and practical implementation of Vierendeel column systems in multi-storey buildings.

### 2.1 Early Studies and Historical Development

The concept of the Vierendeel frame was first introduced by Arthur Vierendeel (1896), a Belgian civil engineer who challenged the conventional reliance on diagonally braced trusses. He proposed a rigid rectangular girder system that derived its stability purely from moment continuity at the joints, rather than axial triangulation. This was a revolutionary departure from classical truss theory and established the foundation for a new class of bending-dominated structures. Early applications of Vierendeel girders were primarily observed in bridge construction and roof systems, where both aesthetic appeal and open, unobstructed spans were desirable.

During the 1930s, European engineers such as Franz Dischinger extended the Vierendeel concept to steel bridge design, applying elastic analysis methods to investigate bending and shear interactions. These studies provided the first analytical insights into the complex moment–shear behavior characteristic of Vierendeel systems, particularly emphasizing the need for accurate modeling of joint rigidity and local stress concentrations at panel corners. These pioneering works collectively laid the groundwork for the later application of Vierendeel frames in architectural and building structures, marking the transition from purely aesthetic interest to a technically viable structural system.

### 2.2 Analytical and Theoretical Investigations

With the mid-20th century came substantial progress in the analytical modeling of rigid frame systems, which further enhanced the understanding of Vierendeel action. Timoshenko and Gere (1961) developed the fundamental elastic formulations for continuous rigid frames, providing theoretical tools for analyzing structures subjected to combined bending and shear forces. These formulations became the cornerstone for modern Vierendeel analysis, particularly for evaluating deflection profiles, moment distributions, and stress interactions within rectangular panels.

Subsequently, Horne and Merchant (1965) introduced simplified analytical procedures for moment and shear

evaluation in rigid frames, facilitating practical design calculations for Vierendeel panels. Their methods allowed designers to approximate internal force distributions without relying on complex elasticity theory, bridging the gap between theoretical and applied engineering.

In more recent years, Lantsoght and De Backer (2010) conducted a comprehensive investigation into the shear behavior of Vierendeel girders, highlighting the importance of nonlinear moment–shear coupling. Their research revealed that shear deformation plays a significant role in influencing the stiffness, ductility, and ultimate load capacity of Vierendeel structures. Building on these findings, Zhao and Chen (2021) employed nonlinear finite element analysis (FEA) to predict plastic hinge formation, yield mechanisms, and ultimate load capacity in reinforced concrete Vierendeel panels. Their results demonstrated that accurate representation of material nonlinearity and joint flexibility is critical for predicting real structural behavior, especially under high-magnitude lateral loads.

### 2.3 Experimental Research

Experimental research has played a vital role in validating analytical theories and numerical models for Vierendeel systems. Nakamura et al. (1997) performed one of the earliest systematic experimental studies on steel Vierendeel frames, subjecting scaled models to cyclic loading conditions to simulate seismic actions. Their results confirmed the ductile flexural response of the system and demonstrated that plastic hinge formation occurs primarily near panel corners, consistent with theoretical predictions.

Later, Kim, Lee, and Park (2018) focused on the seismic performance of high-rise façade-type Vierendeel frames, examining the effects of joint rigidity on overall energy dissipation and post-yield behavior. Their experiments revealed that semi-rigid connections could enhance energy absorption capacity and post-elastic stability, suggesting a viable approach for improving earthquake resistance without compromising architectural openness.

In a similar vein, Lee et al. (2020) conducted a combined experimental and numerical study to investigate deflection control in Vierendeel frames with large rectangular openings. Their work provided empirical stiffness modification factors that can be used in simplified design equations, bridging the gap between full-scale testing and practical engineering

application. Collectively, these studies highlight the continued relevance of physical experimentation in verifying computational models and refining design recommendations for Vierendeel columns and girders.

### 2.4 Finite Element Modeling and Numerical Analysis

The advent of advanced finite element analysis (FEA) software has revolutionized the study of Vierendeel structures by enabling detailed simulations of stress flow, deformation, and local instability. Chen and Lui (2014) developed nonlinear finite element models to capture moment redistribution, local buckling, and plastic hinge propagation in steel Vierendeel columns. Their models accounted for both geometric and material nonlinearities, leading to improved prediction of ultimate failure mechanisms.

Following this, El-Damatty and Korol (2016) used 3D finite element simulations to visualize stress trajectories and identify critical stress zones near panel corners and joints. Their research provided valuable insights into localized stress concentrations and the influence of joint stiffness on the global response of the structure. More recent works, such as those by Zhao et al. (2021) and Lee (2020), have incorporated joint flexibility and geometric nonlinearity into the modeling framework, yielding enhanced accuracy in predicting nonlinear load-deflection behavior and progressive collapse mechanisms.

With the evolution of computational design paradigms, AI-driven optimization techniques have begun to emerge in recent years (2023–2024). Methods such as genetic algorithms, machine learning regression, and topology optimization are now being applied to automate the configuration of Vierendeel openings and member sizing for optimal performance. These developments represent the frontier of Vierendeel research, merging classical structural mechanics with modern computational intelligence to create performance-based and resource-efficient designs.

### 2.5 Application Oriented Studies

Parallel to analytical and numerical advancements, a significant body of research has explored practical applications of Vierendeel columns in real-world construction. Pang et al. (2015) demonstrated the effectiveness of Vierendeel columns as transfer elements in high-rise buildings, where they facilitated load redistribution between podium and tower levels without obstructing architectural spaces. Their work

underscored the structural efficiency and aesthetic versatility of the system in mixed-use developments. Further, Rajendran and Kumar (2017) investigated reinforced concrete (RC) Vierendeel façade columns using commercial software such as ETABS to simulate their behavior in multi-storey buildings. They observed significant improvements in lateral stiffness and deflection control compared to conventional flat-plate structures, confirming the system's suitability for tall buildings subjected to wind and seismic loads.

In a recent contribution, Sharma and Patel (2020) proposed the use of composite steel concrete Vierendeel columns, where concrete infill provided additional stiffness and load-carrying capacity. Their study revealed a 35% improvement in ultimate strength over steel-only configurations, highlighting the benefits of composite action in enhancing both strength and serviceability. These application-oriented studies collectively demonstrate that the Vierendeel column approach is not merely a theoretical concept but a practically adaptable system capable of meeting the complex architectural and structural demands of contemporary high-rise construction.

## 2.6 Summary of Literature Review

The progression of Vierendeel research—from Arthur Vierendeel's pioneering idea to today's advanced computational models illustrates a century-long evolution of thought, experimentation, and application. The body of literature reveals a consistent effort to enhance the structural efficiency, material performance, and aesthetic integration of Vierendeel systems. Despite their inherent bending-dominated nature, modern analyses, composite materials, and optimization algorithms have transformed them into feasible and competitive alternatives for façade systems, transfer structures, and column frameworks in multi-storey buildings.

However, research gaps remain in areas such as progressive collapse behavior, long-term deflection control, and dynamic performance under extreme loading conditions. Addressing these gaps through interdisciplinary approaches involving structural mechanics, materials science, and computational intelligence will be crucial for realizing the full potential of Vierendeel column systems in next-generation architectural engineering.

## 2.7 Research gap identified

Despite extensive research on Vierendeel column systems, several critical gaps limit their widespread

application in modern structural design. A major issue is the lack of dedicated codified design provisions in standards such as IS 800, AISC 360, and Eurocode 3. Existing codes provide general guidance for moment-resisting frames but do not specifically address the unique moment shear interaction, deflection behavior, and joint detailing of Vierendeel systems, forcing designers to rely on empirical methods or conservative assumptions.

Another gap lies in the insufficient large-scale experimental studies, particularly for seismic performance in multi-storey and high-rise structures. While small-scale tests and numerical models exist, the nonlinear interaction of bending, shear, and joint flexibility under earthquake loading remains poorly understood, limiting the development of reliable seismic design guidelines.

Further, optimization of geometric and material parameters is underexplored. Factors such as panel spacing, depth-to-span ratios, and material distribution significantly influence stiffness, deflection, and efficiency, yet most studies adopt fixed assumptions rather than using parametric or AI-based optimization. Other under-researched areas include long-term behavior (creep, shrinkage, fatigue), and fire resistance and durability of steel and composite Vierendeel columns. Addressing these gaps through advanced simulations, large-scale testing, and multi-physics modeling will enhance their reliability and practical applicability in next-generation high-performance multi-storey buildings.

# III. CONCEPT OF VIERENDEEL COLUMNS

## 3.1 Definition and Geometry

A Vierendeel column is a specialized form of a vertical frame composed of rectangular openings formed by rigidly connected horizontal beams (chords) and vertical posts. Unlike conventional trussed systems, which rely on diagonal bracing to resist shear, Vierendeel columns maintain stability purely through moment continuity at rigid joints. Each rectangular opening within the column behaves as a miniature portal frame that can resist both vertical and lateral loads through bending and shear actions. The structural system thus represents a hybrid between beam-column frames and trusses, combining the aesthetic appeal of unobstructed openings with the

structural functionality of a continuous frame system. The geometry of Vierendeel columns provides visual transparency and design flexibility, making them particularly suitable for façade integration, open spaces, and architecturally expressive structures.

### 3.2 Load Transfer Mechanism

The fundamental distinction of the Vierendeel system lies in its mode of load transfer, which eliminates diagonal bracing altogether. Instead, loads are transmitted through bending moments in both the vertical and horizontal members, shear forces acting across the vertical panels, and axial compression or tension in the chords due to the global frame action. As a result, the Vierendeel column behaves as a continuous bending structure where internal forces are distributed and redistributed among members through joint rigidity. This mechanism inherently increases the importance of moment transfer capacity at joints and the stiffness of connecting members.

### 3.3 Comparison with Conventional Systems

When compared to conventional braced or trussed frames, the Vierendeel system exhibits several unique characteristics. While braced frames primarily carry loads through axial forces, Vierendeel frames depend on bending and shear. Consequently, their structural efficiency is moderate rather than high, as bending-dominated systems generally require larger member sizes. However, they provide exceptional architectural flexibility by eliminating diagonal braces, allowing for unobstructed openings. Although deflection levels tend to be higher due to flexural deformation, the Vierendeel frame achieves superior aesthetic appeal. The main drawback lies in fabrication complexity, as rigid joints demand precise detailing and quality control, especially in steel and composite configurations.

### 3.4 Structural Behavior

#### *Bending Action*

Each rectangular bay of a Vierendeel column functions like a small rigid frame subjected to bending. Under vertical loads, significant moments develop at the joints, with the upper chord of each opening experiencing compression and the lower chord tension, similar to the flexural behavior of a continuous beam. These moments are crucial in determining member sizing and joint reinforcement, as localized plastic hinge formation can occur at ultimate load conditions.

#### *Shear Behavior*

In contrast to trussed systems where shear is resisted through diagonal members, the Vierendeel frame must rely on bending-induced mechanisms within its vertical members. This results in shear lag and nonlinear stress distribution along the panel height. The absence of triangulation increases the influence of shear deformation, contributing significantly to total deflection. Accurate prediction of this shear component is essential in the analysis and design stages, particularly for tall or slender frames.

#### *Moment Distribution*

The internal moment distribution within a Vierendeel column is non-uniform and complex. Maximum positive moments typically occur at the mid-spans of horizontal members, while negative moments are concentrated at rigid joints. In addition, secondary bending occurs in the vertical members due to differential joint rotations. This nonlinearity necessitates refined analytical or numerical modeling techniques, such as matrix stiffness methods or finite element analysis, to accurately capture the moment–shear interaction.

#### *Deflection Characteristics*

Deflection control is one of the primary design challenges for Vierendeel columns. Because their primary resistance mechanism is flexural rather than axial, deflections tend to be larger than in trussed or braced frames.

### 3.5 Design Considerations

#### *Material Selection*

The performance of a Vierendeel column system largely depends on the materials used. Steel Vierendeel columns offer high stiffness, ductility, and fabrication precision, making them ideal for slender façade structures and sky bridges. Reinforced concrete (RC) Vierendeel columns provide greater mass, fire resistance, and cost-effectiveness, making them well-suited for podiums and architectural façades. Composite Vierendeel columns, combining steel and concrete, offer the benefits of both—enhanced stiffness, reduced deflection, and improved damping characteristics—making them favorable for high-rise applications where both strength and serviceability are critical.

#### *Design Methodology*

Designing a Vierendeel column involves multiple steps. Preliminary sizing is typically based on an equivalent beam analogy to estimate member stiffness and deflection. The structural analysis is then

performed using matrix stiffness methods or finite element modeling to capture realistic load paths. Following this, designers must verify the interaction between bending moment and shear at joints, check deflection limits under service loads, and ensure ultimate strength under combined loading conditions. Although specific codified provisions for Vierendeel systems are limited, general frame design codes such as IS 800:2007 (for steel structures), AISC 360-16 (for American standards), and Eurocode 3 provide adaptable guidelines.

#### *Joint Design*

The behavior of Vierendeel columns is heavily dependent on the rigidity and integrity of their joints. In steel frames, rigid joints are typically achieved using full penetration welds and stiffened end plates. In reinforced concrete, corner zones are strengthened with additional reinforcement and confinement detailing. Composite connections often use shear connectors, headed studs, or embedded plates to achieve effective composite action. Proper joint detailing is essential to ensure moment transfer and prevent premature failure or excessive deformation.

#### 3.6 Analysis Methods

##### *Analytical Methods*

Early analytical methods for Vierendeel analysis relied on simplified moment distribution or slope-deflection techniques, which are suitable only for small systems. However, due to the geometric nonlinearity of the structure and the coupled nature of bending and shear deformation, such analytical approaches are limited to preliminary design or academic illustration.

##### *Finite Element Analysis (FEA)*

Finite element analysis has become the most reliable approach for modeling and evaluating Vierendeel systems. FEA can capture geometric and material nonlinearities, joint rigidity variations, and localized buckling effects. Advanced software platforms such as ANSYS, STAAD.Pro, and ETABS allow comprehensive 3D modeling of full-height Vierendeel frames, including their integration with floor systems and shear walls. Such simulations accurately predict load-displacement behavior under static, dynamic, and seismic conditions, enabling performance-based design.

##### *Experimental Studies*

Experimental research complements numerical models by validating analytical assumptions. Laboratory tests typically focus on load-deflection

relationships, strain distribution in chords and verticals, and the formation of plastic hinges. Tests have demonstrated that with appropriate detailing, Vierendeel columns exhibit significant ductility and predictable failure modes, confirming their suitability for use in seismic regions when properly designed.

##### *Applications in Multi-Storey Buildings*

Vierendeel column systems are increasingly applied in modern architectural and structural design. In architectural façades, they support transparent curtain walls and glazed exteriors, enhancing the visual appeal of tall buildings. In transfer floors and podiums, Vierendeel frames create open spaces for parking, lobbies, or retail zones by transferring loads around large openings. Sky bridges and atriums utilize these systems for long spans where both strength and elegance are required. Furthermore, in composite high-rise buildings, Vierendeel columns are often integrated with outrigger or shear wall systems to enhance global stiffness and lateral stability. They also find application in retrofit projects, where prefabricated steel Vierendeel modules are used to strengthen or reconfigure existing structures without major architectural disruption.

#### 3.7. Advantages and Limitations of Vierendeel columns

Vierendeel columns provide several distinct advantages. Their configuration allows for unobstructed openings, facilitating mechanical ducts, glazing, or pedestrian passageways. They enhance architectural aesthetics by offering sleek, transparent façades while maintaining structural functionality. The absence of diagonal braces provides spatial flexibility, making them ideal for open-plan designs. Moreover, Vierendeel systems can be efficiently integrated into hybrid structural systems such as composite or outrigger-supported frames. They also simplify service integration, particularly in building façades where functional and aesthetic requirements must coexist.

Despite their advantages, Vierendeel systems possess inherent limitations. The reliance on bending rather than axial load transfer leads to higher stresses in members and joints, reducing structural efficiency compared to trusses. Deflection control becomes critical, especially for large spans. Joint fabrication demands precision and is often more expensive due to the need for rigid moment connections. Additionally, the system's sensitivity to buckling and second-order

effects requires detailed analysis. Another significant limitation is the absence of specific codified design provisions for Vierendeel columns in most national standards, compelling engineers to rely on general frame design principles and experimental data.

### 3.8 Recent Research and Developments

Recent advancements have significantly enhanced the understanding and performance of Vierendeel columns. Finite element-based nonlinear analyses, such as those by Kim et al. (2018), have clarified the stress flow and moment redistribution mechanisms. Chen and Lui (2014) demonstrated improved stiffness and ductility through composite Vierendeel systems. Seismic performance studies have shown that semi-rigid connections increase energy dissipation and improve post-yield behavior. Furthermore, topology optimization has led to reductions in material usage without compromising stiffness, while 3D-printed steel joints have enabled precise fabrication of complex geometries. Emerging technologies like artificial intelligence (AI), parametric modeling through Rhino-Grasshopper, and performance-based seismic design frameworks are revolutionizing how Vierendeel systems are analyzed and optimized.

## IV. SUMMARY

The Vierendeel column system integrates structural engineering and architectural design, transferring loads primarily through bending and shear in rigidly connected rectangular openings. Unlike conventional trussed or braced systems, it achieves stability and stiffness through moment redistribution at rigid joints, enabling open façades, column-free interiors, and flexible layouts in multi-storey and high-rise buildings.

Although bending-dominated and material-intensive, Vierendeel columns offer advantages in aesthetics, spatial functionality, and façade integration. Composite materials such as steel-concrete or FRP-concrete enhance stiffness, ductility, and fire resistance, making them suitable for tall structures. Advanced computational tools, including finite element analysis, parametric modeling, and optimization algorithms, allow precise evaluation of moment-shear interaction, deflection, and joint behavior, bridging theoretical and practical design. Emerging high-performance materials, along with digital fabrication and 3D-printed joints, mitigate

fabrication complexity and improve constructability. Effective in façade frames, atriums, transfer floors, and podiums, Vierendeel columns, when integrated with outrigger or shear-core systems, provide both structural efficiency and architectural expression, ensuring their continued relevance in modern multi-storey architecture

## V. CONCLUSION

The Vierendeel column system provides a unique structural solution, transferring loads through bending and shear in rigid rectangular frames. It enables open façades, column free interiors, and architectural flexibility, making it ideal for modern multi-storey buildings. While bending dominated, its performance is enhanced through composite materials, advanced computational analysis, and digital fabrication, improving stiffness, ductility, and constructability. Integration with outrigger systems and hybrid frames ensures global stability and lateral resistance. Despite challenges in deflection control, joint detailing, and codified design provisions, ongoing research and material innovations make Vierendeel columns a versatile and aesthetically appealing structural option for contemporary architecture.

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