



Comparative Review of Seismic Response and Structural Behavior of Industrial Steel Truss Geometries

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<https://doi.org/10.55041/ijst.v2i6.036>

Cite this Article: Pankaj, (2026). COMPARATIVE REVIEW OF SEISMIC RESPONSE AND STRUCTURAL BEHAVIOR OF INDUSTRIAL STEEL TRUSS GEOMETRIES. International Journal of Science, Strategic Management and Technology, 02(6). <https://doi.org/10.55041/ijst.v2i6.036>

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ABSTRACT

Industrial steel trusses are extensively used in long-span industrial buildings due to their high strength-to-weight ratio, structural efficiency, and adaptability for large unobstructed spaces. However, the seismic performance of truss systems is significantly influenced by their geometric configuration, load-transfer mechanism, stiffness characteristics, and energy dissipation behavior under dynamic loading conditions. This review paper presents a comprehensive assessment of the geometric influence on the seismic response and resilience of commonly used industrial steel truss systems, including Pratt, Howe, Warren, Fink, and Vierendeel trusses. The study synthesizes findings from recent analytical, numerical, and experimental investigations related to truss behavior under cyclic and earthquake-induced loading. The review evaluates the seismic performance of different truss geometries in terms of ductility, stiffness degradation, redundancy, load redistribution capability, hysteretic energy dissipation, and buckling susceptibility. Furthermore, the paper examines the role of computational modeling techniques such as SAP2000, STAAD.Pro, OpenSees, and nonlinear finite element approaches in predicting the structural response of steel truss systems subjected to seismic excitation. Current seismic code provisions and design approaches, including AISC 341, ASCE 7, Eurocode 8, and IS 800:2007, are also critically reviewed with respect to industrial steel truss applications.

The collected literature indicates that Warren truss configurations generally exhibit superior seismic redundancy and more stable energy dissipation characteristics due to their balanced force distribution and reduced stress concentration. In contrast, Vierendeel systems demonstrate comparatively lower seismic efficiency because of their bending-dominated behavior and reduced geometric stability. The review further identifies significant research gaps associated with semi-rigid connection modeling, nonlinear cyclic behavior, soil-structure interaction effects, and performance-based seismic assessment of industrial truss systems.

This paper provides a consolidated technical framework for understanding the relationship between truss geometry and seismic behavior, thereby supporting future research and aiding engineers in the selection and seismic evaluation of industrial steel truss configurations.

Keywords: Industrial steel truss systems; Seismic performance; Truss geometries; Dynamic loading; Finite element analysis; Hysteretic behavior; Nonlinear seismic assessment



1. Introduction

Industrial steel structures constitute a major portion of modern infrastructure systems used for manufacturing facilities, warehouses, logistics centers, aircraft hangars, and heavy industrial plants. Among the various structural systems employed in such facilities, steel trusses are extensively preferred for long-span roof applications because of their high strength-to-weight ratio, efficient load transfer mechanism, ease of fabrication, and economic suitability for large unobstructed spaces.(ARISOY & YAVUZ, 2023) The triangulated configuration of truss systems enables the applied loads to be primarily resisted through axial tension and compression forces, thereby minimizing bending effects and improving structural efficiency under service loading conditions.(Patil et al., 2020)

In seismic regions, however, the structural behavior of steel trusses becomes significantly more complex due to the dynamic nature of earthquake-induced loading. Unlike gravity loads, seismic excitations generate cyclic lateral forces, inertia effects, stress reversals, and large displacement demands within the structural system. These dynamic actions may result in stiffness degradation, local member buckling, excessive vibrations, connection failures, and progressive reduction in the energy dissipation capacity of the structure.(Karayel & Ozay, 2026) Consequently, the seismic performance of industrial truss systems depends not only on material strength but also on geometric configuration, redundancy, ductility, and the capability of the structure to redistribute internal forces during cyclic loading.(Tang et al., 2026)(Liu et al., 2025)

The geometric arrangement of truss members plays a critical role in determining structural response under seismic excitation. Different truss configurations, including Pratt, Howe, Warren, Fink, and Vierendeel systems, exhibit distinct load paths, stiffness characteristics, and deformation mechanisms. Truss systems with balanced force distribution and higher redundancy generally demonstrate improved seismic stability and energy dissipation behavior, whereas geometries dominated by slender compression members or bending-sensitive joints may exhibit increased vulnerability under cyclic loading conditions. Therefore, the selection of an appropriate truss geometry is an important aspect in the seismic design and evaluation of industrial steel buildings. (ARISOY & YAVUZ, 2023)(Patil et al., 2020)

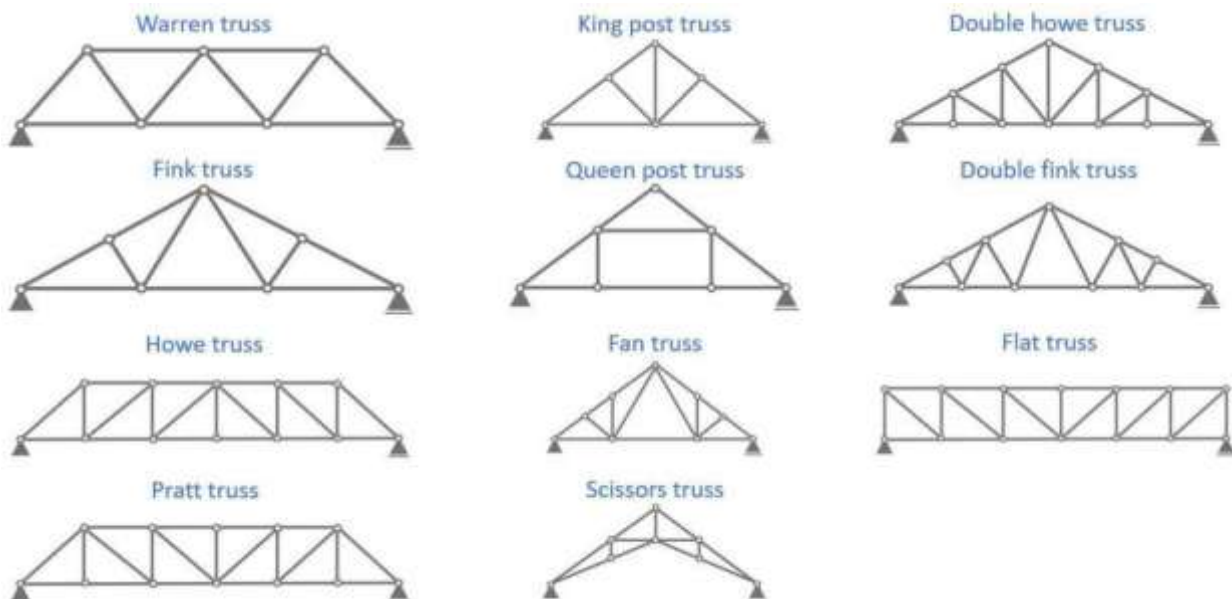
Recent developments in computational structural engineering have enabled detailed assessment of seismic behavior through advanced numerical modeling and finite element analysis. Software platforms such as SAP2000, STAAD.Pro, ABAQUS, and OpenSees are widely employed for static, dynamic, nonlinear, and performance-based seismic analysis of steel structures. These tools facilitate accurate prediction of stress distribution, deformation patterns, plastic hinge formation, hysteretic response, and energy dissipation characteristics under earthquake loading. In addition, modern seismic design approaches increasingly emphasize resilience-based design, controlled inelastic behavior, and damage mitigation through supplemental damping and energy dissipation mechanisms.(Naathan et al., 2023a; Tang et al., 2026; Wu et al., 2025)

Several international codal provisions and seismic design guidelines, including AISC 341, ASCE 7, Eurocode 8, FEMA recommendations, and IS 800:2007, provide design criteria for steel structures subjected to seismic loading. These standards focus on ensuring adequate ductility, stiffness, strength hierarchy, and controlled failure mechanisms in structural systems exposed to earthquake excitation. Nevertheless, despite considerable research on industrial steel trusses, existing literature reveals that comparative understanding of the seismic influence of different truss geometries remains limited, particularly in relation to nonlinear cyclic behavior, redundancy characteristics, and long-term seismic resilience. (AISC 341-16; ASCE 7-22; Eurocode 8; IS 800:2007)

The present review paper aims to provide a comprehensive assessment of the influence of truss geometry on the seismic behavior and resilience of industrial steel truss systems. The study critically reviews analytical, numerical, and experimental investigations related to commonly used truss configurations and evaluates their performance in terms of stiffness, ductility, energy dissipation, buckling resistance, and seismic load redistribution capability. Furthermore, the review discusses current seismic analysis methodologies, codal provisions, and research gaps associated with industrial steel truss systems. The findings presented in this paper are intended to support future research and assist structural engineers in selecting suitable truss configurations for earthquake-resistant industrial structures.

2. Fundamentals of Truss Geometry and Seismic Response

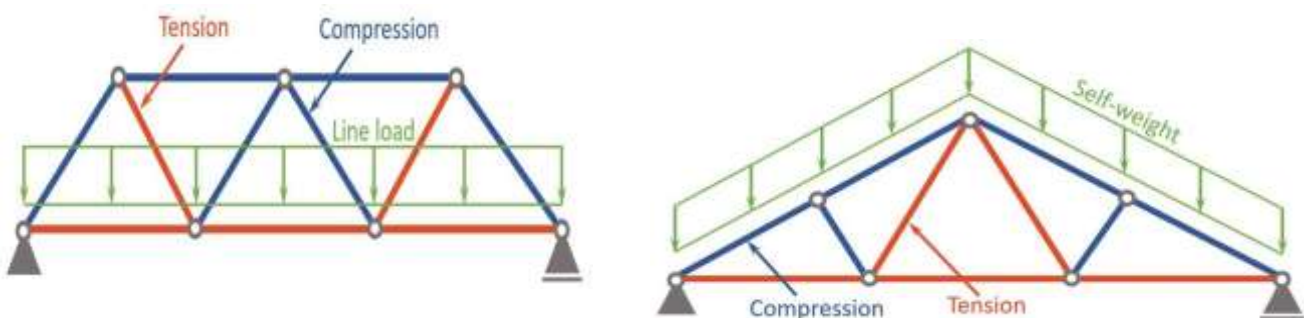
Steel truss systems are widely used in industrial structures due to their ability to efficiently resist large loads over long spans while maintaining relatively low structural weight. A truss is generally composed of interconnected straight members arranged in triangular configurations, where external loads are primarily transferred through axial tension and compression forces. Unlike conventional beam systems, trusses minimize bending moments within members, thereby improving structural efficiency and reducing material consumption. The overall seismic performance of a truss system depends not only on material properties but also on geometric configuration, member arrangement, connection behavior, and load transfer mechanisms. (Patil et al., 2020)(ARISOY & YAVUZ, 2023)



Under seismic excitation, industrial steel trusses are subjected to dynamic lateral forces generated due to structural inertia. These earthquake-induced forces produce cyclic loading conditions that may lead to repeated stress reversals, stiffness degradation, connection distress, local buckling, and progressive accumulation of structural damage. In contrast to gravity loading, seismic loading is highly dynamic and time-dependent, requiring structural systems to possess sufficient ductility, redundancy, and energy dissipation capacity to maintain stability during strong ground motion. Consequently, the geometric arrangement of truss members plays a crucial role in determining seismic response characteristics such as displacement demand, force redistribution, vibration behavior, and collapse resistance. (Liu et al., 2025; Rodríguez et al., 2024)

Truss Force Distribution

The efficiency of a truss system is primarily governed by its ability to distribute applied loads through axial force transfer mechanisms. In ideal truss behavior, joints are assumed to be pin-connected and external loads are transferred directly through members in either tension or compression. The top chord members generally resist compressive forces, whereas bottom chord members predominantly resist tensile forces under gravity loading conditions. Web members contribute to internal force redistribution by transferring shear forces between chord members. The force distribution pattern significantly depends on the truss geometry, panel configuration, span length, support conditions, and loading characteristics. (Patil et al., 2020)



Different truss configurations exhibit distinct force distribution mechanisms. In Pratt trusses, diagonal members primarily resist tension forces while vertical members resist compression under gravity loading. Howe trusses demonstrate the opposite behavior, where diagonal members are generally subjected to compression. Warren trusses distribute loads through alternating diagonal members, resulting in relatively uniform force transfer and reduced stress concentration. In contrast, Vierendeel trusses rely heavily on bending resistance due to the absence of diagonal members, leading to increased joint moments and reduced structural efficiency under dynamic loading conditions. These geometric differences directly influence stiffness characteristics, load redistribution capability, and seismic resistance of the structural system. (ARISOY & YAVUZ, 2023) (Mounika & Mounika, 2020)

During earthquake excitation, stress reversals may occur repeatedly within truss members due to cyclic lateral loading. Members initially subjected to tension may subsequently experience compression, increasing the possibility of local instability and buckling failure in slender members. Therefore, truss systems possessing balanced force distribution and higher redundancy generally demonstrate improved seismic performance and reduced susceptibility to progressive collapse mechanisms (Rodríguez et al., 2024; Wu et al., 2025)

Seismic Load Transfer Mechanism

Seismic forces acting on industrial steel trusses originate from inertial effects generated by structural mass during ground motion. These forces are transferred through the roof diaphragm, purlins, truss members, columns, and foundation system before ultimately dissipating into the ground. The efficiency of this load transfer mechanism depends on continuity of load paths, connection rigidity, member stiffness, and overall structural configuration. Inadequate load transfer paths may result in stress concentration, excessive deformation, or premature connection failure during severe seismic events. (AISC 341-16; ASCE 7-22)



Under lateral seismic loading, industrial truss systems may experience combined axial, shear, and bending actions due to dynamic interaction between structural components. Earthquake loading also induces higher mode effects, torsional irregularities, and amplification of displacement response in long-span roof systems. The seismic response is strongly affected by structural mass distribution, damping characteristics, natural vibration frequencies, and geometric stiffness of the truss configuration. Structures possessing lower stiffness generally experience larger displacement demands, whereas excessively stiff systems may attract higher seismic forces. Therefore, achieving an appropriate balance between stiffness and ductility is essential for seismic-resistant truss design. (Rodríguez et al., 2024)

Modern seismic design approaches emphasize controlled inelastic behavior and energy dissipation through ductile structural response. During severe earthquakes, energy dissipation occurs through yielding, hysteretic behavior, frictional mechanisms, and controlled plastic deformation within structural members and connections. Truss geometries capable of redistributing forces effectively after local yielding generally demonstrate improved seismic resilience and collapse resistance. Supplemental damping systems and friction-based energy dissipation devices have also been increasingly investigated to improve seismic stability of steel truss systems. (Liu et al., 2025; Tang et al., 2026)

Geometric Influence on Structural Behavior

The geometric configuration of a truss system significantly influences its stiffness, strength, deformation characteristics, and seismic performance. Parameters such as panel arrangement, truss depth, member inclination, aspect ratio, and joint configuration affect the overall structural response under both static and dynamic loading conditions. Geometries with efficient triangulation generally provide improved force transfer and enhanced structural stability compared to bending-dominated systems. (Patil et al., 2020)

Pratt and Warren truss systems are commonly preferred for industrial applications because of their favorable axial force distribution and relatively efficient load transfer behavior. Warren trusses, in particular, often demonstrate improved redundancy and smoother stress redistribution under cyclic loading due to their repetitive triangular arrangement. Howe trusses may exhibit higher compression demands in diagonal members, increasing the possibility of local buckling under severe seismic excitation. Fink trusses are effective for roof applications with moderate spans; however, their seismic behavior depends significantly on connection detailing and load distribution patterns. In contrast, Vierendeel trusses experience substantial bending moments at joints because of the absence of diagonal bracing, making them comparatively less efficient under dynamic seismic loading. (ARISOY & YAVUZ, 2023; Patil et al., 2020)

In addition to geometry, connection behavior strongly affects overall seismic response. Semi-rigid or poorly detailed joints may reduce stiffness and increase deformation demands during cyclic loading. Similarly, slender compression members may experience premature local or global buckling under repeated stress reversals. Therefore, seismic performance assessment of industrial steel trusses requires integrated consideration of geometry, connection detailing, material behavior, and nonlinear structural response characteristics. (Naathan et al., 2023b; Rodríguez et al., 2024)

3. Literature Review

The seismic behavior of industrial steel trusses has been extensively investigated through analytical, numerical, and experimental studies over the past decade. Researchers have primarily focused on evaluating the influence of truss geometry, force distribution characteristics, stiffness variation, and dynamic response under seismic loading conditions. Different truss configurations exhibit distinct



structural behavior because of variations in load transfer mechanisms, member orientation, redundancy, and connection detailing. Modern investigations increasingly incorporate nonlinear finite element analysis, cyclic loading assessment, and performance-based seismic evaluation methods to better understand the seismic resilience of steel truss systems. (Naathan et al., 2023b; Rodríguez et al., 2024)

Pratt Truss Systems

Pratt truss systems are among the most commonly used truss configurations in industrial steel structures because of their efficient axial force distribution and relatively simple construction. In a typical Pratt truss, diagonal members are primarily subjected to tension forces, whereas vertical members resist compression under gravity loading conditions. This force distribution mechanism generally improves structural efficiency because tension members are less susceptible to buckling compared to compression members. As a result, Pratt trusses are widely adopted for moderate and long-span industrial roof systems. (Stevenson et al., 2026)

Several researchers have investigated the seismic response of Pratt truss systems using analytical and numerical approaches. (Patil et al., 2020) performed comparative analysis of industrial roof trusses using STAAD.Pro and reported that Pratt trusses demonstrated comparatively lower displacement response and improved structural efficiency under equivalent loading conditions. The study highlighted that the axial-force-dominated behavior of Pratt systems contributes to stable structural response and effective load redistribution.

Despite their structural advantages, Pratt trusses may experience significant stress reversals during earthquake excitation. Under cyclic lateral loading, members initially subjected to tension may subsequently experience compression, increasing the possibility of local buckling in slender diagonal members. Inadequate connection detailing and insufficient lateral bracing may further amplify seismic vulnerability. Therefore, seismic performance of Pratt trusses strongly depends on member slenderness ratio, ductility capacity, and connection rigidity. (Rodríguez et al., 2024)

Recent studies focusing on nonlinear seismic behavior indicate that truss systems possessing higher redundancy and improved ductility generally exhibit better seismic resilience under strong ground motion. Modern seismic design approaches for Pratt trusses increasingly emphasize energy dissipation capacity, controlled inelastic deformation, and performance-based seismic evaluation methods. (Liu et al., 2025; Wu et al., 2025)

Howe Truss Systems

Howe truss systems are characterized by diagonal compression members and vertical tension members. This arrangement differs significantly from Pratt trusses and influences the overall structural response under both gravity and seismic loading conditions. Howe trusses are frequently employed in industrial roof systems because of their geometric simplicity and effective load transfer characteristics. However, the presence of compression-dominated diagonal members increases the possibility of local and global buckling under dynamic loading conditions. (Patil et al., 2020)

Senthil Naathan et al. (2023) conducted analytical and experimental investigations on Howe truss industrial structures using SAP2000 and CIVIL FEM software. The study analyzed load-deflection behavior, axial force distribution, and stiffness characteristics of a scaled industrial truss model. Experimental observations indicated that intermediate truss systems demonstrated higher stiffness compared to end trusses, while numerical analysis showed acceptable agreement with experimental



results. The study further emphasized the usefulness of finite element modeling for evaluating deformation characteristics and stress distribution in industrial steel truss systems. (Naathan et al., 2023b)

Under seismic excitation, Howe trusses may experience significant compression-induced instability because of repeated stress reversals in diagonal members. Slender compression members are particularly vulnerable to local buckling, stiffness degradation, and reduction in energy dissipation capacity during cyclic loading. Consequently, seismic performance of Howe trusses depends heavily on connection detailing, bracing arrangement, and member compactness. (Rodríguez et al., 2024)

Recent seismic studies indicate that nonlinear dynamic analysis and pushover analysis provide improved understanding of progressive stiffness degradation and plastic hinge formation in truss systems subjected to strong earthquake excitation. These approaches enable better prediction of failure mechanisms and collapse patterns under severe loading conditions. (Rodríguez et al., 2024)

Warren Truss Systems

Warren trusses are widely recognized for their efficient triangular geometry and relatively uniform force distribution characteristics. Unlike Pratt and Howe systems, Warren trusses consist of alternating diagonal members without vertical components in many configurations, resulting in balanced force transfer and reduced stress concentration. This geometric arrangement improves structural redundancy and contributes to smoother load redistribution during dynamic loading conditions. (ARISOY & YAVUZ, 2023)

Comparative studies on industrial steel trusses have consistently indicated favorable structural performance of Warren truss systems under seismic loading. (ARISOY & YAVUZ, 2023) reported that Warren trusses demonstrated improved load distribution characteristics and lower stress concentration compared to several conventional truss configurations. The repetitive triangular geometry enhances structural stability while reducing abrupt force transfer between members.

Recent investigations involving cyclic loading and hysteretic response assessment further indicate that Warren trusses exhibit relatively stable energy dissipation behavior under repeated loading cycles. Truss systems with balanced axial-force distribution generally demonstrate improved seismic resilience because of their enhanced ability to redistribute internal forces after local yielding. Additionally, the relatively symmetric geometry of Warren systems contributes to improved dynamic stability and reduced torsional irregularities under earthquake excitation. (Liu et al., 2025; Tang et al., 2026)

However, Warren trusses may still experience localized buckling in compression members under severe seismic loading conditions, particularly in long-span industrial applications with slender structural components. Therefore, seismic design of Warren systems requires careful consideration of member slenderness, connection behavior, and overall geometric stiffness. (Rodríguez et al., 2024)

Fink Truss Systems

Fink trusses are commonly used in industrial roofing systems because of their economical geometry and efficient force transfer mechanism for moderate spans. The subdivided triangular arrangement of Fink trusses allows effective distribution of roof loads while reducing unsupported member lengths. These systems are particularly advantageous in industrial applications requiring lightweight roofing solutions with moderate construction cost. (Patil et al., 2020)



Comparative investigations performed using STAAD.Pro indicate that Fink trusses may provide relatively economical structural solutions because of lower sectional weight and efficient load distribution characteristics. Their geometric configuration reduces bending effects and enables effective axial-force transfer through interconnected members. (Patil et al., 2020)

Despite these advantages, seismic behavior of Fink trusses depends significantly on connection rigidity and load redistribution capability during cyclic loading. Because of their relatively complex web arrangement, stress concentration may occur at critical joints during earthquake excitation. Inadequate joint detailing may lead to premature stiffness degradation and increased deformation demand under repeated loading cycles. Additionally, long-span Fink systems may experience amplification of vibration response due to reduced lateral stiffness. (Stevenson et al., 2026)

Current research related to Fink truss seismic behavior remains comparatively limited when compared to Pratt and Warren systems. Most available studies primarily focus on static analysis, weight optimization, and cost efficiency rather than nonlinear seismic performance evaluation. Therefore, additional experimental and analytical investigations are required to better understand cyclic response characteristics and collapse resistance of Fink truss systems under strong seismic excitation.

Vierendeel Truss Systems

Vierendeel trusses differ fundamentally from conventional triangulated truss systems because they do not contain diagonal members. Instead, structural stability is achieved primarily through rigid frame action and bending resistance at joints. This configuration provides architectural flexibility and allows larger unobstructed openings; however, it significantly alters structural behavior under dynamic loading conditions. (ARISOY & YAVUZ, 2023)

Because Vierendeel systems resist loads primarily through bending action rather than axial-force-dominated behavior, they generally exhibit higher joint moments, increased deformation demands, and lower structural efficiency under seismic loading conditions. The absence of diagonal bracing reduces geometric stiffness and increases sensitivity to lateral displacement during earthquake excitation. Consequently, Vierendeel trusses are generally considered less favorable for high seismic regions unless supplemented with additional lateral load-resisting mechanisms. (Rodríguez et al., 2024)

Under cyclic loading conditions, rigid joints within Vierendeel systems may experience significant plastic deformation, stiffness degradation, and concentration of stress at beam-column intersections. Excessive bending moments may also accelerate fatigue damage and connection deterioration during repeated seismic excitation. Modern seismic design approaches therefore require detailed nonlinear analysis and careful connection design for Vierendeel systems subjected to earthquake loading.

Although Vierendeel trusses offer architectural and functional advantages, current literature indicates that their seismic performance is generally inferior to triangulated truss systems possessing higher redundancy and more efficient axial-force transfer mechanisms. Nevertheless, advancements in material technology, connection detailing, and supplemental damping systems may improve future seismic applicability of Vierendeel configurations in specialized industrial structures.

4. Numerical Modeling and Seismic Analysis Approaches

The seismic assessment of industrial steel truss systems has increasingly relied on advanced numerical modeling and computational analysis techniques for evaluating structural response under dynamic loading conditions. Modern analytical tools enable detailed prediction of displacement behavior, stress distribution, stiffness degradation, plastic hinge formation, and energy dissipation characteristics under



earthquake excitation. Compared to conventional analytical methods, numerical modeling provides improved understanding of nonlinear structural behavior and allows simulation of complex cyclic loading conditions that are difficult to evaluate experimentally. (Rodríguez et al., 2024)

Finite element analysis (FEA) has become one of the most widely adopted approaches for seismic evaluation of steel truss systems because of its ability to represent material nonlinearity, geometric nonlinearity, and dynamic interaction between structural components. Several commercial software platforms, including SAP2000, STAAD.Pro, ABAQUS, ETABS, ANSYS, and OpenSees, are commonly employed for static, dynamic, and performance-based seismic assessment of industrial structures. These software tools facilitate evaluation of modal characteristics, displacement response, internal force redistribution, buckling behavior, and cyclic response of truss members under earthquake loading. (Naathan et al., 2023b; Rodríguez et al., 2024)

SAP2000-Based Studies

SAP2000 is one of the most extensively used structural analysis software platforms for modeling industrial steel truss systems subjected to static and dynamic loading. The software integrates linear and nonlinear finite element analysis capabilities with response spectrum analysis, time-history analysis, and pushover analysis procedures, making it suitable for seismic performance evaluation of steel structures. (Naathan et al., 2023a)

Senthil Naathan et al. (2023) performed analytical and experimental investigation of a Howe truss industrial structure using SAP2000 and CIVIL FEM software. The study evaluated axial force distribution, deformation characteristics, stiffness response, and load-deflection behavior of a scaled truss model. Numerical results demonstrated acceptable correlation with experimental observations, indicating the effectiveness of finite element analysis for predicting structural response of industrial truss systems. The study also highlighted the capability of SAP2000 to model stress distribution, axial forces, and displacement response in long-span steel trusses. (Naathan et al., 2023b)

Comparative truss investigations conducted using SAP2000 have shown that geometric configuration significantly affects structural stiffness, displacement response, and seismic load redistribution. Truss systems with balanced triangulation and improved redundancy generally exhibit more stable stress distribution and reduced displacement demand during seismic excitation. In addition, modal analysis performed through finite element modeling enables identification of dominant vibration modes and dynamic response characteristics that strongly influence seismic behavior. (ARISOY & YAVUZ, 2023)

Modern SAP2000-based seismic studies increasingly incorporate nonlinear response analysis, response spectrum methods, and performance-based design procedures for evaluating industrial steel structures subjected to earthquake loading. These approaches provide improved prediction of structural behavior under severe seismic excitation compared to conventional linear static analysis methods. (Rodríguez et al., 2024)

OpenSees and Nonlinear Analysis

OpenSees has emerged as an important computational platform for nonlinear seismic assessment of structural systems because of its advanced capabilities in modeling cyclic behavior, material nonlinearity, geometric nonlinearity, and dynamic response under earthquake excitation. Unlike conventional linear analysis approaches, nonlinear finite element modeling allows realistic simulation of stiffness degradation, yielding behavior, plastic hinge formation, and collapse mechanisms in steel structures subjected to strong ground motion. (Rodríguez et al., 2024)



Recent studies on seismic assessment increasingly emphasize nonlinear dynamic analysis and pushover analysis for evaluating structural resilience and collapse resistance. Rodríguez et al. (2024) performed comparative evaluation of spectral modal analysis, nonlinear dynamic analysis, and pushover analysis to assess seismic response characteristics of structural systems subjected to earthquake excitation. The study demonstrated that nonlinear dynamic analysis provides improved understanding of displacement demand, ductility response, and plastic hinge development under severe seismic loading conditions. Furthermore, the research highlighted the importance of finite element discretization, damping assumptions, and time-step selection in accurately predicting structural response. (Rodríguez et al., 2024)

Pushover analysis has become an important tool in performance-based seismic evaluation because it enables progressive assessment of structural capacity under increasing lateral loads. Through nonlinear static procedures, researchers can identify critical failure locations, stiffness degradation patterns, and collapse mechanisms within structural systems. Incremental pushover analysis also facilitates estimation of plastic hinge formation and post-yield structural behavior under seismic excitation. (Rodríguez et al., 2024)

Nonlinear seismic studies further indicate that accurate representation of connection behavior and member nonlinearity is essential for reliable prediction of truss system response. Semi-rigid connections, geometric imperfections, and local buckling effects significantly influence seismic performance under cyclic loading conditions. Therefore, modern finite element models increasingly incorporate advanced constitutive material models and nonlinear hysteretic response mechanisms to improve analytical accuracy. (Liu et al., 2025; Wu et al., 2025)

Cyclic Loading and Hysteretic Behavior

Cyclic loading behavior plays a critical role in determining the seismic resilience of industrial steel truss systems. During earthquake excitation, structural members experience repeated stress reversals that may lead to stiffness degradation, local buckling, cumulative damage, and reduction in energy dissipation capacity. The ability of a structural system to sustain repeated inelastic deformation while maintaining overall stability is closely related to its hysteretic response characteristics. (Tang et al., 2026)

Recent experimental and numerical investigations have focused on improving hysteretic performance and energy dissipation capacity of steel truss systems subjected to cyclic loading. Studies involving frictional energy dissipation mechanisms and supplemental damping systems indicate that controlled yielding and friction-based response mechanisms can significantly improve seismic stability and reduce structural damage during earthquake events. (Liu et al., 2025)

Wu et al. (2026) investigated seismic performance of steel truss systems incorporating fluid viscous dampers and demonstrated that supplemental damping devices substantially reduced displacement demand, stress concentration, and residual deformation under dynamic loading conditions. Similarly, recent research on steel truss coupling beams indicated that improved hysteretic energy dissipation behavior enhances seismic resilience and delays progressive structural degradation during repeated loading cycles. (Tang et al., 2026; Wu et al., 2025)

The hysteretic response of steel truss systems is strongly influenced by truss geometry, connection detailing, member slenderness, and material ductility. Truss systems with balanced force distribution and higher redundancy generally demonstrate more stable hysteresis loops and improved post-yield response characteristics compared to geometries susceptible to localized instability and abrupt stiffness degradation. Consequently, modern seismic design increasingly emphasizes ductility-based design

philosophy and controlled energy dissipation mechanisms for improving seismic resilience of industrial steel truss systems.

Table . Comparative Seismic Performance of Industrial Steel Truss Geometries

Truss Type	Seismic Stability	Buckling Resistance	Energy Dissipation	Major Advantage	Major Limitation	Overall Suitability
Pratt	Good	Moderate	Moderate	Efficient axial force transfer	Stress reversal may cause buckling	Good
Howe	Moderate	Low	Moderate	Effective gravity load transfer	Compression member instability	Moderate
Warren	High	High	High	Balanced force distribution	Connection detailing required	Excellent
Fink	Moderate	Moderate	Moderate	Economical roof configuration	Limited seismic research available	Good
Vierendeel	Low	Low	Low	Architectural flexibility	High bending and deformation demand	Limited

Note: The assessment presented in the table is based on qualitative interpretation of findings reported in the reviewed literature.

5. Research Gaps and Future Scope

Although significant research has been conducted on industrial steel truss systems, several limitations remain in the existing literature regarding their seismic performance and nonlinear behavior. Most available studies primarily focus on linear static analysis, weight optimization, and conventional stress evaluation, whereas comparatively fewer investigations address nonlinear cyclic response, progressive collapse behavior, and performance-based seismic assessment of industrial truss structures.

Current literature also demonstrates limited experimental validation related to large-scale industrial steel truss systems subjected to realistic earthquake loading conditions. Many analytical studies rely heavily on simplified numerical assumptions that may not fully represent actual structural behavior during severe seismic excitation. In particular, the influence of semi-rigid connections, local joint nonlinearity, residual deformation, and cumulative damage under repeated loading cycles remains insufficiently investigated.

Another important research gap involves the limited consideration of soil–structure interaction effects and higher-mode dynamic response in long-span industrial truss systems. Existing investigations often neglect the combined influence of foundation flexibility, damping variation, and torsional irregularities on seismic response characteristics. Furthermore, comparatively limited literature is available regarding the seismic behavior of Fink and Vierendeel truss systems when compared to Pratt and Warren configurations.



Future research should therefore focus on advanced nonlinear seismic assessment techniques incorporating cyclic loading behavior, hysteretic response modeling, and performance-based design approaches. Experimental studies involving full-scale or hybrid numerical–experimental testing may provide improved understanding of failure mechanisms, energy dissipation characteristics, and post-yield structural behavior of industrial steel truss systems. In addition, integration of supplemental damping devices, smart materials, and artificial intelligence-based structural health monitoring systems may further enhance seismic resilience and long-term structural safety of industrial steel structures subjected to earthquake loading.

6. Conclusion

This review paper presented a comparative assessment of the influence of truss geometry on the seismic behavior and structural response of industrial steel truss systems. Based on the reviewed analytical, numerical, and experimental studies, it was observed that geometric configuration plays a critical role in determining stiffness characteristics, force distribution mechanisms, buckling resistance, ductility, and energy dissipation capacity under seismic loading conditions. Different truss systems demonstrated distinct response characteristics because of variations in member arrangement, redundancy, and load transfer behavior.

Among the reviewed truss geometries, Warren truss systems generally exhibited comparatively superior seismic performance because of their balanced triangular configuration, improved force redistribution capability, and stable energy dissipation behavior under cyclic loading conditions. Pratt trusses also demonstrated satisfactory seismic stability because of their efficient axial-force-dominated behavior, whereas Howe trusses showed increased susceptibility to compression-induced instability and buckling under repeated stress reversals. Fink trusses were found to provide economical and structurally efficient solutions for moderate-span roofing systems; however, available literature related to their nonlinear seismic behavior remains limited. In contrast, Vierendeel trusses exhibited comparatively lower seismic efficiency because of their bending-dominated structural behavior and higher lateral deformation demand.

The review further highlighted the growing importance of advanced numerical modeling techniques, including nonlinear dynamic analysis, response spectrum analysis, and pushover analysis, for accurate evaluation of seismic response in industrial steel truss systems. Modern finite element platforms such as SAP2000 and OpenSees have significantly improved the capability to simulate cyclic behavior, plastic hinge formation, stiffness degradation, and post-yield structural response under earthquake excitation.

Overall, the reviewed literature indicates that seismic performance of industrial steel truss systems depends not only on structural strength but also on ductility, redundancy, connection behavior, and energy dissipation capacity. Future research should therefore emphasize advanced nonlinear seismic assessment, experimental validation, and performance-based design approaches to improve the long-term seismic resilience and structural reliability of industrial steel truss systems.



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