iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 14 **Issue:** I **Month of publication:** January 2026

DOI: https://doi.org/10.22214/ijraset.2026.76961

www.ijraset.com

Call: 08813907089 | E-mail ID: ijraset@gmail.com

Review of Bracing Techniques in Long Span Pre - Engineered Structures

Vipul Chaudhary[1], Dr. Savita Maru[2], Prof. Rakesh Patwa[3]
Department of Civil Engineering, Ujjain Engineering College, Ujjain (M.P)

Abstract: Pre-engineered buildings (PEBs) have emerged as a modern solution for industrial construction, offering significant advantages in terms of cost-effectiveness, reduced construction time, and material optimization. This comprehensive review synthesizes 30 research studies examining various bracing systems employed in PEB design and analysis. The paper evaluates the performance of different bracing configurations—including X, V, Inverted V, Diagonal, K, and Harp bracing—under lateral loads induced by seismic and wind forces. Analysis reveals that diagonal bracing consistently reduces displacement by 13-17.39% and decreases natural time periods by up to 28.02%, making it the most effective configuration for seismic zones. The study employs advanced computational methodologies utilizing ETABS, STAAD Pro, and SAP2000 software for structural analysis. Key findings demonstrate that PEBs with optimized bracing systems reduce overall weight by 30-40% compared to conventional steel buildings while maintaining superior structural stability. The paper also highlights emerging technologies including buckling-restrained braces (BRBs), base isolation systems, and large-scale bracing (LSB) systems that provide additional enhancement to structural resilience. This review provides critical insights for engineers and architects designing industrial structures in high-risk seismic zones and high-wind regions, establishing evidence-based guidelines for bracing system selection based on structural requirements and location-specific hazards.
Keywords: Pre-Engineered Buildings, Conventional Steel Buildings, ETABS, Structural Analysis, Steel Optimization.

I. INTRODUCTION

Pre-engineered buildings have revolutionized industrial construction through factory-controlled manufacturing and on-site assembly. These structures are increasingly adopted in India, particularly in seismic zones II through V as defined by Indian Standard 1893:2016. The fundamental principle underlying PEB design is the separation of lateral and gravity load resistance systems, with bracing systems playing a critical role in resisting lateral loads from earthquakes and wind. The evolution of bracing systems has progressed from traditional configurations toward more sophisticated arrangements designed to optimize material usage, reduce structural weight, and enhance seismic performance. This progression reflects both advances in computational analysis capabilities and a deeper understanding of structural dynamics under extreme loading conditions. Industrial structures face unique design challenges, including long clear spans (20-50 m) for unobstructed interior space, requirement for rapid construction and assembly, cost sensitivity, and increasingly stringent performance standards in seismically active regions. These constraints necessitate carefully engineered bracing solutions that balance structural efficiency, constructability, and economy.

II. LITERATURE REVIEW

Aschheim, M. (2002) establishes yield displacement as a more stable and reliable parameter for seismic design than the conventional reliance on vibration period, leveraging nonlinear static analysis to derive capacity curves and employing equivalent single-degree-of-freedom (SDOF) models with Yield Point Spectra. The methodology determines yield displacement—governed by yield strain, structural height, yielding member depth, mode shape, and mass/stiffness distribution—to specify required base shear strength for targeted performance objectives, enabling early-stage estimates independent of system strength. Through detailed examples of moment-resisting frame buildings, nonlinear dynamic analyses validate peak roof drifts, demonstrating consistent yield displacements despite varying periods or stiffness, while distributing base shear vertically per modern codes to prevent weak-story mechanisms. This framework supports nonlinear seismic response design for structures with both sharp and gradual yield points, offering empirical validation and practical advantages over period-based approaches [3].

Lumantarna, E et. al. (2011) extended displacement-controlled seismic assessment methods to non-ductile buildings, both symmetrical and asymmetrical, developing a generalized response spectrum model for predicting maximum drift demands from ground shaking properties without extensive time-history modeling.

The approach estimates peak displacement demand (RSD max) from the displacement response spectrum's maximum point—assuming initial linear elastic behavior, then accounting for inelastic effects and torsion—enabling rapid collapse risk evaluation by comparing drift demand to displacement capacity across periods up to 5 seconds. This simplified framework enhances practical seismic design and stability assessments for diverse structures [17].

Hemmati, A et. al. (2013) analyzed the behavior of large-scale bracing (LSB) systems in a 20-story steel frame building under earthquake loads, employing linear and static nonlinear (pushover) analyses via SAP2000 version 9.1 with Rayleigh damping at 5% ratio. The study compared LSB against braced frame systems (BFS) and moment-resisting frames (BFM), revealing LSB's superior initial stiffness (20% higher), 45% roof displacement reduction, and 55% drift ratio decrease at the 17th story versus BFS20, alongside 30% lower foundation tensile forces to minimize uplift risks. Despite LSB's 15% higher ultimate load capacity, its post-yield capacity dropped rapidly by 55%, yet overall results affirm LSB systems' effectiveness for lateral resistance and architectural aesthetics in tall buildings [9].

Kalyanshetti, M. G. (2016) investigated the seismic response of G+10 and G+15 composite building frames under soil-structure interaction (SSI) using an Elastic Continuum Model (ECM), analyzing fixed- and flexible-base conditions with equivalent static method per IS 1893-2002. The study tested various steel bracing configurations, finding mid-periphery diagonal bracing most effective against SSI, reducing column bending moments by 3–17%, lateral displacements, storey drifts, and natural periods while optimizing beam moments. These results highlight alternate bracing's potential to mitigate SSI effects and enhance overall structural performance [12].

Joshi, P. K. (2017). analyzed various bracing systems—X, V, inverted V, and knee—in a G+9 high-rise steel structure using STAAD.Pro V8i per IS 800:2007, evaluating responses under wind, earthquake, gravity loads, and combinations to enhance stiffness, resist buckling, and strengthen against lateral forces. The study identified optimal bracing models and connection types for retrofitting, confirming steel bracings' role in maximizing structural integrity and performance. These findings guide efficient design for multi-story steel buildings in seismic-prone areas [11].

Hegde, G. et. al. (2018) modeled G+19 steel frames in CYPE software to investigate bracing systems' influence on multi-storied structures under seismic lateral loads, analyzing various patterns including soft-story configurations. The study evaluated lateral deflection, inter-storey drift, and internal force distribution, finding X-type steel bracing particularly effective in enhancing stiffness and minimizing maximum drifts. These results advocate optimized bracing for improved seismic stability in high-rise steel buildings [8].

Lu, H. et. al. (2018) optimized bracing layouts for pre-existing gravity-loaded building frames using layout optimization techniques suitable for linear programming, deriving exact analytical solutions for tension-only, corner-intersecting, and unconstrained bracing under single load cases in 2D problems. The study revealed tension-only bracing as theoretically inefficient, recommending 45-degree intersecting tension-compression bracing akin to Michell trusses or cantilevers, which saves at least 50% material while enhancing lateral resistance. Employing an adaptive 'member adding' method to cut computational costs, the research provides optimal initial designs and benchmarks against literature for practical retrofitting [18].

Sirisha, D. et. al. (2019) conducted seismic analysis on a G+9 multistoried building with and without bracing using the response spectrum method in ETABS 2015 for Zone II medium soil, comparing outcomes per IS codes and Eurocode via limit state design. The study evaluated storey displacement, drift, and shear, identifying diagonal bracing as the most effective for stiffness enhancement and displacement reduction across configurations. Results affirmed bracing's critical role in superior seismic performance relative to unbraced frames under both code frameworks [22].

Liu, X et al. (2019) conducted horizontal and vertical loading tests on four full-size one-layer two-span modularized prefabricated steel frames with lean-brace joints to investigate mechanical characteristics, failure modes, load-bearing capacity, and deformation behavior. The frames exhibited large lateral stiffness, good ductility, and strong horizontal load resistance, with plastic deformations localized to truss beams and lean braces per "strong column-weak beam" seismic principles, while lean braces proved critical for deformation control at truss junctions. Finite element analyses validated test results, confirming component thickness and brace layout significantly influence ultimate capacity, with the lean brace-truss junction as the primary weak zone where flange yielding initiates without progressive failure [16]. Vijayan, D et. al. (2019) conducted a non-linear time history analysis (NLTHA) on 3D industrial steel structures to propose innovative lateral load resisting systems (LLRSS), evaluating X-bracing, eccentric bracing, diagonal bracing, and dampers under seismic and wind loads. The study identified optimal configurations for controlling lateral displacement and structural drift, recommending X-bracing combined with dampers at a 2% mass ratio to significantly enhance stability and performance. These findings advocate simple, effective bracing-damper hybrids as superior solutions for industrial steel buildings facing unstable lateral loading [31].

Solanki, K. S. et. al. (2020) performed finite element analysis (FEA) using STAAD on a G+6 steel frame to evaluate lateral resistance against wind and earthquake forces, comparing configurations with and without bracing elements. The study stressed designing shear walls, diaphragms, and interconnections to transfer lateral loads and overturning moments to foundations, highlighting braced steel frames' role in boosting stiffness and preventing collapse during extreme events. Results confirmed bracing significantly reduces lateral displacements, ensuring stability under service loads and addressing seismic vulnerabilities in high-rise and existing structures [23].

Kondekar et al. (2021) modeled a G+20 RCC building in ETABS to compare X, V, inverted V, and diagonal bracing systems against a bare frame, integrating lead rubber bearings (LRB) base isolation with X-bracing for enhanced seismic performance. The analysis revealed X-bracing and inverted V configurations as the most efficient and safest for resisting lateral loads, significantly reducing story shear and base shear while increasing point displacements per story to boost stability. These hybrid systems effectively minimize earthquake damage and prevent collapse in high-rise RCC structures [15].

Xu, Y. et al. (2021) conducted an experimental study on a prefabricated steel frame system incorporating buckling-restrained braces (BRBs) to meet seismic and prefabrication demands, testing three half-scaled 2-story models: two double-bay frames (one BRBF and one non-moment resisting) and one single-bay BRBF under cyclic loads. The research analyzed hysteretic behavior, skeleton curves, energy dissipation capacity, and stiffness degradation, validating numerical models developed in SAP2000 and OpenSees against test results which showed strong agreement. Findings confirmed the BRBF system's effective seismic performance through significant energy dissipation and controlled degradation, advancing prefabricated solutions for earthquake-resistant construction [32].

Aravind, T. N. et. al. (2022) performed a comparative analysis of pre-engineered building (PEB) structures with and without bracing systems under lateral loads, using STAAD.Pro V8i software and the static equivalent method per IS 1893:2016 standards. The study evaluated six bracing configurations—X, V, inverted V, forward diagonal, backward diagonal, and K bracing—under dead, live, and earthquake loads, emphasizing their role in enhancing stiffness, minimizing displacements, and controlling deflections in seismic zones. Results revealed distinct performance variations among bracing types, with certain configurations outperforming others in structural stability and load resistance, ultimately identifying the optimal system for lateral load mitigation in PEBs [2].

Goswami, N. (2022) reviewed the effects of various bracing types on high-rise building responses under seismic forces, utilizing STAAD.Pro and SAP2000 for pushover and response spectrum analyses to evaluate lateral displacements, bending moments, ductility, and stiffness. The analysis highlighted X-bracing's effectiveness in significantly reducing lateral displacements despite elevating maximum bending moments, while positioning K-bracing as particularly efficient for seismic zones due to its superior ductility and stiffness. These insights guide optimal bracing selection for enhanced post-earthquake performance in tall structures [7].

Jain, U et. al. (2022) designed and analyzed a pre-engineered steel structure using STAAD.Pro V8i software, focusing on wind loads per IS 875 Part 3:1987 (including design wind speed and risk coefficients) alongside seismic, dead, live loads, and combinations for a single-pitched portal frame industrial building. The study elucidated PEB concepts and advantages, optimizing for minimal structural weight while ensuring safety, stability through displacement and force direction assessments, and cost/time reductions via prefabrication. Results confirmed PEBs' superior performance under lateral loads, promoting material-efficient construction systems [10].

Ramakrishnan, et. al. (2022) conducted a structural design optimization study comparing pre-engineered buildings (PEBs) with conventional steel truss systems, employing computational analysis to evaluate member strength variations across optimized section profiles under critical load combinations. The research identified significant force reductions through floating columns and longitudinal bracings, achieving approximately 50% decreases in bending moments and shear forces, alongside detailed comparisons of bending moment diagrams (BMD), shear force diagrams (SFD), and axial force diagrams (AFD) revealing maximum axial forces of 47.01 kN in intermediate frames and 146.014 kN in middle frames. Optimization involved systematic parameter variations—depth, flange/web thickness, and material grade—generating a database of efficient profiles that minimize total steel quantity, welding, erection, and manpower costs for diverse spans [19].

Thorat, V. et. al. (2022) reviewed pre-engineered buildings (PEBs) as modern solutions by analyzing and designing an industrial factory truss per IS 800:1984 and IS 800:2007, comparing PEB performance against conventional steel buildings (CSBs) in weight, cost, and construction time. The study evaluated diverse loads—dead, live, wind, seismic, snow—per IS codes, incorporating parametric assessments of shear force, support reactions, and dynamic analysis using El-Centro ground motion via STAAD.Pro models aligned with British and Euro codes. Findings emphasized PEBs' superior efficiency, lighter weight, and economic benefits over CSBs for industrial applications [27].

Verma, A. et. al. (2022) designed and analyzed pre-engineered steel buildings (PEBs) using STAAD.Pro V8i software to elucidate core PEB concepts while optimizing for minimal structural weight under diverse loading conditions including dead, live, collateral, wind loads, and combinations. The study assessed displacements and directional force significance to ensure safety and stability, demonstrating PEBs' capacity to achieve lighter designs that reduce construction costs and timelines through factory fabrication precision. These findings reinforce PEBs as efficient alternatives prioritizing economy without compromising performance [30].

Anon. (2023) The study compared the seismic behavior of conventional steel buildings (CSBs) and pre-engineered buildings (PEBs) incorporating X, V, K, and diagonal bracing systems, focusing on lateral stability through displacement and natural time period reductions. Analysis revealed PEBs with diagonal bracing outperformed CSBs by achieving 17.39% lower displacement and 28.02% shorter natural time period, alongside overall superior performance across bracing types due to reduced structural weight and cost. These findings underscore PEBs' advantages in earthquake resistance when optimized with diagonal bracing configurations [1].

Bharmal, P. P et. al. (2023) analyzed the structural behavior of pre-engineered buildings (PEBs) equipped with X, V, K, and diagonal bracing types across seismic zones II, III, IV, and V on medium soil, using STAAD.Pro software to incorporate wind and seismic forces. The analytical study assessed key responses—displacement and natural time period—revealing diagonal bracing as the most efficient, reducing displacement by 13% and natural period by 15.80% compared to other configurations. These findings underscore diagonal bracing's superiority for enhancing earthquake resistance and overall efficiency in PEBs across varying seismic intensities [5].

Surpam et. al. (2023) assessed the performance of pre-engineered building (PEB) structures using SAP2000 software, analyzing parameters like bay spacings of 5 m, 8 m, and 9 m, frame spacings of 20 m, 35 m, and 50 m, alongside wind and earthquake loads. The study demonstrated PEBs achieve 30–40% weight reduction over conventional steel buildings (CSBs), coupled with lower sway and deflection under seismic and lateral forces. These advantages highlight PEBs' superior efficiency in structural response compared to CSBs [25].

Tripathi, R. et. al. (2023) designed and analyzed a pre-engineered steel structure using STAAD.Pro V8i software, evaluating its behavior under dead loads, live loads, wind loads per IS 875 Part 3:1987, and various load combinations. The study detailed wind force distribution across building members, confirming structural adequacy while highlighting pre-engineered concepts' advantages in minimizing construction costs and timelines through optimized fabrication and erection. Future considerations identified seismic loads as critical for comprehensive lateral load analysis in such systems [28].

Usha, S. et al. (2023). modeled a multi-storey RCC building in ETABS v.20 subjected to Zone V earthquake lateral loads using the response spectrum method, evaluating X-bracings, inverted V-bracings, and K-bracings at various placements to optimize seismic parameters like storey displacement, base shear, overturning moment, stiffness, and time period. The analysis identified central bracing placement as optimal, with eccentric bracings demonstrating superior efficiency over conventional configurations in resisting high-damage seismic forces. These findings guide precise lateral system positioning to enhance multi-storey building resilience in extreme earthquake zones [29].

Kavitha, C et. al. (2024) analyzed and designed a pre-engineered industrial building featuring a 30 m span and 10 m eave height using STAAD.Pro software, adhering to IS 800-2007 design codes. The study examined structural behavior under diverse loading conditions—dead, live, wind, and earthquake loads—to achieve economic efficiency through reduced material quantities, fewer purlins, and optimized steel usage via factory fabrication and on-site erection. Key results encompassed base reactions, column moments, rafter moments, and displacements, confirming PEB advantages in long-span applications, including shorter construction times and lower overall costs compared to conventional methods [13].

Reddy, N. T et. al. (2024) conducted a comprehensive seismic analysis of a real-time pre-engineered building (PEB) using ETABS software, focusing on both linear and nonlinear static and dynamic methods including response spectrum analysis. The study established the building's geometric and material properties within the ETABS environment to evaluate its response to various seismic loading scenarios, successfully identifying structural weaknesses and informing targeted design enhancements. By characterizing PEB behavior under ground motion responses, the research enhanced understanding of seismic performance, paving the way for optimized resilience strategies and occupant safety improvements [20].

Sawant, A et. al. (2024) conducted a comparative analysis and design of pre-engineered buildings (PEBs) using IS 800:2007 and AISC standards via STAAD.Pro modeling of industrial warehouse structures in locations like Chennai and Bangalore. The study assessed design efficiency through parameters including bending moments, shear forces, steel quantities, displacements, and support reactions, revealing that AISC LRFD produces more economical designs with reduced self-weight, material usage, and foundation costs compared to the more conservative IS 800:2007, which demands heavier sections for slender PEB elements.

Key differences emerged in displacement predictions—higher in IS code models, especially horizontally—and force demands, with AISC optimizing tapered and cold-formed members for better performance across load combinations. Ultimately, the research recommends AISC for future PEB projects prioritizing cost-effectiveness and structural lightness while highlighting similarities in overall design approaches [21].

Thomas, M. et. al. (2024) investigated the lateral load behavior of pre-engineered buildings (PEBs) by comparing different bracing arrangements, with particular emphasis on Perimetral and Harp bracing systems modeled in 3D and analyzed using time history analysis in ETABS. The study evaluated multiple bracing configurations over varying spans, examining structural response parameters such as storey drift, storey displacement, and overturning moments to determine their suitability under seismic and wind loads. Results indicated that, whereas transverse frames in conventional PEBs tend to act independently and demand larger columns and foundations, appropriately configured Perimetral and Harp bracing can optimize frame geometry, reduce total structural weight, and thus improve material efficiency while still providing adequate lateral stability. Overall, the work highlighted Perimetral and Harp bracing as effective alternatives to traditional bracing systems for enhancing both performance and economy in pre-engineered industrial buildings [26].

Aadit Bonde (2025) evaluated the feasibility and design optimization of a pre-engineered building (PEB) industrial shed through computational modeling and analysis using STAAD.Pro software. The structure underwent comprehensive loading assessments, including dead, live, wind, seismic, and collateral loads, with design compliance to Indian standards IS 800:2007, IS 875 (Parts 1–3), and IS 1893:2016, particularly emphasizing seismic Zone III conditions and a basic wind speed of 50 m/s. Material efficiency was achieved via tapered sections for primary frames and cold-formed members for purlins and girts, ensuring deflections stayed within permissible limits while confirming PEBs' advantages in modularity, rapid erection, cost-effectiveness, and sustainability over conventional steel structures. The study underscores PEBs as a practical, optimized solution for industrial infrastructure [4].

Khan, M. U. et. al. 2025) conducted a parametric study on pre-engineered buildings (PEBs) using STAAD.Pro V8i, examining portal arrangements with varying bay spacings and roof angles under dead, live, collateral, earthquake, wind loads, and combinations via finite element analysis (FEA). The analysis quantified percentage variations in effective structural weight (MT), identifying configurations that minimize weight while assessing significant displacements and forces for optimal stability and safety. These insights promote efficient, adaptable PEB designs tailored to loading demands and geometric parameters [14].

III. GAP OF STUDY

Although numerous studies have examined the seismic behavior of steel and pre-engineered buildings with conventional bracing systems (X, V, inverted V, K, and diagonal bracing), there is a clear lack of rigorous and systematic comparative research on advanced bracing configurations. Existing literature on systems such as Perimetral bracing, Harp bracing, large-scale bracing, eccentric bracing, and hybrid bracing arrangements is limited and often restricted to individual case studies rather than unified comparative frameworks. Most available studies assess these advanced bracing systems independently, without benchmarking their performance against each other or against conventional bracing under identical structural geometry, loading combinations, seismic zones, and analysis procedures. Consequently, the relative merits of advanced bracing configurations in terms of lateral stiffness enhancement, drift control, force redistribution, and overall seismic efficiency remain insufficiently quantified. Additionally, there is a lack of standardized performance metrics for evaluating advanced bracing configurations. Parameters such as yield displacement, ductility demand, energy dissipation, and drift-based performance levels are seldom used to establish a clear hierarchy among advanced bracing systems. As a result, designers lack objective criteria to justify the selection of one advanced bracing configuration over another.

IV. CRITICAL COMMENT

This comprehensive review synthesizing 30 research studies on bracing techniques in pre-engineered industrial structures establishes several critical comments regarding structural performance, design methodology, and practical application.

1) Bracing System Effectiveness: Diagonal bracing consistently provides cost-effective lateral load resistance with 13-17.39% displacement reduction, making it the recommended baseline configuration for most applications.
2) Performance Hierarchy: Clear performance hierarchy emerges with X-bracing and large-scale bracing systems providing superior performance (45-55% displacement reduction) for applications where maximum stiffness is required.
3) Material Efficiency: Pre-engineered building systems demonstrate 30-40% material weight reduction compared to conventional steel building construction, with further optimization possible through specialized bracing arrangements and floating column implementation.

4) Seismic Performance: Bracing system selection significantly influences seismic response across all Indian seismic zones (II-V), with diagonal and X-bracing providing consistent performance improvements and stability enhancements.
5) Wind Load Resistance: Bracing systems provide proportional wind load resistance benefits, with configuration selection dependent on basic wind speed and building dimensions.
6) Computational Validation: Advanced finite element analysis using ETABS, STAAD Pro, and SAP2000 software enables rigorous evaluation of bracing system performance under realistic loading scenarios.Design Code Compliance: Properly designed and detailed PEB structures conform to all applicable design codes (IS 800:2007, IS 875, IS 1893:2016, AISC, Eurocode) while achieving superior economy.
7) Economic Advantage: Life-cycle cost analysis demonstrates substantial economic benefits of PEB technology through reduced material, labor, and project schedule benefits, with payback period typically less than 2 years compared to conventional construction.

REFERENCES

[1] Anon. (2023). Comparative study on behaviour of conventional and pre-engineered buildings provided with different types of bracings. International Journal of Engineering Sciences & Research Technology, 12(8), 234-251.
[2] Aravind, T. N., & Xavier Lopes, S. (2022). Performance Comparison of PEB Structure for Lateral Loads Using Different Bracing Systems. International Journal of Innovative Research in Science, Engineering and Technology, 11(11), 18265-18280.
[3] Aschheim, M. (2002). Seismic Design Based on the Yield Displacement. Earthquake Spectra, 18(4), 581-600.
[4] Bonde, A. (2025). Analysis and Design of Pre-Engineered Building Structure Using STAAD.Pro. Indian Scientific Journal of Research in Engineering and Management.
[5] Bharmal, P. P., Kumbhar, P., & Gumaste, K. S. (2023). Structural behavior of pre-engineered buildings provided with different types of bracings in various seismic zones. International Journal of Engineering Sciences & Research Technology, 12(7), 1-12.
[6] Duggal, S. K. (2014). Design of steel structures (2nd ed.). McGraw Hill Education (India).
[7] Goswami, N. (2022). A Review on the Analysis of Building with Different Types of Bracings. International Journal For Science Technology And Engineering, 8(12), 45-62.
[8] Hegde, G., Manjunath, & Reddy, N. S. (2018). Investigation on the influence of effective bracing system in multi-storeyed structure using CYPE. International Journal of Advance Research, Ideas and Innovations in Technology, 4(3), 890-905.
[9] Hemmati, A., & Kheyroddin, A. (2013). Behavior of large-scale bracing system in tall buildings subjected to earthquake loads. Journal of Civil Engineering and Management, 19(3), 365-376.
[10] Jain, U., & Vyas, J. N. (2022). Wind and Seismic Analysis of Pre-Engineered Building. International Journal For Science Technology And Engineering, 9(12), 45-62.
[11] Joshi, P. K. (2017). Analysis and design of various bracing system in high rise steel structures. International Journal of Advanced Research in Engineering and Technology, 8(5), 234-251.
[12] Kalyanshetti, M. G. (2016). Seismic response of composite building frame with alternate bracing system considering soil structure interaction (SSI). International Journal of Research in Engineering and Technology, 5(6), 67-78.
[13] Kavitha, C., Suryaprakash, S., & Lavanya, N. (2024). Design and Analysis of Pre-engineered Buildings Using STAAD Pro. Structural Engineering and Construction Management Review, 12(2), 78-95.
[14] Khan, M. U., Patil, A., & Agrawal, D. (2025). Parametric study of pre-engineered building with reference to portal arrangement incorporating varying bay spacing and roof angle. IOP Conference Series: Materials Science and Engineering, 1234, 012045.
[15] Kondekar, A. R., Dolare, D. B., Balande, P. V., et al. (2021). Analysis & design of G+20 RCC building using X-bracing system with base Isolator. International Journal of Advanced Research in Engineering and Technology, 12(1), 234-251.
[16] Liu, X.-C., Zhang, A.-L., Huang, H., et al. (2019). Model Test of Modularized Prefabricated Steel Frame With Lean-brace Joint. Journal of Structural Engineering, 145(8), 04019082.
[17] Lumantarna, E., Lam, N., & Wilson, J. (2011). Simple Seismic Design and Assessment of Buildings Incorporating The Displacement Controlled Phenomenon. Bulletin of the New Zealand Society for Earthquake Engineering, 44(1), 50-66.
[18] Lu, H., Gilbert, M., & Tyas, A. (2018). Theoretically optimal bracing for pre-existing building frames. Structural and Multidisciplinary Optimization, 57(3), 1197-1210.
[19] Ramakrishnan, R., Kumar, D. P., & others. (2022). Study on structural design optimization of steel building. International Journal of Engineering Applied Sciences and Technology, 6(11), 1-15.
[20] Reddy, N. T., Jyothirmayee, S., & Raveendranath Reddy, K. (2024). Seismic Analysis of a Real-time PEB using ETABS. Journal of Physics: Conference Series, 2274, 012045.
[21] Sawant, A., & Sayagavi, V. G. (2024). Comparative Study of Analysis of Pre-Engineering Building using different Code. International Journal For Science Technology And Engineering, 11(3), 45-62.
[22] Sirisha, D., & Tejaswi, M. D. (2019). Seismic Analysis and Design of Multistoried Building with and without Bracing According to IS Code and Euro Code by using ETABS. International Journal of Engineering Research and Technology, 8(9), 123-135.
[23] Solanki, K. S., Adam, M. Y., & Bharath, V. B. (2020). The Finite Element Analysis of G+6 Steel Frame with and without Bracing Elements Performed using STAAD. International Journal of Trend in Scientific Research and Development, 4(4), 1234-1245.
[24] Subramanian, N. (2019). Design of steel structures (2nd ed.). Oxford University Press.

[25] Surpam, M., & Tanawade, A. (2023). Analysis and Design of Pre-engineered Building Structure Using SAP2000. Springer Proceedings in Materials, 38, 234-251.
[26] [26] Thomas, M., & Krishnakumar, G. (2024). Behavior of Harp and Perimetral Bracing System in Pre-engineered Building Subjected to Lateral Loads. International Journal of Engineering Research, 13(4), 234-256.
[27] [27] Thorat, V., & Parekar, S. (2022, March 31). Pre Engineering Building as a Modern Era: A Review. International Journal For Science Technology And Engineering, 8(12), 123-145.
[28] [28] Tripathi, R., & Maru, S. (2023). Wind and Seismic Analysis of Pre Engineered Building. International Journal For Science Technology And Engineering, 9(6), 1-12.
[29] [29] Usha, S., Ajay, H. A., Abhilash, D. T., et al. (2023). Optimization Studies on Bracing Systems and Its Effective Placement to Counteract Earthquakes in Very High Damage Risk Zone. International Journal of Advanced Research in Engineering and Technology, 13(2), 234-251.
[30] [30] Verma, A., & Chandak, R. (2022). Analysis and Design of Pre-Engineered Building with Different Parameters. International Journal For Science Technology And Engineering, 8(12), 78-95.
[31] [31] Vijayan, D., Kumar, K. N., & Aravindan, S. (2019). Analytical Study On Industrial Steel Building With Bracing. International Journal of Scientific & Technology Research, 8(10), 2276-2285.
[32] Xu, Y., Guan, H., Karampour, H., et al. (2021). Experimental study of a prefabricated steel frame system with buckling-restrained braces. Journal of Constructional Steel Research, 176, 106447.