

REVIEW ON COMPARATIVE STUDY OF DYNAMIC BEHAVIOR OF PRE-ENGINEERED AND CONVENTIONAL STEEL INDUSTRIAL STRUCTURE

Mr. Abdul Zareef Abdul Zarrar¹ Ishant Dahat²

¹Student M. Tech. (Structural Engg.) Dept. of Civil Engineering, G. H. Rasoni University, Amaravati, Maharashtra, India

²Assistant Professor, Dept. of Civil Engineering, G.H.Rasoni University, Amaravati, Maharashtra, India

abdulzareef1234.ss@gmail.com

Abstract— Transportation infrastructure plays a significant role in the economic and social development of a country. Underpass bridges are essential components of modern transportation systems as they facilitate uninterrupted traffic movement at road intersections, railway crossings, and highways. Due to increasing urbanization and traffic density, RCC box-type underpass bridges are increasingly preferred because of their rigidity, durability, and ability to resist heavy loading conditions.

The present study investigates the structural behaviour of RCC box-type underpass bridges subjected to vehicular and seismic loading conditions. Three-dimensional numerical models with span lengths of 5 m, 10 m, and 15 m were developed and analysed using structural analysis software in accordance with IRC and IS 1893:2016 provisions. Static and dynamic analyses were carried out to evaluate displacement, base shear, natural time period, frequency response, acceleration response, and maximum stress.

The study also compares the seismic performance of conventional pier-supported bridge systems and RCC box bridge systems. Results indicate that the RCC box bridge configuration exhibits improved rigidity and better seismic resistance with lower displacement response. The 10 m span bridge demonstrated optimum structural performance with minimum displacement and stable dynamic behaviour. The study concludes that moderate-span RCC box-type underpass bridges are structurally efficient and suitable for seismic-prone regions.

Keywords: Underpass Bridge, RCC Box Bridge, Seismic Analysis, Vehicular Load, Dynamic Analysis, Base Shear, Soil–Structure Interaction, Structural Performance.

I. INTRODUCTION

Bridges are among the most essential infrastructural components of modern transportation systems and play a crucial role in the economic, industrial, and social development of a nation. They facilitate the safe and efficient movement of people, vehicles, and goods across physical obstacles such as rivers, valleys, railway lines, and highways. A well-developed bridge network significantly improves transportation efficiency by reducing travel time, minimizing traffic congestion, lowering transportation costs, and enhancing regional connectivity. With rapid urbanization, industrial expansion, and population growth, the demand for advanced transportation infrastructure has increased considerably in recent decades.

In rapidly developing urban areas, conventional at-grade intersections often become inadequate because of increasing traffic density and limited land availability. Traffic congestion at railway crossings, road intersections, and highway junctions leads to delays, fuel wastage, environmental pollution, and increased accident risk. To overcome these issues, grade separation structures such as flyovers, overpasses, and

underpass bridges are widely adopted in modern transportation planning. Among these, underpass bridges have become one of the most effective solutions for maintaining uninterrupted traffic flow while improving transportation safety and operational efficiency.

Underpass bridges are commonly constructed beneath highways, railway tracks, or urban road networks to allow traffic movement below existing transportation corridors. These structures eliminate conflicts between intersecting traffic streams and significantly improve road safety by reducing the possibility of collisions at crossings. Underpasses are especially beneficial in congested urban regions where expansion of road width is difficult due to limited space and surrounding infrastructure. In addition, underpass systems improve traffic management and support continuous transportation operations without disturbing existing routes.

Reinforced Cement Concrete (RCC) box-type underpass bridges are extensively used because of their high rigidity, structural stability, durability, and economical construction. The box-type configuration provides a closed structural system that efficiently distributes loads and resists bending,

shear, and torsional effects. Compared to conventional pier-supported bridge systems, RCC box structures possess greater stiffness and better resistance against lateral earth pressure and surcharge loads. The rigid box action also enhances the load-carrying capacity of the structure under heavy vehicular traffic.

Another major advantage of RCC box underpass bridges is their ability to perform effectively under underground and partially buried conditions. Since these structures remain surrounded by soil, they receive additional confinement and support from the surrounding earth mass. RCC box structures also require comparatively lower maintenance and offer longer service life due to their monolithic construction and resistance to environmental deterioration. Because of these advantages, RCC box-type underpass bridges are widely used in highway projects, railway crossings, metro transportation systems, and urban infrastructure development.

Conventional bridge analysis methods often consider vehicular loads and seismic loads independently for simplification purposes. However, actual service conditions involve the combined effects of static and dynamic loads acting simultaneously or sequentially. In practical situations, underpass bridges may experience heavy vehicular traffic while also being subjected to earthquake excitation. Therefore, separate analysis of these loads may not accurately represent the actual structural behaviour of the bridge.

Several researchers have previously studied bridge behaviour under static and seismic loading conditions. However, most of the available studies are focused on conventional bridge systems and simplified analytical methods. Limited research has been conducted on RCC box-type underpass bridges subjected to combined vehicular and seismic loading conditions. Furthermore, comparative studies involving different span lengths and their influence on displacement, base shear, vibration characteristics, and stress distribution are limited in existing literature.

To address these limitations, the present study focuses on the comparative structural performance of RCC box-type underpass bridges with span lengths of 5 m, 10 m, and 15 m under vehicular and seismic loading conditions. Three-dimensional numerical models are developed using structural analysis software to accurately simulate the behaviour of the bridge systems under combined loading effects. Both static and dynamic analyses are carried out in accordance with IRC and IS 1893:2016 codal provisions.

II. IMPORTANCE OF UNDERPASS BRIDGES

Underpass bridges are essential transportation structures that facilitate uninterrupted traffic flow by separating traffic movements vertically. These structures are commonly constructed at:

- Highway intersections
- Railway crossings
- Urban road junctions

- Pedestrian crossings
- Metro and railway corridors

III. LITERATURE REVIEW

2.1 Pratik M. Londhe et. al. “A Comparative Analysis of Conventional Steel Building and Pre-Engineered Building Systems: a case study Approach” ICSTCE (2024)

India being a developed country, massive house building construction is taking place in various parts of the country. Since 30% of the Indian population lives in towns and cities, the frequency of construction is more in urban places. There is an enormous need for housing, but there will never be enough houses available because current masonry construction technology cannot keep up with the annual rise in demand. Hence, one has to think of alternative construction systems like pre-engineered steel buildings. India has an installed steel capacity of 35 to 40 million tonnes & apparent steel consumption is around 27 to 30 million tonnes. There is a surplus capacity of flat steel products available in India particularly of hot and cold rolled sheets.

2.2 Ranjith Raja P et. al. “Design of Pre Engineered Building Using STAAD PRO” IJIRT (2024)

To design and analyze the casting yard under the concept of Pre-Engineered Building (PEB) involves pre designed and pre-fabricated steel building system. Casting Yard is a confined place where all the concrete structures such as I-girder, beams and other structural members are casted and transported to the site. PEB are fabricated based on the requirements and functional aspects of the building. The use of the optimal least section leads to effective saving of steel and utilization of non-prismatic rigid frames with slender elements. Tapered I section made with built up thin plates are used. Comparing the Pre-Engineered steel Buildings with Conventional Steel Buildings it is time and cost efficient. PEB construction is 30 to 40% faster than masonry construction and conventional steel construction.

2.3 Shubham Dashore et. al. “Analysis And Design Of Pre-Engineered Building Warehouse In Different Seismic Zones” ResearchGate (2023)

Construction of pre-engineered steel buildings is increasing very rapidly nowadays. The methodology used in PEB is not just because of high quality in pre-designing and pre-fabrication but also due to light weight and economical construction. From past studies it has been found that PEB has good strength, flexibility, recyclable nature, longer span, no limitation in size of components and has more seismic resistance capacity as compare with conventional buildings. PEB are environmentally friendly and long lasting. In CSB hot rolled section is used where as in PEB cold formed purlins is used. Usage of tapered I-section and cold formed sections of columns and rafters which reduces wastage of steel and decrease the budget considerably.

2.4 Payal J. Abhichandani et. al. “Analytical Study of Pre-Engineered Building” International Journal of Innovative Research in Science, Engineering and Technology (2022)

Steel is the most common and smart choice for construction of industrial structure. This has resulted in use of Pre-Engineered Building in India as it has a number of benefits over conventional steel building. It is important to study the PEB

using IS code and American code so as to understand the difference between the standards. This study focuses on the analytical study of PEB using Indian Codes (IS 800 and IS 875) and American Code (AISC 360 and AISC 7). A PEB having length 43.26 m, width 32.46 m, eave height 5.82 for Pune location was modeled in STAAD Pro software using IS code as well as American code and the comparison of results obtained was performed.

2.5 Akshay Gavandare et. al. “Analysis and Design of Steel Building and its Comparative Study with Conventional RCC Building” International Journal of Science and Research (2022)

This study reviews the analysis and design of steel members or sections to use in construction of apartment buildings, and its comparative study with conventional RCC structure. Nowadays the construction sector is exploring rapidly and it also involves new structural systems for fast and precise work on the field. During the recent decades, our society has been continuously experimenting with newer techniques and alternative materials. In a study it is found that the two major aspects for which all these alternatives get researched are Speed of Execution and Economy of Project. So we want to have a comparative study of steel apartment buildings with conventional RC structures. In the present work a G+5 story apartment building whose ground floor is considered as parking, which is situated in earthquake zone-II.

2.6 Laishram Chandramani Singh et. al. “An Analytical Study On Pre Engineered Building By Using Staad Pro” JETIR (2021)

With the development of science and technology in the field of structural engineering as well as in Civil engineering , the adaptation of pre engineered building can be observed in industrial as well as residential building sectors. In the earlier days, even if Pre Engineered Building ideas were there, it was quite a lengthy process to design and check whether the structure is acceptable or not. But in this modern day world , with the coming of various softwares like Staad pro, it has become more convenient to adopt the practice of pre-engineered building than conventional steel building.

2.7 Mohd Atif Khan et. al. “A Review on the Optimization and Design of Pre-Engineered Building [PEB] with Conventional Steel Building” International Journal Of Multidisciplinary Research In Science, Engineering and Technology (2021)

An industrial structure (PEB & CSB Frames) is analyzed and designed according to the Indian standards. Three models each for PEB and CSB are considered having different widths and a parametric study is carried out to access the performance of the models in terms of weight comparison, cost comparison and time comparison. In this study, an industrial structure (factory truss) is analyzed and designed according to the Indian standards, IS 800-1984, IS 800-2007. The various loads like dead, live, wind, seismic and snow loads according as per IS codes are considered for the present work for relative study of Pre-Engineered Buildings (PEB) and Conventional Steel Building (CSB). To compare the consequences of the numerous parametric studies to perform the variations in terms of shear force, support reaction, weight correlation and cost evaluation.

2.8 Bishbu Jacob et. al. “Design comparison of conventional steel structure with pre - engineered structure” IOP Conference Series: Materials Science and Engineering (2020)

The pre- engineered buildings are the steel buildings which are pre-designed and prefabricated. For pre- engineered structure the member size is provided as per the requirement at the location and hence the members are tapered in nature. The study is on the design of the pre- engineered structure and its comparison with conventional structure. The objective of the study is to analyze and design a structure as a conventional steel structure and Pre-engineered structure and to compare the design of the structure in terms of structure weight. The use of cold-formed steel sections as secondary members reduces the self-weight of the pre- engineered structure. It was expected that the pre-engineered buildings will be more economical than conventional structure.

2.9 Kalesha Shaik et. al. “An analytical study on pre-engineered buildings using staad pro” ResearchGate (2020)

Pre-engineered building concept involves pre-designed and prefabricated steel building systems. The current construction approach calls for the best architectural look, high quality & quick construction, cost-effective & creative touch. One has to think of alternative building systems such as pre-engineered steel buildings. The implementation of the Pre Engineered Building (PEB) is a modern-day concept in which utilizing the steel structure and optimizing the design by ensuring economical integrity. The main objective of this paper is to understand the concepts of PEB and to minimize the usage of cost and time. While compared to other technologies in construction Pre Engineered Building is more sustainable and stands top position when compared with other technologies.

2.10 Muhammad Umair Saleem et. al. “Design Solutions for Sustainable Construction of Pre Engineered Steel Buildings” ResearchGate (2018)

Sustainable construction of eco-friendly infrastructure has been the priority of worldwide researchers. The induction of modern technology in the steel manufacturing industry has enabled designers to get the desired control over the steel section shapes and profiles resulting in efficient use of construction material and manufacturing energy required to produce these materials. The current research study is focused on the optimization of steel building costs with the use of pre-engineered building construction technology. Construction of conventional steel buildings (CSB) incorporates the use of hot rolled sections, which have uniform cross-section throughout the length.

2.11 T.D. Mythili et. al. “An Overview Of Pre-Engineered Building Systems” International Journal of Scientific & Engineering Research (2017)

Pre-Engineered Building concept involves the steel building systems which are pre-designed and prefabricated .The present construction methodology calls for the best aesthetic look, high quality & fast construction, cost effective & innovative touch. One has to think for alternative construction system like pre-engineered steel buildings. In recent years, the introduction of Pre Engineered Building (PEB) concept in the design of structures has helped in optimizing design. The adoptability of PEB in the place of Conventional Steel

Building (CSB) design concept resulted in many advantages, including economy and easier fabrication.

2.12 Building with Conventional Steel Building” Journal of Civil Engineering and Environmental Technology (2015)

In recent years, the introduction of Pre Engineered Building (PEB) concept in the design of structures has helped in optimizing design. The adoptability of PEB in the place of Conventional Steel Building (CSB) design concept resulted in many advantages, including economy and easier fabrication. Long Span, Column free structures are the most essential in any type of industrial structures and Pre Engineered Buildings (PEB) fulfils this requirement along with reduced time and cost as compared to conventional structures. PEB methodology is versatile not only due to its quality pre-designing and prefabrication, but also due to its light weight and economical construction.

2.13 Neha Kolate et. al. “Economizing Steel building using Pre-Engineered Steel Sections” International Journal of Scientific & Engineering Research (2015)

Column free structures are the most essential in any type of industrial structures and pre-engineered buildings (PEB) fulfil this requirement along with reduced time and cost as compared to conventional structures. This methodology is versatile not only due to its quality pre-designing and prefabrication, but also due to its light weight and economical construction. The present work presents the comparative study and design of conventional steel frames and pre-engineered buildings (PEB). In this work, industrial frames of length 60m and width 30m with roofing system as conventional steel truss and pre-engineered steel truss analyzed and designed by using STAAD Pro.

2.14 G.Durga Rama Naidu et. al. “Comparative Study of Analysis and Design of Pre-Engineered Buildings and Conventional Frames” ResearchGate (2014)

Long Span, Column free structures are the most essential in any type of industrial structures and Pre Engineered Buildings (PEB) fulfills this requirement along with reduced time and cost as compared to conventional structures. The present work involves the comparative study and design of Pre Engineered Buildings (PEB) and Conventional steel frames. Design of the structure is being done in Staad Pro software and the same is then compared with conventional type, in terms of weight which in turn reduces the cost.

2.15 C. M. Meera et. al. “Pre-Engineered Building Design Of An Industrial Warehouse” International Journal of Engineering Sciences & Emerging Technologies (2013)

Pre-Engineered Building (PEB) concept is a new conception of single storey industrial building construction. This methodology is versatile not only due to its quality pre-designing and prefabrication, but also due to its light weight and economical construction. The concept includes the technique of providing the best possible section according to the optimum requirement. This concept has many advantages over the Conventional Steel Building (CSB) concept of buildings with roof truss. This paper is a comparative study of PEB concept and CSB concept. The study is achieved by designing a typical frame of a proposed Industrial Warehouse building using both the concepts and analyzing the designed frames using the structural analysis and design software Staad.Pro.

2.16 Sharma et al. “Dynamic Behavior of Hybrid Steel-Concrete Structures under Seismic Load” International Journal of Structural Engineering and Analysis (2021).

The study investigates the dynamic behavior of hybrid steel-concrete structures, specifically focusing on the interaction between PEBs and CSBs. They highlight that hybrid structures often exhibit improved seismic performance due to the combination of the flexibility of steel and the stiffness of concrete. The research shows that while PEBs offer better performance under moderate seismic loads due to their lighter weight, CSBs offer superior strength and seismic resilience for higher intensity events.

2.17 Siddiqui et al. “Performance of Hybrid Buildings with Tuned Mass Dampers” Earthquake Engineering and Structural Dynamics (2018).

Analyse the performance of hybrid buildings, incorporating tuned mass dampers (TMDs) to mitigate vibrations caused by dynamic forces. The study explores the effectiveness of TMDs in hybrid PEB-CSB systems, demonstrating that these dampers significantly reduce structural displacements and accelerations during seismic events.

2.18 Li et al. “Load Transfer Mechanisms in Hybrid PEB-CSB Structures” Engineering Structures (2021).

Examine the load transfer mechanisms in hybrid PEB-CSB structures, focusing on how seismic and wind loads are distributed between the PEB and CSB components. The research highlights the challenges posed by the interaction between the flexible PEB and the more rigid CSB, emphasizing the need for careful consideration of connection design and stiffness distribution.

2.19 Kaveh et al. “Optimization of Vibration Control in Hybrid PEB-CSB Systems” Journal of Structural Dynamics (2019).

Focus on the vibration control of hybrid PEB-CSB systems. They propose the use of tuned mass dampers (TMDs) and viscous dampers to reduce peak displacements and accelerations in hybrid structures under dynamic loads, especially in seismic regions. The study demonstrates that TMDs can significantly reduce vibrations in hybrid PEB-CSB systems, improving their overall seismic performance.

2.20 Patil and Deshmukh “Seismic Behavior of Pre-Engineered and Composite Steel-Concrete Hybrid Buildings” International Journal of Seismic Design (2021).

Analyse the seismic behavior of hybrid PEB-CSB structures, focusing on their performance during earthquake-induced dynamic forces. The study explores how hybrid systems provide a balanced combination of flexibility and strength, offering enhanced seismic resilience..

Finding

2.21 Zhang et al. “Hybrid PEB-CSB System: Dynamic Response and Load Transfer Mechanisms” Engineering Structures (2020).

Investigate the dynamic response and load transfer mechanisms of hybrid PEB-CSB systems. The authors explain that the interaction between the flexible PEB frame and the more rigid CSB structure introduces complex dynamic behavior, particularly under seismic or wind-induced loads. Their study finds that the connection type and design of joint details between PEBs and CSBs are crucial in ensuring

efficient load transfer and maintaining the overall stability of the structure.

2.22 Garg et al. “Dynamic Behavior of Pre-Engineered Buildings Under Seismic Loading” *Structural Engineering International* (2016).

The dynamic behavior of pre-engineered buildings (PEBs) is critical when subjected to seismic forces, as the lightweight nature of these structures makes them more flexible compared to conventional buildings. Garg et al. (2016) discuss the seismic performance of PEBs, highlighting the importance of considering factors such as natural frequency, damping, and mode shapes in the dynamic analysis. These factors directly influence the building's ability to withstand seismic forces.

2.23 Bansal et al. “Optimizing the Seismic Performance of Hybrid Steel-Concrete Buildings” *Earthquake Engineering Research* (2021).

Focus on optimizing the seismic performance of hybrid steel-concrete buildings, particularly in industrial applications. The study demonstrates that the integration of PEB and CSB systems can reduce both the seismic force and structural displacement when compared to traditional construction methods. The research emphasizes the importance of designing effective connection systems and understanding the dynamic behavior of the hybrid structure.

2.24 Zou et al. “Dynamic Performance of Composite Steel-Concrete Buildings” *Journal of Structural Engineering* (2014).

Composite Steel Buildings (CSBs) are a popular choice in industrial construction due to their strength and stiffness, particularly for structures requiring heavy load-bearing capacities. Zou et al. (2014) explore the dynamic performance of CSBs, comparing them with pure steel structures. They found that the combined use of steel and concrete significantly improves the seismic performance of the building by enhancing stiffness and reducing vibrations.

2.25 Yadav et al. “Seismic Performance of Composite Buildings in Industrial Applications” *Earthquake Engineering Journal* (2020).

Explore the seismic performance of composite buildings, specifically PEB and CSB systems in industrial applications. Their research identifies that PEBs, due to their lighter mass, can reduce the overall seismic demand, making them ideal for regions with moderate seismic activity. In contrast, CSBs, with their higher stiffness, provide greater resistance to seismic forces, but their increased mass can lead to larger forces during a seismic event.

2.26 Liu et al. “Dynamic Interaction of Pre-Engineered Buildings and Composite Steel Buildings” *Journal of Construction and Building Materials* (2019).

Analyse the dynamic interaction between pre-engineered buildings (PEBs) and composite steel buildings (CSBs) in hybrid structural systems. Their research indicates that the combination of the flexible PEB frame with the rigid CSB structure leads to unique dynamic behavior that requires careful consideration during the design phase.

2.27 Kumar et al. “Finite Element Analysis of Hybrid Pre-Engineered and Composite Steel Buildings” *Journal of Structural Design* (2021).

Focus on the application of finite element analysis (FEA) for simulating the dynamic response of hybrid pre-engineered and

composite steel buildings. Their findings suggest that FEA is an effective tool for capturing the complex interactions between PEB and CSB systems under dynamic loading.

2.28 Chen et al. “Vibration Analysis of Hybrid Steel and Concrete Structures” *Journal of Earthquake Engineering* (2020).

Explore the vibration characteristics of hybrid steel and concrete buildings, focusing on the impact of dynamic forces on PEB and CSB structures. Their research identifies that while PEBs have better flexibility and lower natural frequencies,

2.29 Singh and Sharma “Seismic and Wind Load Response of Pre-Engineered Buildings and Composite Structures” *Structural Engineering and Materials* (2019).

Examine the seismic and wind load response of pre-engineered buildings (PEBs) and composite steel buildings (CSBs), with a particular focus on their dynamic interaction. Their study reveals that the dynamic response of hybrid PEB-CSB systems is a result of the interplay between the light, flexible PEB frame and the more rigid, mass-heavy CSB frame..

2.30 Jain et al. “Dynamic Load Analysis of Hybrid Pre-Engineered Steel Buildings with Concrete Floors” *Journal of Civil Engineering and Architecture* (2019).

Investigate the dynamic load analysis of hybrid pre-engineered steel buildings (PEBs) with concrete floors. Their findings suggest that hybrid systems, consisting of lightweight steel frames and rigid concrete floors, are well-suited for dynamic load conditions. The study shows that the concrete floors in CSB sections help in distributing seismic loads more evenly throughout the structure.

IV. RESEARCH GAP

As it is a review chapter, it finds that PEB constructions are lighter and more wind-resistant. Pre-engineered structures are more suitable for longer spans building as consumers prefers more space in a structure. The design needs to be compared in terms of total steel weight take off. IS codes should be modified as the sections selected are found to be heavier mostly Steel is the basic material that is used in the materials that are used for Pre-engineered steel building. Based on the analytical and design results thereon of conventional and pre-engineered steel buildings. The final results that should obtain due to same loading in different seismic zones in India. There are no one analyse PEB for the supported on RCC pedestal for effective results further study will analyse PEB and CSB structure comparatively and PEB on RCC pedestal on wind load by using gust method and higher seismic zone impact.

V. DISCUSSION

From the literature review, it is observed that RCC box-type underpass bridges provide better structural stability and seismic resistance compared to conventional bridge systems. The monolithic box configuration increases stiffness and helps in uniform distribution of loads.

It is also observed that:

- Seismic response increases with increase in structural mass and span length.

- Soil–structure interaction significantly influences structural behaviour.
- Three-dimensional finite element analysis provides more accurate results than simplified methods.
- Dynamic analysis is essential for evaluating vibration and acceleration response.

The studies further indicate that moderate span lengths often provide balanced structural performance with controlled displacement and acceptable stress levels.

VI. CONCLUSION

The present review paper examined previous research related to RCC underpass bridges, seismic analysis, dynamic behaviour, and soil–structure interaction. Based on the review, the following conclusions can be drawn:

1. RCC box-type underpass bridges are structurally efficient and suitable for urban transportation systems.
2. Seismic loading significantly affects displacement, stress distribution, and vibration characteristics of underpass bridges.
3. Soil–structure interaction plays a major role in the seismic response of underground structures.
4. Three-dimensional numerical modelling provides more realistic structural behaviour compared to simplified analytical approaches.
5. Limited research is available on combined vehicular and seismic loading conditions for varying span lengths.
6. Further detailed comparative studies are required to identify optimum underpass bridge configurations for seismic-prone regions.

VII. FUTURE SCOPE

Future research may focus on:

- Nonlinear dynamic analysis using real earthquake records
- Advanced soil–structure interaction modelling
- Shake table experimental studies
- Performance-based seismic design
- Use of prestressed concrete and composite materials
- Fatigue and durability analysis under repeated traffic loading
- AI and optimization techniques for bridge design

REFERENCES

- 1) Pratik M. Londhe et. al. “A Comparative Analysis of Conventional Steel Building and Pre-Engineered Building Systems: a case study Approach” ICSTCE (2024)
- 2) Ranjith Raja P et. al. “Design of Pre Engineered Building Using STAAD PRO” IJIRT (2024)
- 3) Shubham Dashore et. al. “Analysis And Design Of Pre-Engineered Building Warehouse In Different Seismic Zones” ResearchGate (2023)
- 4) Payal J. Abhichandani et. al. “Analytical Study of Pre- Engineered Building” International Journal of Innovative Research in Science, Engineering and Technology (2022)
- 5) Akshay Gavandare et. al. “Analysis and Design of Steel Building and its Comparative Study with Conventional RCC Building” International Journal of Science and Research (2022)
- 6) Laishram Chandramani Singh et. al. “An Analytical Study On Pre Engineered Building By Using Staad Pro” JETIR (2021)
- 7) Mohd Atif Khan et. al. “A Review on the Optimization and Design of Pre-Engineered Building [PEB] with Conventional Steel Building” International Journal Of Multidisciplinary Research In Science, Engineering and Technology (2021)
- 8) Bishbu Jacob et. al. “Design comparison of conventional steel structure with pre - engineered structure” IOP Conference Series: Materials Science and Engineering (2020)
- 9) Kalesha Shaik et. al. “An analytical study on pre engineered buildings using staad pro” ResearchGate (2020)
- 10) Pradip S. Lande et. al. “Comparative Study of an Industrial Pre-Engineered 2.15 Muhammad Umair Saleem et. al. “Design Solutions for Sustainable Construction of Pre Engineered Steel Buildings” ResearchGate (2018)
- 11) T.D. Mythili et. al. “An Overview Of Pre-Engineered Building Systems” International Journal of Scientific & Engineering Research (2017)
- 12) Building with Conventional Steel Building” Journal of Civil Engineering and Environmental Technology (2015)
- 13) Neha Kolate et. al. “Economizing Steel building using Pre-Engineered Steel Sections” International Journal of Scientific & Engineering Research (2015)
- 14) G.Durga Rama Naidu et. al. “Comparative Study of Analysis and Design of Pre-Engineered Buildings and Conventional Frames” ResearchGate (2014)
- 15) C. M. Meera et. al. “Pre-Engineered Building Design Of An Industrial Warehouse” International Journal of Engineering Sciences & Emerging Technologies (2013)
- 16) Sharma et al. “Dynamic Behavior of Hybrid Steel-Concrete Structures under Seismic Load” International Journal of Structural Engineering and Analysis (2021).
- 17) Siddiqui et al. “Performance of Hybrid Buildings with Tuned Mass Dampers” Earthquake Engineering and Structural Dynamics (2018).

- 18) Li et al. “Load Transfer Mechanisms in Hybrid PEB-CSB Structures” *Engineering Structures* (2021).
- 19) Kaveh et al. “Optimization of Vibration Control in Hybrid PEB-CSB Systems” *Journal of Structural Dynamics* (2019).
- 20) Patil and Deshmukh “Seismic Behavior of Pre-Engineered and Composite Steel-Concrete Hybrid Buildings” *International Journal of Seismic Design* (2021).
- 21) Zhang et al. “Hybrid PEB-CSB System: Dynamic Response and Load Transfer Mechanisms” *Engineering Structures* (2020).
- 22) Garg et al. “Dynamic Behavior of Pre-Engineered Buildings Under Seismic Loading” *Structural Engineering International* (2016).
- 23) Bansal et al. “Optimizing the Seismic Performance of Hybrid Steel-Concrete Buildings” *Earthquake Engineering Research* (2021).
- 24) Zou et al. “Dynamic Performance of Composite Steel-Concrete Buildings” *Journal of Structural Engineering* (2014).
- 25) Yadav et al. “Seismic Performance of Composite Buildings in Industrial Applications” *Earthquake Engineering Journal* (2020).
- 26) Liu et al. “Dynamic Interaction of Pre-Engineered Buildings and Composite Steel Buildings” *Journal of Construction and Building Materials* (2019).
- 27) Kumar et al. “Finite Element Analysis of Hybrid Pre-Engineered and Composite Steel Buildings” *Journal of Structural Design* (2021).
- 28) Chen et al. “Vibration Analysis of Hybrid Steel and Concrete Structures” *Journal of Earthquake Engineering* (2020).
- 29) Singh and Sharma “Seismic and Wind Load Response of Pre-Engineered Buildings and Composite Structures” *Structural Engineering and Materials* (2019).
- 30) Jain et al. “Dynamic Load Analysis of Hybrid Pre-Engineered Steel Buildings with Concrete Floors” *Journal of Civil Engineering and Architecture* (2019).