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A Review of Comparative Study of Pre-Engineered Building and Conventional Building and Development of Fragility Curves

Ganesh Nimbalkar [a,*], Atul Patane [a]

[a] *Applied Mechanics, Walchand College of Engineering, Sangli, Maharashtra, India*

*Corresponding author: *ganesh.nimbalkar@walchandsangli.ac.in*

Abstract— **This review paper presents comparative study of Pre-engineered buildings (PEBs) and conventional structures. In this study, with an emphasis on a number of factors including structural performance, cost-effectiveness, construction time, and sustainability. The assessment entails a thorough examination of the planning, execution, and performance attributes of both building types, taking into account elements such as labour needs, environmental effect, and material consumption. Using a multidisciplinary approach, the study incorporates sustainability issues, construction management, and structural engineering. A comprehensive grasp of the advantages and disadvantages of pre-engineered and conventional buildings is provided by analysing a variety of case studies and real-world situations. The research advances the area by creating fragility curves for conventional and pre-engineered buildings in addition to the comparative analysis. Fragility curves provide important information for risk assessment and mitigation.**

Keywords— **Pre-Engineered Buildings (PEB); conventional buildings; comparative structural analysis; seismic fragility curves.**

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I. INTRODUCTION

Pre-engineered buildings (PEBs), which make use of sophisticated predesign and prefabrication procedures, have caused a paradigm change in the evolution of building construction technologies. PEBs have attracted a lot of interest lately due to their clear advantages over conventional steel constructions. PEBs have advanced significantly, according to Sharma et al. [1], providing advantages such shorter construction schedules, cost effectiveness, improved structural performance, and more architectural flexibility. Gawade and Waghe [2] underline the usefulness and adaptability of PEBs in the Indian civil industry, especially by using web-tapered components to maximise structural efficiency, which further emphasises this tendency. To further elaborate on this discussion, Ramakrishnan [3] makes a comparison between PEBs and traditional steel constructions as well as a truss arrangement building system.

In the meantime, Liu et al. [4] investigate the seismic susceptibility of nuclear power facilities, using incremental dynamic analysis to comprehend structural reactions to different intensities of ground motion. By using modelling techniques to predict structural behaviour and create fragility curves, Saler et al. [5] expand on the investigation and offer insights into the possibility of damage under seismic loads. Hamida and Mohamada [6] employ fragility curves from experimental studies to focus on the seismic evaluation of precast homes. Additionally, Shabani et al. [7] examines low-rise, seismically vulnerable buildings composed of unreinforced masonry, using a specialised modelling technique to evaluate seismic resilience.

Last but not least, Shaik et al. [8] add to the conversation by assessing the structural performance of PEBs in various locations under variable wind zones, highlighting the flexibility and resilience of the advancements, comparisons, and seismic assessments within the realm of pre-engineered buildings and conventional structures.

When taken as a whole, these studies add to a thorough knowledge of the developments, contrasts, and seismic evaluations that occur between pre-engineered buildings and conventional building techniques.

II. MATERIAL AND METHOD

Sharma et al. [1] The notion of pre-engineered buildings, which are built using predesign and prefabrication techniques, is introduced in the introduction of the article. Comparing these buildings to traditional steel structures, they have a number of benefits. Pre-engineered buildings have made substantial advancements, according to the authors, and now provide advantages like faster construction times, lower costs, better structural behavior, and more flexible architectural options. The study's main goal is to make comparisons between pre-engineered and traditional steel structures based on a variety of criteria. To do this, the authors created a pre-engineered building and compared it to a building of the same configuration that was built conventionally. Bentley STAAD PRO, a widely used structural analysis and design application, was used to design and analyze the buildings.

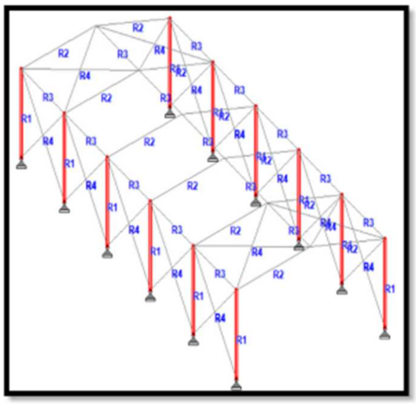

Fig. 1 Design and analyze the buildings

In this study by Sharma, Taak, and Mishra [1], the performance of pre-engineered buildings (PEBs) is fully analysed and compared to traditional steel buildings. The design outcomes and ratios that are displayed show how much better PEBs perform than conventional structures. One important factor in PEBs' superior performance over traditional steel buildings is their integral framing system. Furthermore, PEBs benefit from the application of modelling and simulation tools, which provide improved structural characteristics that are impractical for conventional buildings.

III. RESULT AND DISCUSSION

According to the study, PEBs reduce overall structural weight by 20 to 25 percent, which has an immediate effect on the amount of structural steel used and building costs. Notably, PEBs exhibit a noticeably faster rate of delivery—projects are completed in 8 to 10 weeks as opposed to the 24 to 30 weeks needed for traditional steel buildings. PEBs exhibit greater seismic performance, which is attributable to their lightweight construction and enhanced structural behaviour. PEB members' overall structural performance is further enhanced by their ease of erection and speed, which outperforms traditional buildings where labour-intensive, customised design processes might be a hindrance. The results highlight the several benefits of pre-engineered buildings, including cost-effectiveness, seismic resistance, and structural efficiency

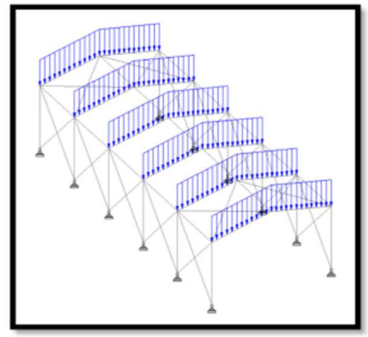

Fig. 2 Application of Dead Load

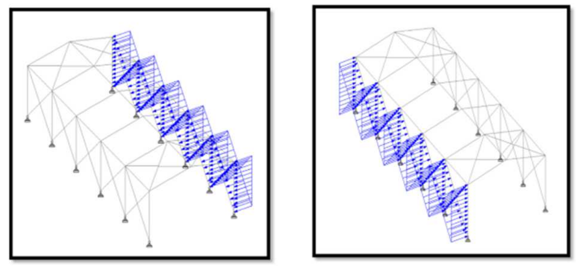

Fig. 3 Application of Dead Load

Gawade and Waghe [2] studies the steel construction industry, PEBs are emphasized as a practical and uncomplicated building form. They are renowned for having numerous uses in the Indian civil industry. The importance of tapering elements, such as columns and rafters, in PEB design is emphasized in the paper. To maximize structural performance and cost-effectiveness, these members are crucial. Web-Tapered Members: One method for boosting PEB effectiveness is the use of web-tapered members. These members are probably employed to decrease the amount of material utilized and increase load-bearing capability.

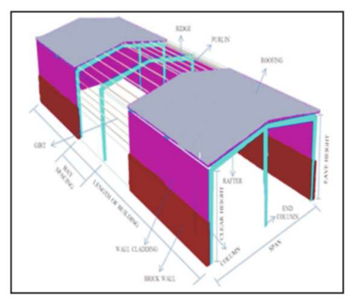

Fig. 4 Components of PEB

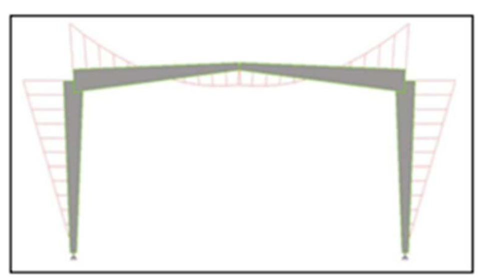

Fig. 5 PEB Frame and Respective area Bending Moment

PEB is an effective building alternative as opposed to CSB when it comes to steel constructions. Numerous decisions can be made about the structural arrangement of PEB. According to earlier studies, PEB weighs significantly less than CSB, even though they both have the same load carrying capacity. In contrast to CSB, PEB demands extremely precise design and detailing.

Ramakrishnan [3] this research paper focuses on comparing two different building systems: Pre-Engineered Buildings (PEB) and a truss arrangement building system. The goal is to determine which system is more economical for industrial pitched roof buildings of various sizes (15x30m, 40x80m, and 90x180m). The study addresses a gap in existing research, as most previous studies have primarily compared PEB with conventional steel buildings, and there's limited research on PEB's effectiveness for smaller and larger span buildings. The paper highlights the growing popularity of steel over Reinforced Concrete Construction (RCC) due to steel's advantages, including malleability, re-usability, and fire resistance.

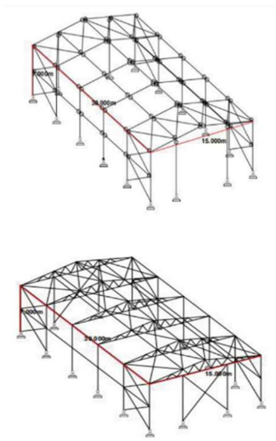

Fig. 6 Application of Dead Load

Result discussion, the height of building kept as 7m and spacing of bays as 6m c/c throughout. The location is taken as Chennai, India for analysis purpose. The dead load is considered due to purlins, girts and sheet. Dynamic forces like earthquake and wind are calculated as per Indian standard provision.

Liu et al. [4] this study examines how seismic instability affects nuclear power plants' transfer and purging chambers. The assessment is based on the incremental dynamic analysis approach, a method used to gauge how a structure would react to different levels of ground motion. The measure of ground motion intensity used in this investigation is the peak ground acceleration. The structural reaction is examined by the researchers using a variety of damage metrics. These measurements include the peak displacement of the structure, the steel plate stress, and the concrete's compressive strain. The researchers want to comprehend the conditional failure probability at different levels of damage, such as no damage, moderate damage, recoverable damage, and serious damage, by looking at these parameters under 160 different seismic circumstances.

Result discussion, this provided a computationally efficient way for the quick assessment of bridge fragility using artificial neural networks. In keeping with this, a bridge design process was created for the comprehensive FE models based to modern seismic codes and engineering experience.

This method took into account a number of model parameter and ground motion uncertainties. Both the associated seismic fragility curves and the specifics of the intended bridge model were found to be trustworthy and in line with accepted practices. Subsequently, 516 thoroughly examined bridges were assembled into a bridge database, which was utilised for the test sets' validation and training. The ANN-based fragility model was created based on the information above, and it successfully captured the seismic performance of the bridge under study.

Overall, it was determined that the suggested methodology can serve as a helpful substitute for traditional fragility methods, obtaining a comparable level of accuracy in a much smaller amount of time , computation duration.

The seismic assessment of the damage statuses of structures and the related decision-making can be made easier by the ANN-based methodology.

Nonetheless, the international literature and design practice inform the development of the ANN-based fragility model, which is based on the 11 most influential criteria. Incorporating additional significant factors, like soil characteristics or a customised ground motion selection that accounts for seismic risk at a particular location of interest, can also be done in a more sophisticated fragility development using the same process. It should be mentioned that this ANN-based fragility model is only applicable to bridges with regular plans and curvatures.

Saler et al. [5] to simulate the behavior of various structural components, researchers employed modeling approaches. Half-height infills were represented by a single-strut macro-model, and masonry components were modeled using an equivalent frame model (EFM). Plasticity hinges were employed for the brickwork and infills to capture the structure's nonlinear behavior, while a fiber model was applied to the reinforced concrete frames. Between structural units, the presence of non-seismic joints was also taken into account. Fragility Assessment: From the results of the nonlinear time history analysis (NLTHA), fragility curves were created. The likelihood of various degrees of structural damage or failure under seismic loading can be learned from fragility curves.

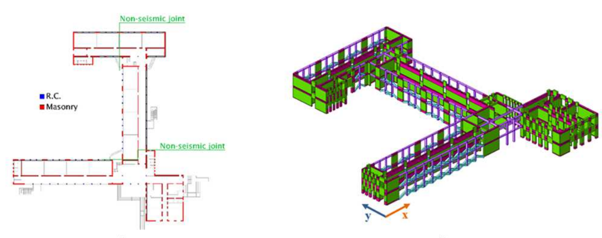

Fig. 7 Scheme of plan arrangement (a), and F.E. model (b) of case study

Result discussion, the discussion of linear dynamic analysis results has shown how much the masonry and RC components contribute to base shear, respectively. The building's overall modelling results indicated that r.c. frames would be viewed as secondary, but a closer examination of each s.u. revealed the significance of r.c. contribution in the reaction of the earthquake.

Low degrees of damage were caused by the failure of masonry piers, which were shown to be crucial components in the structural reaction, according to preliminary nonlinear static analysis. Moreover, a fragility set for four damage states was produced by nonlinear time history analyses, by applying a suite of 84 natural ground motion records.

This contribution has provided one of the first fragility model for mixed masonry-r.c. schools, representing the expected seismic response of a mixed building with two storeys, built in the period 1950s-1960s, characterised by r.c. frames on façades, coupled with longitudinal and transverse masonry walls.

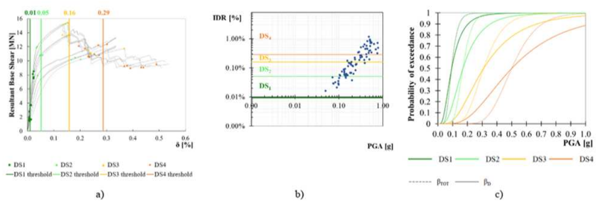

Fig. 8 IDR thresholds identified on pushover curves (a), cloud plot (b), and derived fragility set (c) for case study

The results of this study shed light on the seismic vulnerability assessment of mixed buildings, which make up a sizable percentage of Italy's architectural legacy and originate mostly from the Second World War's reconstruction.

Hamida and Mohamada [6] This research paper focuses on the seismic assessment of a double-storey precast house using fragility curves. The main goal of this study is to assess the seismic performance of a double-storey precast house. This assessment is based on the development and utilization of fragility curves derived from experimental work. A full-scale precast house is constructed and placed on a strong floor. The house is subjected to quasi-static lateral cyclic loading, simulating seismic forces. The focus is on two parallel walls within the house. The fragility curves are used to assess the safety of the double-storey house. This assessment includes determining the predicted damage states of the house under both Design Basis Earthquake (DBE) and Maximum Considered Earthquake (MCE) scenarios. In other words, it helps estimate how the house would fare in different seismic events.

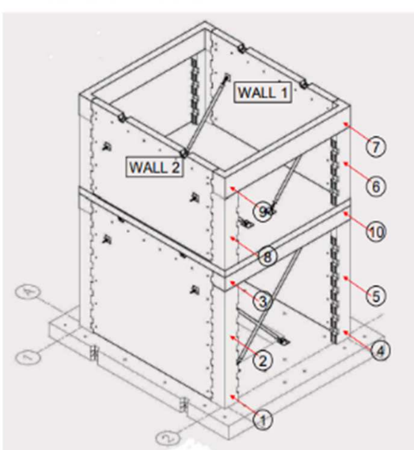

Fig. 9 Isometric view of a double-storey house

Result discussion, The assessment of a double-story house's seismic risk in a low-seismic region—like Malaysia—is covered in this literature. The probability of structural damages above predetermined levels under different seismic excitations is represented by fragility curves, which are shown. Equations (5) and (6) serve as the foundation for the curves, which use the x-axis to represent Peak Ground Acceleration (PGA) and the y-axes to represent Cumulative Probability Function (CPF) and Confidence Interval (CI).

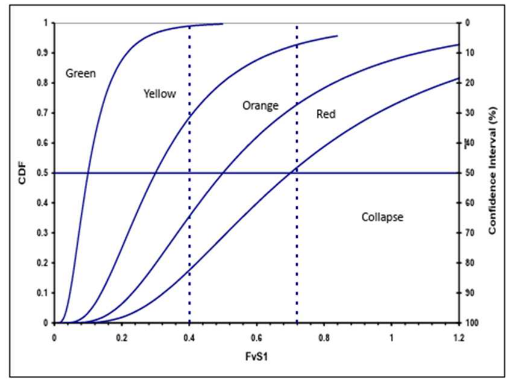

Fig. 10 Fragility curve for precast double-storey house constructed using shear-key wall panel

The building is considered safe for habitation for the Design Basic Earthquake (DBE) with PGA=0.12g; functional and fully functioning states are indicated by the 40% confidence interval (green) and 95% confidence interval (yellow), respectively. The building faces major structural damages in the Maximum Considered Earthquake (MCE) with PGA=0.22g, with confidence intervals ranging from 10% (green) to 95% (red). In the most dire circumstances of PGA=0.8g, a partial collapse of the building is anticipated.

In order to assure life under Maximum Considered Earthquake conditions, the conclusion recommends that the building adapt to current seismic norms, such as Eurocode 8, for higher reinforcement, improved strength capacity, stronger connections at interfaces, and enhanced system ductility. The body of research emphasises how crucial it is to use sound seismic design techniques in order to reduce structural vulnerabilities in areas that are prone to earthquakes.

Shabani et al. [7] this paper examines a study that was done to determine how earthquake-prone low-rise buildings made of unreinforced masonry (URM) are. URM structures are thought to be economical in these situations, although they are susceptible to earthquakes, particularly if they are close to the epicenter (near-field ground movements). When compared to earthquakes that originate farther away (far-field seismic events), these near-field earthquakes frequently produce high-velocity pulses that can be more damaging. The researchers used four distinct URM wall layouts to test the seismic resiliency of low-rise URM buildings. They used a particular modeling method known as the double-modified, multiple vertical line element model (DM-MVLEM) to create nonlinear models of these walls. The zero-moment coefficient, which establishes the effective uncracked section length of a pier in the URM, is a significant parameter

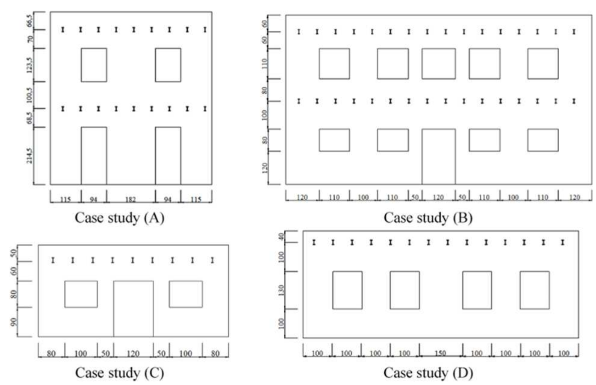

Fig. 11 Four low-rise URM walls as case studies

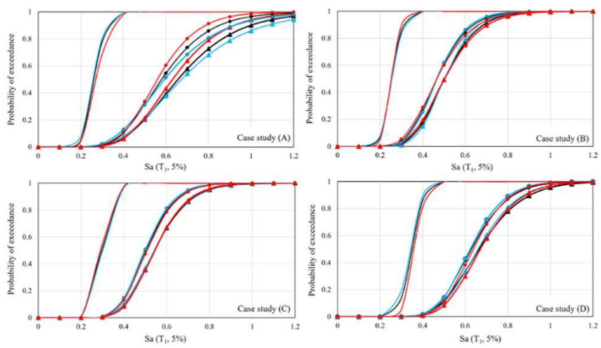

Fig. 12 Fragility curves of the case studies subjected to FF and NF ground motions for all three damage limit states for case studies A-D

This study examines the fragility curves under far-field (FF) and near-field (NF) ground motions in order to assess the vulnerability of low-rise unreinforced masonry (URM) buildings in high seismic zones. For four low-rise perforated URM walls, the study uses nonlinear models based on the double-modified multiple vertical line element model (DM-MVLEM). The structural behaviour is characterised by determining key parameters such the zero-moment coefficient (α0) and maximum lateral strength (Vm).

The results show that a simplified analytical method for calculating α0 can be provided and is shown to be accurate when compared to conventional linear equivalent frame models. The study underlines how varied displacement capacities for piers with shear or flexural failure modes must be taken into account and how inadequate specified inter-story drift ratios are for damage limit states. The seismic demands for the analysed URM buildings under FF and NF ground motions are not considerably different, according to fragility curves produced by incremental dynamic analysis (IDA). For medium-high intensity seismic events, the research indicates that seismic fragility analysis based just on FF ground motions is accurate enough, with suggestions tailored specifically for one- and two-story URM buildings. The publication also suggests directions for further investigation, such as lowering parameter prediction uncertainty and expanding the study to 3D models, and exploring the influence of different ground motion intensity measures on seismic fragility curves.

Shaik et al. [8] this research paper focuses on the application of Pre Engineered Buildings (PEB) in two different locations, Vijayawada and Hyderabad, and evaluates their structural performance under different wind zones. The paper begins by highlighting the significance of technological advancements in structural engineering, particularly the Pre-Engineered Building (PEB) concept. PEB is praised for its ability to offer optimal design, aesthetic appeal, rapid construction, and reduced erection time. It is noted for its adaptability due to high-quality pre-designing and prefabrication. The primary objective of the study is to compare the structural performance of a multi-bay PEB system in two different locations: Vijayawada and Hyderabad. These locations likely have different wind zone characteristics, and the study aims to understand how these variations affect the structural design.

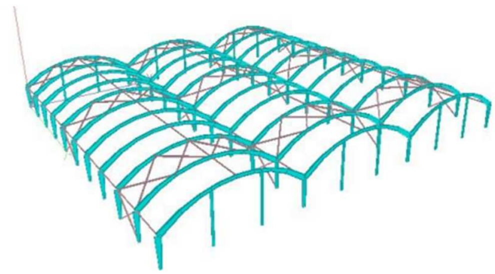

Fig. 13 3D view of ware house

The research findings reveal significant variations in the structural characteristics between buildings located in Vijayawada and Hyderabad. Significant differences in the structural properties of buildings in Hyderabad and Vijayawada are revealed by the research findings. First, it is seen that the Vijayawada structure weighs 11.04% more than the Hyderabad structure. This significant weight differential raises the possibility of discrepancies in the two structures' construction materials, design choices, or load-bearing capacities. Second, a comparison of the column and rafter section sizes shows that the Hyderabad structure has somewhat smaller columns and rafters than the Vijayawada building. The Hyderabad structure's reduced bending moments (BM) and shear forces (SF) are the cause of this disparity. The found relationship between section sizes and structural weight emphasises how design choices affect the total dimensions of the building components. Additionally, the study finds that the seismic zone and wind speed are important variables influencing the section sizes and structural weight in the places under investigation. These results highlight how important it is to take local environmental factors and seismic hazards into account when designing and building structures in order to maximise material efficiency

Fig. 14 Bending moments on typical frame for Vijayawada location

IV. Conclusion

In summary, the several research that were presented provided insight into the complex relationships between traditional construction techniques and pre-engineered buildings (PEBs). Together, these investigations deepen our knowledge of the advantages, difficulties, and particular uses of conventional construction techniques and pre-engineered buildings in a range of structural scenarios and contexts. The study helps the building sector make well-informed decisions by taking into account variables including cost, flexibility, seismic resilience, and structural performance.

REFERENCES

[1] L. Sharma, N. Taak, and P. K. Mishra, "A comparative study between the pre-engineered structures and conventional structures using STAADPRO," *Mater. Today: Proc.*, vol. 45, pp. 3469–3475, 2021, doi: 10.1016/j.matpr.2020.12.942.

[2] M. D. Gawade and U. P. Waghe, "Study of Pre-Engineered Building Concept," *JREAS*, vol. 3, no. 3, pp. 88–91, 2018, doi: 10.46565/jreas.2018.v03i03.003.

[3] R. Ramakrishnan, "Comparative Study of Pre-Engineered Building and Truss arrangement Building for varying spans," *Zenodo*, 2022, doi: 10.5281/ZENODO.6467617.

[4] X. Liu, X. Li, X. Wang, N. Wang, and Z. Li, "Seismic fragility analysis of the transfer and purging chamber in a nuclear power plant based on incremental dynamic analysis," *J. Radiat. Res. Appl. Sci.*, vol. 15, no. 3, pp. 133–141, 2022, doi: 10.1016/j.jrras.2022.07.003.

[5] E. Saler, A. Caprino, G. Scarabottolo, and F. Da Porto, "Seismic analysis and fragility estimate of a mixed masonry-r.c. school building," *Procedia Struct. Integrity*, vol. 44, pp. 179–186, 2023, doi: 10.1016/j.prostr.2023.01.024.

[6] N. H. A. Hamid and N. M. Mohamad, "Seismic Assessment of a Full-Scale Double-Storey Residential House using Fragility Curve," *Procedia Eng.*, vol. 54, pp. 207–221, 2013, doi:10.1016/j.proeng.2013.03.019.

[7] A. Shabani, M. Zucconi, D. Kazemian, and M. Kioumarsi, "Seismic fragility analysis of low-rise unreinforced masonry buildings subjected to near- and far-field ground motions," *Results Eng.*, vol. 18, 2023, Art. no. 101221, doi: 10.1016/j.rineng.2023.101221.

[8] K. Shaik, R. R. B. S. S., and D. C. K. Jagarapu, "An analytical study on pre engineered buildings using staad pro," *Mater. Today: Proc.*, vol. 33, pp. 296–302, 2020, doi: 10.1016/j.matpr.2020.04.076.