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A Construction Technology Adaptations in Composite RCC–Pre-Engineered Residential Building: A Case Study from Kathmandu Valley

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ABSTRACT. The devastating earthquake that highly affected Nepal in April of 2015 raised awareness of the country's building practices and escalated the transition to a modern, resilient building system, especially in the rapidly growing housing settlements of Kathmandu. In this meantime, the efficiency and structural merit of RCC–Pre-Engineered Building (PEB) construction have drawn a lot of attention from different societies; but fewer studies and research have responded to practical on-site adaptations in urban zones. This case study focusses on a three and half story residential building of height 12 meters in total, that integrates a hybrid RCC-steel structural building. RCC beam and columns, a mid-bay PEB beam, composite slabs, integrated footings with anchor bolts, and lift pit make up the structure modern and incorporating urban amenities. The implementation of pulley-based erection techniques supported by RCC columns permitted the safe and effective lifting of heavy fabricated PEB beams after observations showed that typical crane mobilization was difficult to mobilize. These technique—pulley systems, integration of RCC and PEB members, and optimized detailing—systematically addressed site limits while withstanding structural integrity. The research focus that these methods are repeatable and context-specific, connecting theoretical design with real-world practical implementation and providing clear information about resilient building construction in countries like Nepal where developing physical infrastructure industries are growing rapidly and possible area for generating employment which leads to uplift developing economies and businesses.

Keywords: Construction technology adaptation; Composite structures; RCC–PEB integration; Erection methods; Composite slab; Urban construction

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1. INTRODUCTION

The structural composition of RCC–PEB structures are growing structural preferences due to their capability to combine the stability of reinforced cement concrete (RCC) with the modular efficiency of pre engineered buildings (PEB). While design and analysis of such systems are well reviewed in literature, there is limited academic reporting on how construction technologies are executed to site constraints in practice. This research presents a case study from Kathmandu Valley, where a composite RCC–PEB building was constructed under restricted site conditions. The structure elevates to 12 m with three and a half stories, withstanding by RCC columns — 500 × 500 mm on the left side and 600 × 600 mm on the right side of building respectively— with an on-site fabricated PEB steel section in the midbay. At the top floor, 2 ISMC 300 columns were installed above the left RCC column to balance roof loads and integrate with the midbay steel structure. The foundation consists of combined RCC footings, while the superstructure integrates RCC beams, ISMB steel beams, and a composite slab of 150 mm thickness with 0.8 mm decking sheets and 13 mm shear studs as specified by design drawing and as-built drawings at site. A lift pit was also integrated within the footing level to accommodate vertical transportation systems observing need of residential building and owner's need for future provision as a part of urban amenities.

The case study draws attention to how construction technology adaptations were performed to overcome site limitations. Typical crane mobilization was less feasible, leading to the acceptance of pulley based erection methods with anchor support to RCC columns. This method confirmed safe and efficient lifting of PEB beams overcome the site limitation. Service integration was addressed through the lift pit provision, while detailing technologies such as decking sheets and shear studs ensured effective composite action between RCC and steel PEB structural members.

While focusing on this academic study, the paper rec-ords practical breakthroughs in Nepal's construction industries, demonstrating how local methods pulley systems, lift pit integration, and slab detailing con-tribute to the successful project execution of structure composition of RCC–PEB. Pre-engineered buildings are structure designed and fabricated using standard and verified material be-cause of its advantages like reduced construction time, cost efficient, lighter weight and flexibility in design than that to typical concrete structure with followed by improved sustainability compared to traditional construction approach practiced in general construction industries.

2. LITERATURE REVIEW

The structure composition of RCC–Pre Engineered Building (PEB) reflects a hybrid construction technique that combines the stability of reinforced cement concrete (RCC) with the modern and efficient design of pre engineered buildings. Concrete structure has traditionally dominated Nepal's construction industries due to material availability and familiarity but struggles in such a way as heavy and self weight followed by slower construction speed, and formwork difficulty limit its efficiency [1]. In context, PEB systems are fabricated off site and on-site and assembled quickly, offering modularity, reduced construction duration, and cost-effective options [2].

Varieties of comparative studies have spotlighted the merits of PEB structure systems. Ingole and Changhode [2] showcased faster construction cycles and reduced costs, while Parveen and Hegde [3] underlined superior strength to weight ratios using software like STAAD Pro and SAP2000. Patidar and Maru [4] reasoned that these kinds of composite structure are more reliable and sustainable compared to typical RCC structure. International works (Kalesha et al. [5]; Sharma et al. [6]; Saleem et al. [7, 8, 9]; Roopesh et al. [10]) add more force to these findings, focusing optimization of steel sections, sustainability, and proficient practices. The studies highlighting comparision (Meera [11]; Jinsha & Mathew [12]; Vishnu Sai et al. [13]; Zoad [14]; Wakchaure & Dubey [15]; Zende et al. [16]; Charkha & Sanklecha [17]) continuously focuses to reduced construction time and cost, although most are best suited for industrial contexts.

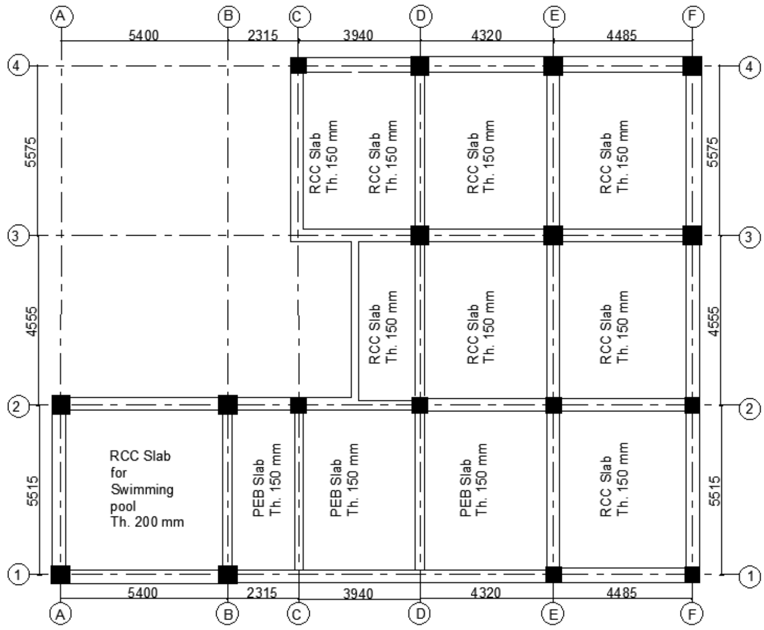

FIGURE 1. Schematic representation of the slab plan at the G+2 floor level above Columns A1, A2, and B1 where 2 ISMC sections installed as columns

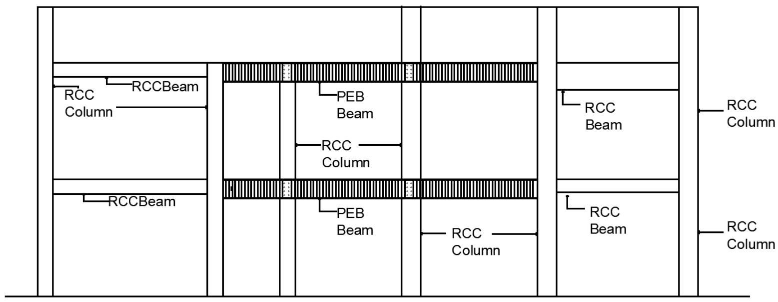

FIGURE 2. Schematic representation of structural elevation

Despite these points, most studies focus on design and analysis rather than construction technology adaptations in real world. International practice and codes emphasize mechanized erection approach such as cranes and hydraulic lifts, but these are often difficult in execution in Nepal's dense urban metropolitan cities. Local techniques, such as pulley systems, scaffolding based lifting, and modular assembly, remain under documented academically yet being impactful. Codes such as IS 456 [1], IS 800 [18, 19], IS 2062 [20], and the updated version IS 11384:2022 [21] defines the need for concrete, steel, and composite construction, while IS 14665 [22] and OSHA guidelines [23] provide safety touchstone. Thus, practical components such as decking sheet thickness or shear stud diameter are rarely accentuated in published papers and studies.

The National Building Code (NBC) of Nepal has provisions for the regulatory framework for both seismic and composite construction through NBC 105:2025 (Seismic Design of Buildings in Nepal), NBC 111:1994 (Steel) , NBC 201 (Mandatory Rules of Thumb for Reinforced Concrete Buildings with Masonry Infill), NBC 205 : 2024 (Ready-to-Use Detailing Guideline for Low-Rise Reinforced

Figure 3. Erection of PEB 600 beam section in G+1 and G+2 floor level

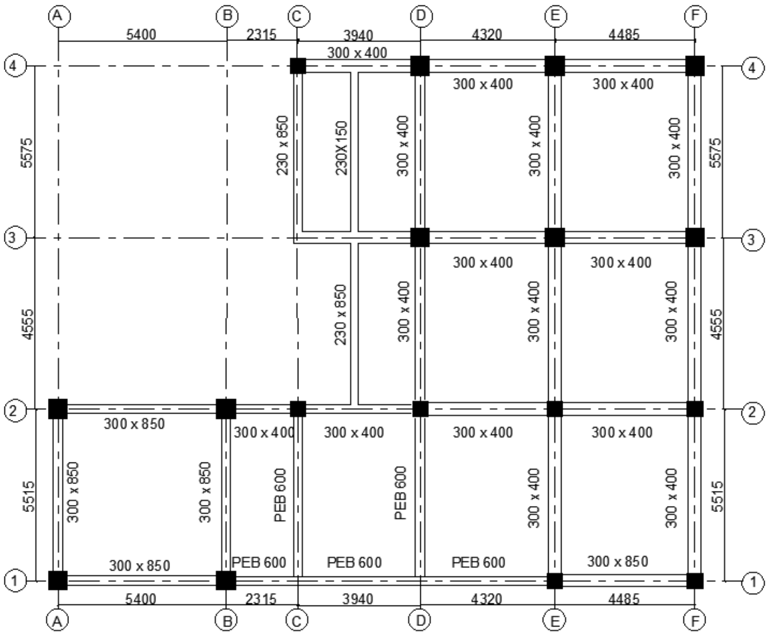

Figure 4. Schematic representation of structural beam layout plan

Concrete Buildings without Masonry Infill), and NBC 206: 2024 (Architectural Design Requirements). This code related regulatory protocol are essential for the frames for site practices, which often depends upon Indian Standards such asthe IS 875 series [24, 25, 26] and IS 1893:2016 [27]. In general, revising references from IS 11384:1985 to IS 11384:2022 is highly relevant for composite slab design in both structural engineering and construction engineering and management. Also, international references books, including MBMA (2006) [28] and Zamil Steel (1999) [29], provide insightful knowledge for the design and execution plan of pre-engineered building structures.

Current Nepalese studies cater essential context for the structures which are composed of RCC–PEB construction buildings in Kathmandu Valley. Shrestha et al. (2019) [30] and Khadka, Motra, G.B., et al. (2022) [31], examined seismic performance and hybrid RCC–steel building systems, underlining NBC 105 and NBC 201 observance. Shrestha & Shrestha (2024) [32], also with Motra, focused studies in construction technology in constrained urban sites which is more related to current Kathmandu valley, directly applicable to pulley based erection methods. K.C., Motra, G.B., et al. (2019) [33] and Shrestha, Motra, G.B., et al. (2024) [34], recorded behavior of composite slab and reconstruction practices executed post earthquake, reflecting hybrid structure like RCC–PEB adopted in residential contexts to equilibrium speed and resilience. International case studies also encourage the role of bracing in steel frame structures. Adithya et al. (2015) [35] explains that single diagonal bracing systems are more efficient than other setups in reducing bending moments and shear forces in columns of high rise steel frame buildings. Similarly, Suwal et al. (2022) [36] showed that bracing positions significantly affect story drift and base shear in Nepalese steel buildings, reinforcing the importance of arrangements for bracing strategies within regulatory framework design for seismic activities.

Prevailing literature confirms the superiority of composite RCC–PEB structures in regards of efficiency, sustainability, and seismic performance. However, there is a research gap in construction technology documentation — specifically in context of developing countries like Nepal in specific — where pulley systems, lift pit provisions, slab detailing, and bracing strategies are judgmental adjustment. By situating site observations and difficulties within the framework of updated codes (NBC 105, NBC 111, NBC 201, NBC 205, NBC 206, IS 11384:2022) and fresh Nepalese research studies (Suwal et al. [36]; Shrestha et al. [30]; Khadka et al. [31]; Shrestha & Shrestha [32]; K.C. et al. [33]; Shrestha et al. [34]), this research addresses that gap through a case study from urban sites located within Kathmandu Valley, thereby contributing both for academic oration and practical assistance for construction and design industries of Nepal.
Institutional contribution led by the National Society for Earthquake Technology–Nepal (NSET) have recorded code compliance and retrofitting practices executed in various location of Nepal. NSET publications, including the Building Permit Process Resource Book and Building Code Implementation Success Stories [37], underlies the municipal enforcement of NBC provisions and practical execution of retrofitting strategies for concrete and pre engineered buildings. These works go with academic studies by situating hybrid structure composed of concrete and steel within broader resilience agenda of Nepal particularly focusing in post earthquake reconstruction practices. The rational work by Bhatt et al. [38] estimated concrete, steel, and structure composited of both using ETABS under NBC 105:2020. Their study found that hybrid frames achieved 17% lower base shear than RCC, intermediate drift and displacement values, and superior pushover performance with no hinges formed at performance point. The hybrid system balanced rigidity at the base with ductility at upper levels, making it a practical, efficient, and resilient key for staged mid rise construction in context of seismic zone of Nepal.

3. SCOPE

There are several published research articles but limited are published on construction technology for composite structure of RCC and PEB. This paper hold opportunity to document the construction technology adaptation in structure composed of RCC and steel PEB in mid-rise and post-earthquake reconstruction activities, it also ensures standard code compliance ensuring safety and integrating Nepal specific literature review.

4. LIMITATION

This document is limited to simple arithmetic calculation and does not constitute any kind of structural modeling or analysis. Although, all construction activities were performed as per design

FIGURE 5. Erection of 2 ISMC column (toe to toe connection)

structural drawing. Therefore, the paper is composed as qualitative field documentation which enable to represent construction technology with clearly stated scope limitations.

5. METHODOLOGY

This research was conducted on a composite RCC–Pre Engineered Building (PEB) located in Kathmandu Valley. The structure has a total height of 12 m and consists of three and a half stories. The site was selected due to its constrained urban setting, where typical crane deployment was prohibited. This provided an opportunity to document construction technology adaptations, specifically pulley based erection, lift pit provision, and composite slab detailing.

Connection details were prepared with all dimensions expressed in millimeters (mm) unless otherwise specified. The building is located on plain terrain with an overall slope of less than 3°, though a local terrain height difference of approximately 3600 mm was observed across the site. The total ground coverage of the building is 383 m^2. Two types of flooring systems were adopted:

- Steel deck composite slab supported by steel PEB girders.
- RCC slab supported by RCC beams.

These deviations reflect the integration of RCC and PEB systems to optimize construction under site constraints.

5.1. **Structural Description.** The composite structure of RCC–PEB building was designed with RCC columns on either side and PEB sections in the midbay, with further adaptation at the top floor:

- **Left Side:** RCC columns of sizes 500 × 500 mm cross section.
- **Right Side:** RCC columns of sizes 600 × 600 mm cross section.
- **Midbay:** PEB steel sections fabricated from IS 2062 E250 grade steel of sizes 400 and 600 mm along with ISMB beam 150, 200 and 250 as per design requirement.
- **Top Floor components:** 2 ISMC 300 built-up columns above the left RCC column installed to support roof loads and provide scalable consistency.

FIGURE 6. Case study methodology flowchart for pulley-assisted PEB erection in constrained sites

This setup showcases a composite structural system where RCC provides stability and anchorage at the edges, while PEB sections confirms modularity and reduced erection time in the midbay section.

5.2. **Construction Technology Observed.**

- **Pulley System:** Manual chain pulley was harnessed for beam erection. Each pulley had a rated breaking load of 3000 kg, with observed field capacity of 2300 kg at site during erection phase.
- **Anchorage system:** RCC columns provided stable fastening points for pulley installation.
- **Sequence:** Beams were lifted floor by floor, with pulleys fixed at beam ends and midbay.
- **Adaptation setup:** The pulley system was selected due to site constraints that prohibited crane mobilization.

Observed Parameters:

- Beam length: 6.0 m
- Beam weight: 850 kg
- Number of pulleys used: 3
- Load per pulley: 283 kg
- Breaking load per pulley: 3000 kg
- Safety Factor: 10.6
- Efficiency: 76.7%

5.3. **Analytical and Regulatory Framework.** The analytical and regulatory framework adopted in this study was intentionally limited to field based calculations, documented from direct site observation. The primary parameters considered were load distribution across pulleys, safety factor, and efficiency ratio. These were calculated using simple arithmetic relationships based on observed beam weights, pulley capacities, and erection sequences:

$$\text{Efficiency}(\%) = \frac{\text{Observed Field Capacity}}{\text{Rated Capacity}} \times 100$$

This setup showcases the execution of construction drawings by site engineers as per structural drawings. While structural modeling under NBC 105:2025 and IS 1893:2016 would provide deeper analysis, such modeling was not feasible due to confidentiality of design data and resource limitations. The study therefore does not claim to provide full design verification; instead, it records construction technology adaptations in urban sites where mechanized erection was inaccessible or limited for mobilization during execution phase.
The physical cross-sections of the existing RCC column heads were measured and documented to examine their capacity to anchor the lightweight extension, aligning with the structural ideology of National building code (NBC) issued by Nepal for construction practices.

Figure 7. PEB Beam connection to RCC column in G+1 and G+2 floor

Steel-to-RCC Column Connection Detailing: The dimensions, spacing, edge distances, and anchor bolt setup securing the 2 ISMC 300 vertical elements to the concrete column heads were recorded. These physical adaptations were analyzed using the limit state design principles of IS 800:2007 in regards of safety concerns.
Composite Floor Geometry: The thickness of the composite slab (150 mm), the profile of the 0.8 mm steel deck sheets, and the layout of the 13 mm diameter shear studs were executed as per as-built drawings.
The observational findings are interpreted within the benchmark of updated codes— NBC 105:2025 (Seismic Design of Buildings in Nepal), NBC 201 (Mandatory Rules of Thumb for Reinforced Concrete Buildings with Masonry Infill), NBC 205 : 2024 (Ready-to-Use Detailing Guideline for Low-Rise Reinforced Concrete Buildings without Masonry Infill), NBC 206: 2024 (Architectural Design Requirements ,IS 11384:2022 (Composite Construction in Structural Steel and Concrete – Code of Practice, First Revision), and S 1893 (Part 1):2016 (Criteria for Earthquake Resistant Design of Structures – Part 1: General Provisions, Sixth Revision) .This alignment demonstrates

awareness of requirements defined by building construction code while specifying the limits between documentation and design for execution.
During the lifting procedure, structural liability relating to localized web buckling and web crippling at concentrated load zones were recorded. To mitigate this risk without altering the primary member configurations, transverse plate stiffeners (10 mm thickness, spaced at 300 mm c/c) were introduced at critical hoisting hooks and bearing connections. This field-driven adaptation was verified post-execution using the detailing criteria of IS 800:2007.
Ethical compliance was maintained throughout the study. The confidentiality of project drawings, technical documents, and ownership information was strictly preserved. No conflicts of interest were identified or declared by the author. Furthermore, the field notes, site observations, and supporting diagrams used in the study are available upon reasonable request, subject to confidentiality requirements and project authorization.

Table 1. General Architectural Description

Attributes	**Specification**
Type of Building	Residential
Number of floors	3.5
Building Height	12 m
Terrain	Plain terrain (slope $< 3°$)
Ground Coverage	383 sq. m
Floor System Types	1. Steel deck composite slab supported by steel PEB girders 2. RCC slab supported by RCC beams
Service Provision	RCC lift pit for vertical transportation
Foundation Type	Combined footing supported by RCC piles as a deep foundation system

Table 2. General Structural Description

Attributes	**Specification**
Structural System	Composite RCC–PEB hybrid frame
Column Sizes	500×500 mm, 600×600 mm (with 2 ISMC 300 Built-up columns above at top floor)
RCC Beam Sizes	350×400 mm and 300×400 mm
Steel Beam	ISMB 150, ISMB 200 and ISMB 250
PEB Beam Sizes	400 mm and 600 mm
Stiffener Sizes	10 mm TH. Stiffening sizes 300 c/c
Base Plate Size	$500 \times 500 \times 20$ mm PLATE

5.4. **Data Collection.**

- **Direct Observation:** Measurements of structural components, pulley loads, and lifting heights were recorded during the site execution phase.
- **Permits and Safety Records:** Lifting permits and safety checklists were examined to verify compliance with safety protocols.
- **Documentation Approach:** Due to confidentiality restrictions, original design drawings were not produced. Instead, tabular summaries and schematic drawings have been used to illustrate the construction technology.

The study evaluated the safety margins, losses recorded during efficiency evaluation, and the possibility of pulley-based erection methods as a sustainable application in the construction industry.

Table 3. Data of Structural Elements

Element	Material Properties	Rebar Properties
RCC Columns & Beams	M25 grade concrete	Fe 500 D reinforcement steel
PEB Steel Sections	IS 2062 E250 grade steel	–
Composite Slab	150 mm slab with 0.8 mm decking sheet	13 mm shear studs (for composite action)
RCC Slab	150 mm RCC slab supported by RCC beams	Fe 500 D reinforcement steel
Foundation	Combined footing supported by concrete piles as a deep foundation system	Fe 500 D reinforcement steel

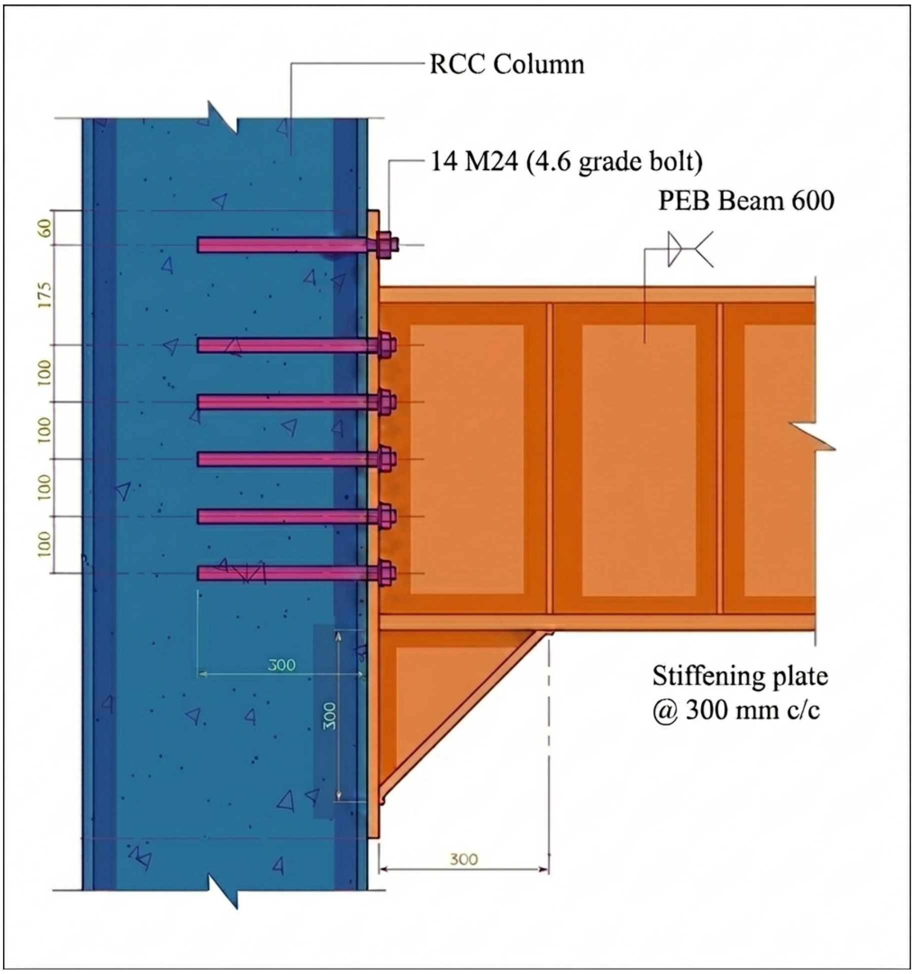

Figure 8. Schematic representation of RCC column–PEB beam connection

A stiffener is a secondary plate or member welded or bolted to the main structural element (such as a beam web or flange) to prevent local buckling, distribute stresses, and enhance rigidity at concentrated load points.

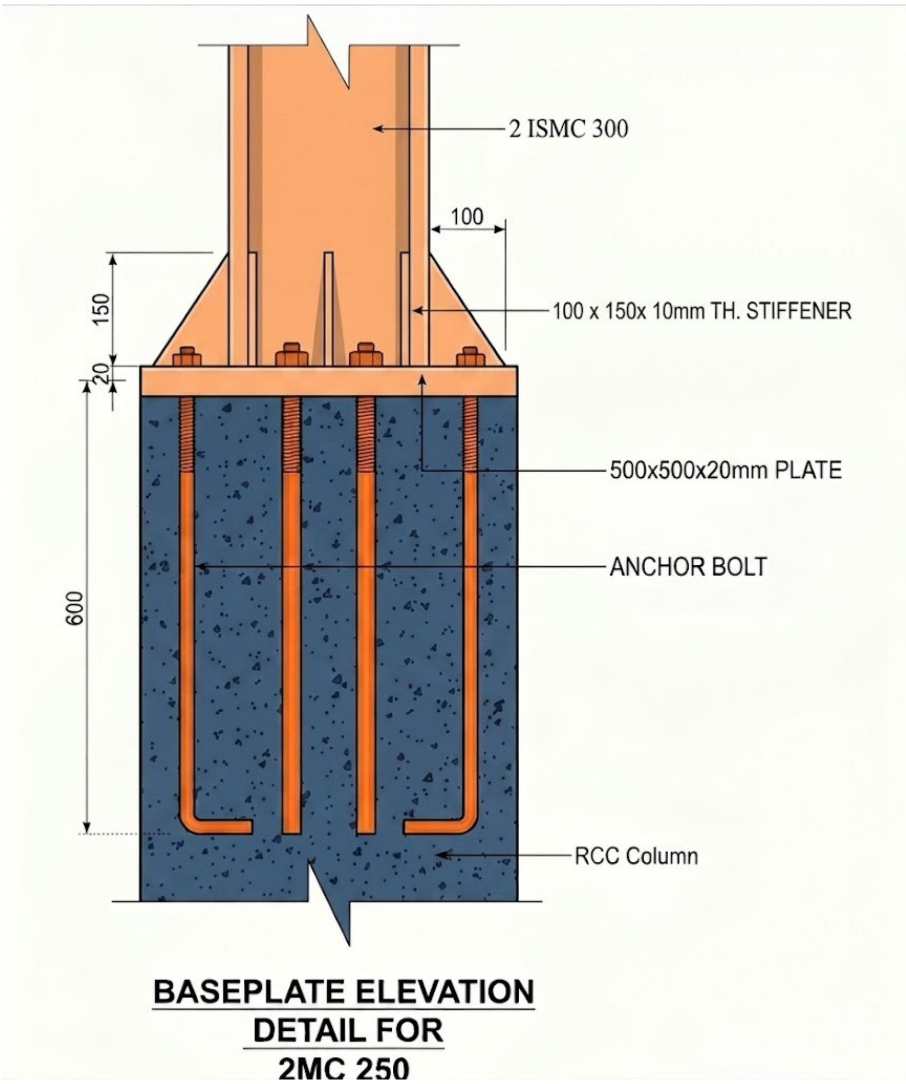

FIGURE 9. Schematic representation of RCC–2 ISMC built-up column connection detail

Web buckling is a structural failure mode in which the thin vertical portion (web) of a beam deforms or collapses under concentrated loads or reactions. It occurs when the web thickness is insufficient to resist compressive stresses and is commonly mitigated using stiffeners.

6. FINDINGS

This paper concentrates on the construction technology of structural systems composed of RCC–PEB structures where pulley-based erection applications are implemented in the Kathmandu Valley, where typical crane deployment is limited.
The following findings were derived from site observations, activity logs, and analytical calculations:

6.1. **Load Distribution.** A PEB beam weighing 850 kg was lifted using three pulleys. The load distribution per pulley was evaluated as:

$$\text{Load Per Pulley} = \frac{\text{Total Member Weight}}{\text{Number of Pulleys}}$$

For a PEB 600 beam of length 6 m, with a calculated weight of 850 kg and three pulleys:

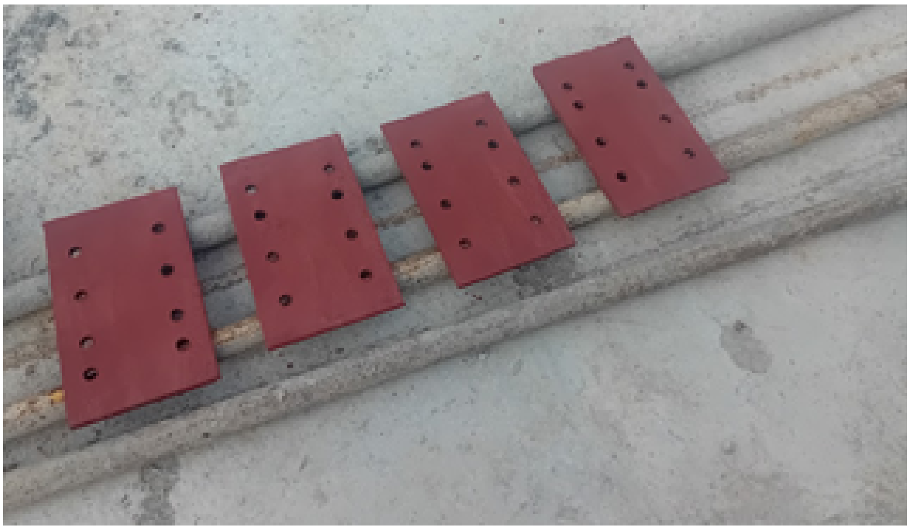

FIGURE 10. Base plate prepared for installation as per structural design and as-built drawings

$$\text{Load Per Pulley} = \frac{850}{3} = 283 \text{ kg}$$

This distribution ensured that considerable loads were transferred across each pulley system installed for erection.

6.2. **Safety Factor.** Each pulley had a rated breaking load capacity of 3000 kg. The safety factor was determined by comparing the breaking load capacity of the pulley with the applied load:

$$\text{Safety Factor} = \frac{\text{Manufacturer's Rated Breaking Load}}{\text{Applied Load per Pulley}}$$

Given:

$$\text{Manufacturer's Rated Breaking Load} = 3000 \text{ kg}$$

$$\text{Applied Load per Pulley} = 283 \text{ kg}$$

$$\text{Safety Factor} = \frac{3000}{283} = 10.6$$

This value exceeds the recommended safety margin of 4–6, demonstrating that the pulley system provided a high level of reliability under site conditions for rigging equipment used in the erection of fabricated PEB beams.

6.3. **Efficiency Ratio.** The observed field capacity of the pulley system was 2300 kg compared with the rated capacity of 3000 kg.
The efficiency ratio was calculated as:

$$\text{Efficiency}(\%) = \frac{\text{Observed Field Capacity}}{\text{Rated Capacity}} \times 100$$

Substituting the values:

$$\text{Efficiency}(\%) = \frac{2300}{3000} \times 100$$

$$\text{Efficiency} = 76.7\%$$

FIGURE 11. Installation of base plate prior to PEB beam installation

The reduction in efficiency was attributed to worker fatigue, project coordination challenges, and site limitations related to resources and time scheduling.
The actual field capacity refers to the load-carrying capacity of a structural component observed under real site conditions. It accounts for installation practices, material tolerances, and environmental influences, and is often lower than the rated design capacity.
The rated field capacity is the theoretical maximum load-carrying ability of a structural component as specified by design standards and manufacturer data. It is calculated under ideal conditions and serves as the benchmark for performance comparison.

7. DISCUSSION

This study highlights how construction technology adaptations enable composite structures to be executed effectively in urban sites with limited resources for crane deployment. Conventional crane deployment, though efficient, was impractical in most parts of the Kathmandu Valley due to narrow access, site restrictions, and insufficient road bearing capacity for the mobility of heavy vehicles.
The adoption of pulley-based erection facilities provides a safe, low-cost, and adaptable alternative, demonstrating how construction technology can be adjusted to local site conditions.
The pulley system achieved a safety factor of 10.6, far exceeding the recommended margins in construction and structural engineering practice, confirming its reliability for beam erection. Although efficiency was reduced to 76.7% of rated capacity, this was primarily attributed to worker fatigue and coordination challenges rather than inherent limitations of the technology.
With standardized procedures and improved training, pulley systems can deliver both safety and efficiency, making them a reliable construction technology for project execution in urban sites similar to the Kathmandu Valley where crane deployment is limited during the construction phase.
Beyond erection methods, construction technology adaptations also extend to service integration. The provision of a lift pit within the foundation demonstrates foresight in accommodating vertical transportation systems and modern building facilities. This provision ensures functional compatibility with contemporary building requirements, reflecting how construction technology must balance structural and service requirements in composite structures.

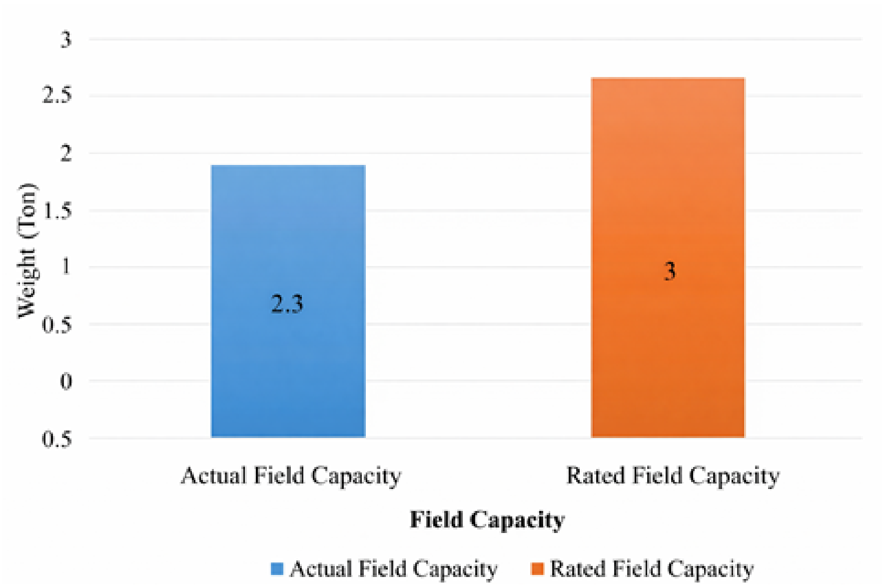

FIGURE 12. Comparison of rated versus actual pulley capacity showing efficiency gap

The integration of structural components such as shear studs and steel decking sheets with concrete slabs contributes to the overall structural integrity of composite steel structures.

8. RECOMMENDATIONS

This paper recommends that future studies expand beyond arithmetic calculations by incorporating structural modelling and analysis to evaluate bending moment, shear force, deflection, and other relevant structural parameters. Further research should examine code compliance of composite structural connections and apply finite element modelling techniques for hybrid structural systems. The study also proposes the development of standardized procedures for pulley-based erection methods through regulatory bodies and industrial partnerships. Conventional crane systems should be deployed wherever feasible to improve construction efficiency.

9. CONCLUSION

This study presents a unique construction technology executed through a structural system composed of concrete and steel PEB elements, demonstrating distinctive design approaches in residential buildings while highlighting advantages in terms of cost, time, and construction execution. The integration of concrete structures with steel components such as PEB beams, ISMB beams, and 2ISMC built-up columns demonstrates the potential of hybrid structural systems. This study documents field execution and design implementation, showing that resilient and efficient construction practices can emerge from site-specific adaptations. The study provides academic researchers with evidence of evolving construction technologies and offers guidance to practitioners seeking to balance structural integrity, resource limitations, and construction feasibility. Therefore, this case study highlights the importance of recording and analysing real-world construction practices to strengthen academic research and professional practices in construction activities.

Acknowledgement. The author gratefully acknowledges the cooperation of the site construction team and contractor, who provided access to lifting registers and observational data during the erection of Pre-Engineered Building beams and steel structures. Their assistance in documenting field data and observations enabled the preparation of this case study on construction technology applications for urban sites with limited access for crane deployment.

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