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HYBRID PRECAST-CAST-IN-PLACE METHODOLOGY FOR ACCELERATED PIER TABLE CONSTRUCTION IN EXTRADOSED BRIDGES

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Abstract

This paper presents a hybrid construction methodology for pier tables in extradosed bridges, integrating precast and cast-in-place techniques to overcome the limitations of conventional fully cast-in-place construction. The pier table, a key element transferring forces from the superstructure to the substructure, poses challenges due to its large dimensions, heavy reinforcement, and complex geometry. The proposed hybrid method enhances construction speed, safety, and quality control while maintaining structural integrity comparable to traditional methods. In this approach, the pier table is divided into multiple precast segments, each designed within the lifting capacity of available erection equipment. The precast segments are subsequently placed over the lower pylon platform, ensuring reinforcement continuity is achieved using couplers or lap splices. A central cast-in-place core accommodates the reinforcement from both the upper and lower pylons, ensuring monolithic action and effective load transfer. The assembled system is further integrated by transverse prestressing to ensure monolithic behavior as cast in place but with enhanced methods. The study focuses on construction methodology optimization, emphasizing measurable savings in construction duration and improved dimensional accuracy due to controlled off-site fabrication. A comparative analysis between conventional and hybrid practices highlights the efficiency gained through off-site fabrication, simplified erection, and reduced dependence on temporary support. The results demonstrate that the hybrid system offers significant advantages in terms of time, cost, and safety, making it especially suitable for challenging environments such as wide rivers, deep scour conditions, deep valleys, or constrained urban sites. It is particularly advantageous in locations where natural conditions limit the effective construction period to less than six months annually. For instance, river bridge sites where prolonged flooding restrict workable conditions for more than six months each year thereby making faster and more efficient erection methods essential.

Keywords: extradosed bridge, pier table, hybrid construction, precast segments, cast-in-place core, accelerated bridge construction across wide rivers with deep scour

1 Introduction

1.1 Background

Extradosed bridges have become a preferred solution for medium- to long-span crossings due to their structural efficiency, reduced pylon height, and improved stiffness compared to conventional cable-stayed bridges. A critical structural component in such bridges is the pier table, which serves as the primary load transfer zone between the superstructure, pylons, and substructure.

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Owing to high bending moments, axial forces, and cable anchorage loads, pier tables are typically massive, heavily reinforced, and geometrically complex. Traditionally, pier tables are constructed using fully cast-in-place (CIP) methods supported by extensive formwork and falsework systems. While structurally reliable, these methods are often time-consuming, labor-intensive, and highly dependent on favorable site conditions.

1.2 Challenges in conventional pier table construction

Conventional CIP construction of pier tables presents several challenges, particularly in extradosed bridges:

- long construction durations due to sequential reinforcement placement and concrete typically more than 4 weeks
- congested reinforcement zones affecting quality and constructability
- high dependency on temporary work and working platforms
- increased safety risks during construction at height or over water
- limited productivity in sites with restricted construction windows, such as flood-prone river crossings or deep valleys.

These challenges are increased in environments such as wide rivers, flood-prone areas, deep scour, deep valleys, and dense urban corridors, where access, working platforms, and construction windows are severely constrained. In many river bridge projects, effective construction periods are limited to less than six months annually due to seasonal flooding, making traditional CIP methods with prolonged time than scheduled.

1.3 Accelerated bridge construction and hybrid approaches

Accelerated Bridge Construction (ABC) techniques emphasize off-site fabrication, modular construction, and rapid on-site assembly to reduce construction time and improve quality and safety. Precast concrete elements fabricated under controlled conditions offer improved dimensional accuracy and reduced site dependency. However, fully precast pier table solutions are often impractical due to the complexity of integrating reinforcement from both upper and lower pylons to achieve true monolithic structural behavior. In addition, erection of a fully precast pier table would require high-capacity lifting equipment, which may be uneconomical. In the present case, the erection system is limited to a lifting capacity of 200 MT, consistent with the typical deck segment weight range. This constraint restricts the feasibility of adopting a fully precast alternative. Hybrid precast–cast-in-place construction methods provide a balanced solution by combining the advantages of prefabrication with the structural continuity of in-situ concrete. Such approaches have been successfully applied to bridge decks, pier caps, and pylons, but their application to extradosed bridge pier tables remain limited.

1.4 Objectives and scope of the study

The primary objective of this study is to develop a hybrid precast–cast-in-place construction methodology for extradosed bridge pier tables that achieves structural performance comparable to conventional cast-in-place construction while enhancing constructability. The specific objectives are to: (i) propose a practical, stage-wise construction sequence for hybrid pier tables (ii) detail reinforcement and connection strategies to ensure continuity and monolithic behavior (iii) assess improvements in construction efficiency, safety, and quality. The study is limited to construction methodology and qualitative performance evaluation, with particular focus on bridges in constrained or seasonally restricted environments.

2 Literature review

The literature on accelerated bridge construction (ABC) and hybrid precast–cast-in-place systems extensively addresses pier substructures, connection behavior, and segmental superstructure performance. However, focused research on pier table construction in extradosed and cable-stay bridges remains limited. A relevant industry example is the Hodariyat Cable-Stayed Bridge, Abu Dhabi [1], where hybrid precast shell elements were adopted to accelerate substructure construction in a marine environment. In this project, precast shells served as permanent formwork for pile caps and pier segments, fabricated off-site and positioned over extended column reinforcement. After placing supplemental reinforcement, the internal diaphragm was cast in-situ, integrating precast quality control with cast-in-place structural continuity. This approach is consistent with the methodology outlined in Chapter 4 of the Construction Practices Handbook for Concrete Segmental and Cable-Supported Bridges [2], where precast pier shells are erected over continuous reinforcement and completed with in-situ concrete. The Hodariyat project thus demonstrates a practical hybrid shell application that informs future ABC strategies for pier tables and segmental substructures in cable-supported bridges.

3 Proposed hybrid construction methodology

The proposed methodology adopts a hybrid precast cast-in-place (CIP) approach for pier table construction in extradosed bridges, aiming to accelerate construction while ensuring structural continuity and constructability. The pier table is subdivided into precast and in-situ components based on lifting capacity, reinforcement congestion, and load transfer requirements.

3.1 Conceptual framework

In the proposed system, the pier table is subdivided into four precast units and a cast-in-place core that integrates all units into a complete pier table. The precast units are designed to remain within the lifting capacity of available erection equipment and to minimize on-site formwork and falsework. Structural continuity between precast elements and the supporting pylons is achieved through a combination of reinforcement couplers, lap splices, and in-situ concrete joints. Transverse prestressing is introduced after assembly to ensure monolithic behavior in well-defined manner. The conceptual framework thus balances off-site efficiency with on-site adaptability, providing a practical solution for constructing large, heavily reinforced pier tables in constrained or seasonally limited environments, while maintaining safety, structural integrity, and quality. The pier table has an overall depth of 5.75 m, with a deck width of 28 m and a length of 9.4 m along the traffic direction.

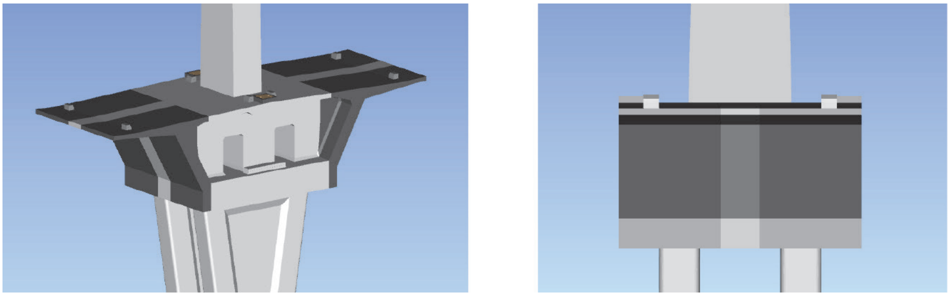

Figure 1 Conceptual arrangement of the hybrid precast–cast-in-place pier table integrating the lower and upper pylons of an extradosed bridge

3.2 Construction sequence

The proposed hybrid pier table construction is organized into discrete stages to ensure safety, structural continuity, and efficiency. The sequence integrates precast segments with cast-in-place concrete while accommodating reinforcement, post-tensioning, and temporary support requirements. Temporary steel support brackets are installed on the lower pylon to safely carry the self-weight of the precast pier table during erection as shown in figure 2(a). These brackets act as short term support, eliminating the need for extensive falsework and providing stability during lifting and placement operations. Accuracy is critical, as precast portions are connected temporarily by steel frames.
Precast pier table units are connected using a steel frame, weighing approximately 200MT, including the lifting frame as shown in figure 2(b). These stage wise erection reduces structural and handling risks, ensures proper alignment with reinforcement in the pylons, and allows sequential integration of subsequent precast units. Precision at this stage ensures continuity in the final monolithic system. Once the precast segments are in position, longitudinal and transverse post-tensioning ducts are installed as shown in figure 2(c), followed by remaining reinforcement. These elements are critical for structural integrity, ensuring monolithic action between precast and cast-in-place components. Proper placement also controls cracking, enhances stiffness, and prepares the pier table for staged concrete pours. Cast-in-place concrete is executed in multiple stages to integrate the precast segments and complete the pier table core. The first-stage pour fills recesses and embeds reinforcement up to the soffit level of the manhole opening, the second-stage pour continues up to the top of the manhole opening, completing the integration of vertical reinforcement and the final-stage pour fills the remaining portion of the pier table, forming a monolithic cast-in-place core that fully unifies the precast segments as shown in figure 2(d).

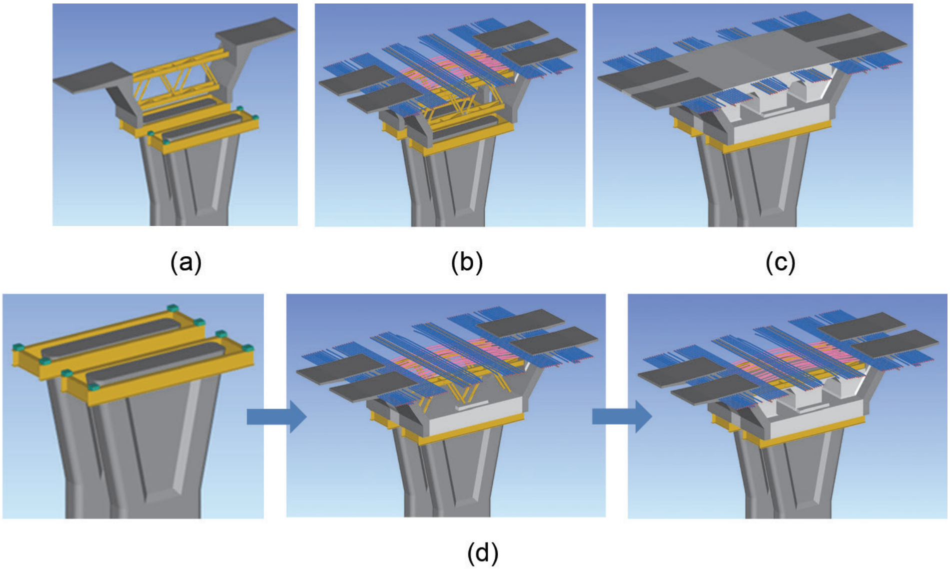

Figure 2 (a) Installation of Temporary Support Brackets (b) Lifting and Installation of Precast PierTable Segment (c) Placement of Post Tensioning Ducts & Reinforcement (d) Cast-in-Place Concrete Works

This staged approach ensures monolithic structural behavior, accommodates complex reinforcement layouts, and allows controlled curing for quality and durability.

3.3 Applicability and advantages

The proposed methodology is particularly suited to bridges constructed in flood-prone rivers, deep scour, deep valleys, and congested urban environments where conventional formwork-intensive construction is impractical. By shifting a significant portion of construction off-site, the method reduces dependency on seasonal work windows, improves safety, and achieves substantial reductions in construction duration while maintaining required structural performance.

Table 1 Comparison between Conventional CIP & Hybrid Precast–CIP Method

Parameter	Hybrid Precast–CIP Method	Conventional CIP Method
Construction duration	Rapid due to off-site fabrication	Longer due to on-site casting
Seasonal sensitivity	Can be done in a week	Typically, more than 4 weeks
Quality control	High and consistent	Site-dependent
Site impact & safety	Reduced on-site work, safer	Higher exposure
Design flexibility	Moderate	High
Transportation	Specialized transport required	Minimal
Cost implication	Higher initial cost but reduces construction time of pier table by 1/4th, saving overall project cost	Lower initial cost
Durability & maintenance	Multiple joints require detailing to ensure monolithic behaviour	Fewer joints, higher durability
Adaptability	Limited post-fabrication	Flexible
Aesthetic finish	Superior factory finish	Workmanship-dependent

3.4 Structural integration and performance considerations

The hybrid system ensures effective load transfer between the superstructure, pier table, and pylons through monolithic action. The use of in-situ concrete at critical junctions accommodates complex reinforcement detailing and ensures continuity of axial forces, bending moments, and shear. Transverse prestressing makes easy integration of precast parts with cast in situ resulting in good structural performance.

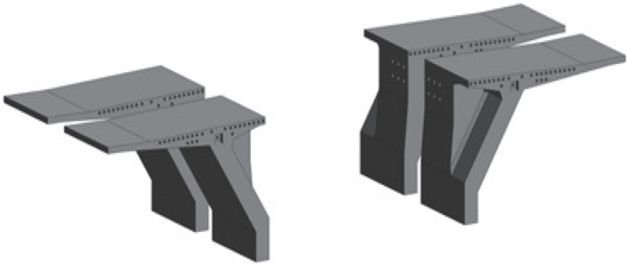

Figure 3 Isometric View - Precast Portion

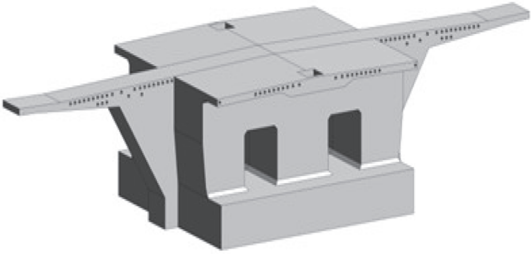

Figure 4 Isometric View - Cast in Place Portion

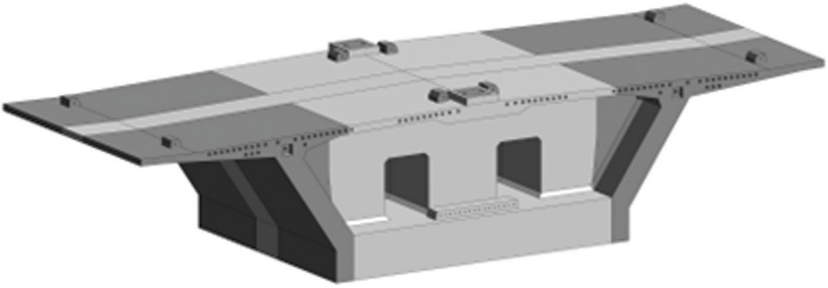

Figure 5 Isometric View – Piertable

3.5 Practical challenges and limitations

Despite its advantages, the hybrid precast pier table system presents certain practical challenges. During erection, the stability of the precast segment units must be carefully evaluated, since they are temporarily connected using steel frames. Additionally, precise alignment of precast segments survey control, erection tolerances, and lifting frame calibration must be rigorously maintained. Misalignment may lead to stress concentrations at temporary steel structure joints and difficulties in achieving monolithic behavior after casting the in-situ core. Furthermore, special attention must be given to reinforcement continuity between precast and cast-in-place components. Proper detailing and positioning of reinforcement couplers are essential to ensure accurate alignment of projecting bars and effective force transfer across the interface. Inadequate coordination at this stage may affect monolithic behavior and structural integrity of the completed pier table.

4 Results and discussion

The proposed hybrid pier table method was qualitatively assessed in comparison with conventional cast-in-place construction based on the aspects outlined below, demonstrating improved construction efficiency while maintaining structural performance.

4.1 Construction duration and efficiency

The adoption of precast pier table segments resulted in an estimated reduction of more than three weeks in the overall construction cycle for each pier table. The time savings were primarily achieved through parallel off-site fabrication, elimination of extensive on-site reinforcement placement, and reduced curing dependency at elevation. This reduction is particularly significant in projects with limited seasonal construction windows.

4.2 Constructability and site adaptability

The proposed methodology demonstrated superior constructability in constrained environments. The use of temporary support brackets eliminated the need for extensive falsework in rivers or deep valleys, reducing interference with water flow and minimizing environmental impact. The staged cast-in-place pours accommodated complex reinforcement detailing and ensured proper integration between precast units and the supporting pylons. Conventional methods were found to be less adaptable due to their heavy reliance on large staging systems and uninterrupted working conditions.

4.3 Quality control and structural continuity

Precast fabrication under controlled conditions resulted in improved dimensional accuracy and surface quality of the pier table segments. Structural continuity was achieved through cast-in-place joints, reinforcement couplers, and transverse prestressing, enabling effective force transfer across precast and in-situ interfaces. The observed behavior is consistent with findings from prior studies on hybrid bridge components, indicating that monolithic performance can be achieved when connection detailing is appropriately designed.

4.4 Safety and risk reduction

The hybrid approach reduced on-site labor intensity and work at height, leading to improved safety outcomes. Shorter construction durations and reduced dependency on temporary work lowered exposure to site hazards, particularly in high-risk environments such as flood-prone rivers. Conventional cast-in-place construction involves extended periods of formwork installation and reinforcement fixing, increasing safety risks.

4.5 Discussion and implications

The results confirm that the proposed hybrid methodology offers a balanced solution between construction acceleration and structural performance. While the method requires careful planning of lifting operations, temporary support, and interface detailing, these challenges are offset by significant gains in cheaper construction cost, execution efficiency and safety. These findings support the applicability of the hybrid approach for extradosed bridge pier tables, particularly in projects constrained by environmental, spatial, or seasonal limitations, and may offer a competitive advantage through overall construction cost reduction.

References

[1] VSL International Ltd., VSL News Magazine, No. 1-2012, Hodariyat Bridge, Abu Dhabi, 2012.

[2] American Segmental Bridge Institute (ASBI), Construction Practices Handbook for Concrete Segmental and Cable-Supported Bridges, 3rd ed., Phoenix, AZ, 2019.