CHAPTER 79

Implementing Precast Technology: A Roadmap to Mitigate Time and Cost Risk in Indian Road Infrastructure

Vedant Ladsaria[1], Sanskar Sethi[2], Tanmay Rajendra Poddar[2] and Hariom Vidhudi[2]

ABSTRACT

The road infrastructures are prone to time and cost overrun. However, this potential technology has been shown to mitigate the problems in the real estate sectors. Precast technology mostly allows for the possibility of identification concerning usage for a similar type of road infrastructure technology. This paper reviews the implementation of precast concrete technology as a prospective solution toward mitigating time and cost. Extensive research has been done on the utilization of precast pavements in several countries with physical models assessed. Similar research programs and physical models need to be developed for understanding the real-time data in Indian conditions. The ever-growing requirement for durable, faster, and cost-effective road development motivated the quest towards advanced construction techniques such as precast technology. A comparative study was devised for traditional cast in situ model and precast pavement about cost and time. This paper provides a comprehensive roadmap detailing the advantages, challenges, and strategies for adopting precast solutions in Indian road construction. Precast results in faster construction, with higher initial investments. Higher initial investments result in better quality pavement, and with increasing acceptance of the precast usage will bring down the cost. Precast technique would eventually triumph over road construction.

Keywords: Cast-in-situ; Cost overrun; Precast concrete pavements (PCCP); Quality control; Time overrun.

1.0 Introduction

1.1 Background

The precast concrete technology introduced by John Alexander Brodie, a British engineer in 1905, has gained importance all over the world and has become the backbone of the infrastructure of India, especially in the construction of bridges, flyovers, viaducts and tunnels (Construction World, 2022). Despite the importance of the technology, it still accounts for less than 2% of India's construction industry valued at around ₹2,48,000 crores, which indicates that there is a huge potential that is yet to be tapped (IBEF, 2023).

[1]*School of Construction, NICMAR University, Pune, Maharashtra, India*

[2]*Corresponding author; School of Construction, NICMAR University, Pune, Maharashtra, India*

(E-mail: P2370623@student.nicmar.ac.in)

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In India, the road development sector is the key to economic growth and national integration. A major shift in the government's policy since 2014 on the development of roads is the withdrawal of bitumen-asphalt in favor of cement-based concrete roads in new projects. The reason for this is the long-term financial benefits of concrete roads, which are much more durable and do not require a lot of repairs and resurfacing in the future (MoRTH, 2021).

Besides, the adoption of precast concrete in road construction is not spared as it still has its challenges. Precast concrete takes much higher initial cost compared to the traditional methods of construction due to the high cost of the specialized components required and the technical skills needed both in the design and execution (ICJ, 2023). Also, precast elements are difficult to handle during transportation and handling, especially in urban areas. The availability of skilled labor for such systems is another pretty critical factor for the successful implementation of the same. The other very significant constraint is the typical mindset in the construction sector in India where they are very much bent on the use of conventional methods (CII, 2023). Nevertheless, precast concretes' benefits including faster installation, long-term cost savings, and durability make it a compelling forward-looking alternative for road construction. Innovations such as Precast Concrete Pavements or PCP, combines the installation speed of flexible pavements with the low-maintenance benefits of concrete, would be ideal for India's urban growth challenges (IRC, 2022).

1.2 Aim

To analyse the cost and time comparison of constructing concrete pavement by using In-situ casting and precast method.

1.3 Objectives

- Analyse the challenges of time and cost overruns in Indian infrastructure projects.
- Evaluate the potential of precast concrete technology to address these challenges.
- Develop a roadmap for implementing precast technology in various infrastructures.
- sectors (roads, bridges, buildings etc.).
- Identify factors critical for successful precast implementation, such as design
- optimization, material selection, and quality control measures.
- Recommend strategies for overcoming potential barriers to precast adoption in India.
- including skill development and regulatory frameworks.

2.0 Literature Review

2.1 Time efficiency and construction productivity

On another hand, precast technology cuts down on the time of construction, owing to the preparation off the site and work on the site simultaneously. Tomek (2017) points out that because parts are brought ready for the assembly, prefabrication allows to reduce the time needed for installation. Chang-Geun (2019) also underlines that the technology helps with time management and productivity, particularly for the large infrastructure projects, where every minute counts.

2.2 Cost optimization and economic benefits

Despite the fact that the high initial costs of the project may be a problem, according to some sources, the researchers are confident that the total costs for the project can be reduced. Tomek (2017) and Chang-Geun (2019) highlight the fact that labor costs and the reduction of time loss can lead to the reduction of costs, while Novak *et al.*, (2017) found that the reduction in material costs and the reduction of waste services will lead to the reduction of costs. In this regard, Liu *et al.*, (2023) argued that the hybrid genetic algorithms can be used to improve the design efficiency.

2.3 Environmental sustainability

The environmental benefits of the precast methods are comprehensively recognized. As the research by Graybeal *et al.* (2017) shows, prefabrication reduces water use, energy consumption, and on-site waste. The research by Yuan *et al.*, (2014) also confirms that the precast systems ensure a greener infrastructure by minimizing environmental impacts throughout the project lifecycle.

2.4 Durability and lifecycle performance

Compared to cast-in-place equivalents precast members e.g. prestressed slabs, bridges show superior durability. Allotey *et al.*, (2015) find the reduction of maintenance needs, longer service life. Tomek (2017) reports lifecycle savings, proposing the precast systems as an acceptable sustainable solution for essential infrastructure.

2.5 Precast concrete pavements PCP for road infrastructure

PCPs result in lesser construction time and therefore reduce the road user costs. Allotey *et al.* (2015) and Tomek *et al.* (2011) concur that PCPs decrease delays and traffic interruptions significantly, thus are perfect for urban road networks.

2.6 Barriers to adoption in developing countries

Despite their benefits, the adoption of precast concrete construction systems is limited in many developing countries because of poor infrastructure, a lack of skilled labor, and regulatory hurdles (Cho *et al.*, 2019). Ma *et al.* (2016) point out that in India, in particular, high initial costs and traditional construction practices are limiting the use of precast.

2.7 Research gap

While available research has substantiated the potential of precast technology for enhancing productivity, cost-efficiency, sustainability, and long-term durability, many crucial

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gaps remain. Most of these studies are from developed countries and therefore offer little insight into the way these systems work under the complicated conditions of India's construction industry (Daniel, 2017; Yan, *et al.* 2016). Comprehensive project-based evaluations that look at the association between time efficiency and factors like project size or location are largely missing (Wu *et al.* 2017). When it comes to costs, while many report about savings, only a few have conducted full LCCs in the context of developing countries (Liu *et al.* 2023; Novak *et al.* 2017). Very little is also known in terms of environmental assessment, with a lack of comparative LCA across different climatic zones (Yuan *et al.* 2014). Finally, durability is often discussed without the necessary component-level analysis under real-world conditions (Allotey *et al.* 2015). Precast technology literature is also silent on the tools and mechanisms to be employed for overcoming labor, infrastructure, and policy barriers for popularizing these technologies in emerging markets.

3.0 Data Analysis and Results

Precast Concrete Pavement systems offer a successful solution to the long-standing issue with the delays and inefficiencies of the roadway construction projects. Field performance and productivity data indicate that in the case of single-lane closure, the construction rate of precast pavement panels can be up to 14-18 panels per 6-8-hour window, which corresponds to about one panel every 20-25 minutes. The reason for such high efficiency is the use of the alternating two crews: one for drilling and epoxy insertion of dowel bars and another for the placement of the panels. Consequently, 50% of the construction time can be saved, and the onsite construction disturbance can be minimized, which is especially important in urban areas with high traffic volume and limited working windows. (Zhu, 2024)

This work also compared different repair strategies such as one-sided, two-sided, and four-sided repairs in terms of their repair rates to identify the most time-effective and structurally sound method. According to the results of the comparison, one-sided slab repairs are the best method as they offer the best balance of the speed of repair, material consumption, and benefits of their installation. This provides evidence for the claim that modular repair methods with the use of ready-made components are the best solution for infrastructure systems that are to be repaired or modernised frequently under constrained timelines. Pavement performance requires solid load transition at joints. This is an essential element for long-term sustainability and user comfort. Dowel bar connections are the most effective mechanisms for this purpose. Tests revealed that dowel bars support load transition at 95% efficiency (Liu, 2024). The joints only deflect less than 0.2 mm under the force of 40 kN (Liu, 2024). Furthermore, the joints have structural stability that remain unaffected across numerous load cycles. This makes these joints suitable for roads that are likely to experience a high volume of traffic or frequent axle load stresses (Ou, 2024). Combined with high-strength precast panels, such joint systems can reduce maintenance, which is a critical consideration for sustainable road infrastructure in India.

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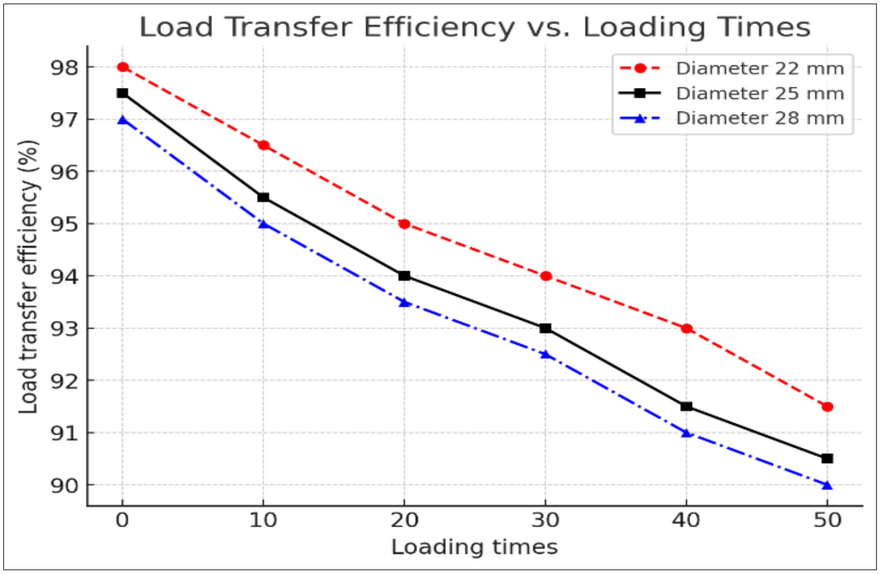
Figure 1: Load Transfer in Relation to the Number of Loading Cycles



Source: Liu, 2024; Li Ou, 2024

3.1 Comparative analysis

Table 1 shows a comparative view of different pavement repair techniques, time required and estimated cost. It underlines the balance between speed and investment by emphasizing the strategic advantages of precast concrete despite being slightly more expensive initially.

Table 1: Comparison of Precast Concrete Slabs with those of Other Methods

Repair Type	Repair Details	Time to Complete	Estimated Cost (in Rs)
Fast-curing top layer/crushed stone mix	254 mm top layer cap 102 mm compacted crushed stone mix	3.7 hrs	98,900
Fast-curing top layer/lightweight foam	254 mm top layer cap 102 mm lightweight foam	3.2 hrs	1,47,140
Fast-curing top layer/pumped lightweight foam	254 mm top layer rubble 102 mm lightweight foam	3.9 hrs	1,11,100
Fast-curing top layer/fluid backfill	254 mm cap 102 mm flow able fill	3.4 hrs	1,20,000
Precast pan-el/flow able fill	279 mm panel 76 mm fluid backfill	4.8 hrs	1,04,000
Traditional Portland cement concrete (PCC)	356 mm PCC	28 days	72,200

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At a comparative evaluation level, it is possible to see that precast systems cost more than traditional concrete methods, taking into consideration that each installation is costlier in itself. But on the other hand, the time frame is substantially reduced. In high-traffic and time-sensitive areas, this time saved is a significant factor leading to savings that are related to not having to close roads, have detours, and the resultant revenue losses.

4.0 Findings of the Research

The results are in and they confirm that pre-cast concrete technology can have a transformative role in the future of Indian infrastructure. It results in quicker construction, less disruption to road users, and long-lasting durability with less maintenance required. These results align with the aim of improving efficiency in the delivery of projects in the rapidly expanding urban and national road networks in India. After testing, the pivotal technical attributes were discovered to be the application of post-tensioned slabs, monitored panel pouring, the precise positioning, and high-efficiency load transfer devices. As a result, it is critical to integrate optimization of design, material innovation, and quality control into the strategy for implementing precast products. Several implementation challenges were observed at the same time. These include limited availability of trained personnel, nonuniformity in panel specifications, transport of large precast units, and resistance of stakeholders who are accustomed to traditional construction practices. Removing obstacles will require a concerted effort on the part of policy, education, and industry. Among the proposed measures are the development of training programs for engineers and contractors, the establishment of regional production of precast units to reduce transportation costs, the introduction of precast design standards into national construction codes for the construction of highways. Overall, the research reveals that with the correct technical setup and facilitating setup, precast concrete systems can play a very crucial role in ensuring that there is a faster, more durable, and cheaper infrastructure across the urban and rural parts of the country.

5.0 Conclusion

The purpose of the study was to explore the feasibility of using prefabricated concrete technology to address Indian infrastructure projects' key issues—specifically, time, cost, quality, and sustainability. The study results clearly suggest that prefabricated systems can significantly enhance the efficiency of the project while improving structural reliability and long-term cost-effectiveness. With reference to the objective of understanding time and cost overrun related to precast pavement systems, the research observed that they are time-efficient in terms of construction. According to the data from the research, the precast pavement system can reduce their construction time significantly because the installation can be done very fast, with as much as 18 panels per shift (Zhu, 2024). This results in less time wastage for traffic disruption, which makes the construction faster than other techniques. In reference to quality

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and consistency, the precast pavement system ensures dimensional accuracy, minimum errors, and better-quality control because they are done in a controlled environment. This makes the pavement in line with the objective of improving construction quality.

Precast systems were noted to create on-site emissions and material waste from a sustainability point of view, while advanced load transfer systems, such as dowel bars, created better results under repetitive loads, contributing to lower maintenance and longer pavement life (Liu, 2024; Li Ou, 2024). In general, these realizations are consistent with the objective of developing a sustainable infrastructure system with a long life. Factors critical to successful implementation were examined in the study as well. Design optimization, availability of skilled labor, transport logistics, regulatory support are identified as key enablers, hence the need to address them in mainstreaming the adoption of precast. The high initial costs and logistical constraints were identified as significant challenges; however, the lifecycle cost savings and speed of construction justify investment—particularly for high-traffic corridors and time-sensitive projects.

5.1 Stakeholder impact

Precast concrete technology in India is a collective endeavor, the need for which is understood by all its participants. Government agencies and policymakers are responsible for creating favorable conditions (for example, by providing tax incentives or incorporating precast standards into legislation) and supporting pilot programs (NITI Aayog, 2020). Infrastructure developers and contractors need to ensure the integration of this technology in their operations by investing in equipment, adjusting logistics, and adapting their workflow to modular construction systems. The producers of precast elements must focus on the challenges that arise from a scarcity of regional supply by building production sites in the vicinity of a project, which reduces the cost of transport and time. Training institutions and schools must play the leading role in bridging the skills gap by providing specialized training on the technologies of precast building, handling, and installation (Cho et al., 2017). The urban planners and consultants of the project should normalize the use of precast elements by designing the project at the planning stage in a way that makes it easy to integrate these components in the design and hence integrate the modular advantage in the early stages of the project. Finally, the ultimate beneficiary of shorter construction durations, safer roads, and more durable infrastructure, the public, although indirectly, has a crucial role in promoting and adopting the technology. The interconnected stakeholder ecosystem must align around a shared mission: To modernize the delivery of Indian infrastructure with faster, cleaner, and more durable building methods. Precast concrete technology is a real, scalable way forward if everyone is brought along proactively.

5.2 Recommendations

Incorporate precast standards into the codes and tenders of countries to make it mainstream across infrastructure industries. Constructing regional precast manufacturing centers for the sake of restive logistics and optimizing supply chain efficiency. Develop precast design

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assembly wearing handling courses. The partnership that will be sourced for the program are training entities and construction companies. Convince leaders of the value of pilot projects in urban centers and national highways, where conventional methods are less efficient due to time and space constraints. Provide policy incentives and funding support to promote early adoption, particularly in public infrastructure projects. Encourage a collaborative design that takes into account precast modularity from the planning stage, this will improve cost efficiency and structural integration. Make use of precast in green infrastructure projects. This can be achieved by combining it with sustainable materials and by making sure that the production processes are low emission. Aligning technology, workforce development and policy reform will enable precast concrete to become the foundation of India's infrastructure modernization, offering projects that are faster, cleaner, more durable and financially sustainable in the long term.

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