Available Accelerated Bridge Construction Options for Short Span Bridges

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CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

Abstract

Accelerated Bridge Construction (ABC) significantly reduces on-site construction time and minimizes traffic disruptions by employing prefabricated bridge elements and systems. This approach enhances life cycle costs through improved scheduling control and typically higher quality of elements, leading to enhanced long-term performance. ABC is particularly advantageous for short-span bridges, which are well-suited to standardized prefabrication techniques. In such cases, entire bridge spans can often be constructed using prefabricated deck elements, modular decks, or systems that span the full bridge width. Additionally, the substructures of these bridges can often be constructed using prefabricated elements without necessitating specialized treatments. For shorter spans, the option to prefabricate the entire bridge, including both substructure and superstructure, is also viable. The construction of short-span ABC bridges can utilize a range of methods, from traditional crane installations to innovative approaches like Self-Propelled Modular Transport (SPMT) units for moving entire superstructures, or slide-in construction techniques. Definitions of what constitutes a 'short span' vary, with some sources considering spans of 20-45 ft. as short (as per FDOT), others up to 70 ft., and some even extending to spans of 100 ft. This book introduces the concept of ABC and examines its application in the context of short-span bridge construction. It categorizes and details short-span bridges based on various criteria including access, topography, geographic conditions, roadway functional categories, span length, elements and systems, time constraints, and construction methods. The performance of these bridges is evaluated based on existing literature. Decision-making processes regarding the adoption of ABC, choice of elements, systems, and construction methods are also discussed. Additionally, the book covers the inspection of short-span bridges and includes a design example. The book's definition of short-span bridges aims to clarify the selection limitations of ABC

components and provide a clearer understanding of the project scope for involved parties.

Background

The primary objective of ABC (Accelerated Bridge Construction) is to maximize the utilization of prefabrication techniques to minimize on-site construction processes and their associated impacts on traffic flow. In this context, bridges with short spans serve as an exemplary application for a broad spectrum of ABC methodologies. The definition of a 'short span' bridge varies: the Florida Department of Transportation (FDOT) categorizes bridges with spans between 20 and 45 feet as short-span, while other definitions extend this range up to 70 feet or even 100 feet. ABC strategies for these bridges can range from the prefabrication of individual elements and members to the complete pre-construction of the entire bridge structure. Typically, structures exceeding 20 feet in span are classified as bridges, whereas those under 20 feet are termed culverts, even if they bear direct vehicular load. However, it is important to recognize that certain structures exceeding 20 feet are designed both hydraulically and structurally as culverts (Ryan, Mann, Zachary, & Ott, 2002). Culverts exceeding 20 feet often incorporate design considerations for support from the surrounding soil. Structures that necessitate an analysis of static soil-structure interaction are referred to as "buried bridges." These can have spans up to 100 feet, demanding the same safety and design considerations as conventional bridges (Beaver, 2016). Many culverts and buried structures are constructed using ABC techniques, and thus, they are included in the discussion of ABC short-span bridges in this book. Examples of short-span and buried bridges, as well as other ABC elements and methods, are presented in Fig. 1-1 and Fig. 1-2, respectively.

Fig. 1-1 Examples of short-span and buried bridges (Beaver, 2016).

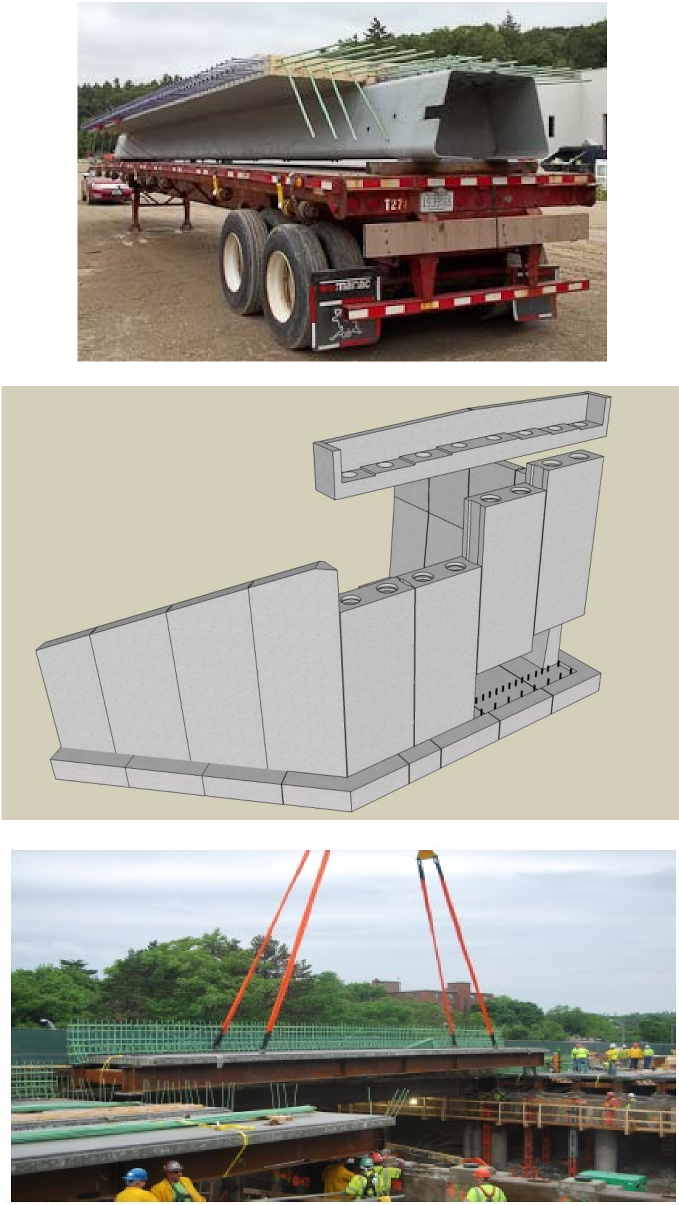

Fig. 1-2 Other elements and methods for short-span bridges (Azizinamini, 2018) (Culmo, Lord, Huie, & Beerman, 2011).

The selection of elements and construction methodologies for Accelerated Bridge Construction (ABC) of short-span bridges is influenced by a multitude of factors, including accessibility, topographical and geographical conditions, the functional category of the roadway, span length, available elements and systems, and time constraints. It is crucial to provide users with a comprehensive array of available element types, subsystems, and systems suitable for short-span ABC bridges. A clear identification and description of these components, highlighting their respective advantages, potential applications, and limitations, will facilitate informed decision-making. Typically, the span length emerges as a pivotal determinant in shaping both the structural design and the economic aspects of bridge construction.

The design and detailing of bridges, particularly the establishment of structural integrity through on-site methods such as cast-in-place closures and other in-situ joints, present notable challenges. In this context, the role of ABC connections and joints is significant, and a thorough understanding of their application and limitations is imperative. A common issue observed in ABC bridge decks is cracking, often accompanied by efflorescence and leakage (Attanayake & Aktan, 2015). This defect is particularly prevalent in a specific ABC construction approach involving side-by-side box precast concrete beams. Survey data indicates that these issues predominantly occur at the interfaces between deck panels and at the connections of deck panels with piers or abutments. Consequently, there is an increased need for inspection and performance evaluation of joints, especially closure joints, in short-span bridges.

The process of decision-making regarding the implementation of Accelerated Bridge Construction (ABC), encompassing the selection of specific elements, systems, and construction methodologies, is crucial for the successful initiation, management, and contractual handling of projects. A comprehensive examination of ABC methodologies is imperative, addressing key facets such as construction techniques, detailing, performance metrics, inspection protocols, and decision-making processes. These aspects must be effectively communicated to all stakeholders involved. This book aims to compile and present relevant information and materials specifically pertaining to short-span bridges within the context of ABC.

Objectives of the Book

The primary objective of the development of this book is to provide comprehensive insights into the application of Accelerated Bridge

Construction (ABC) techniques for short-span bridges. This encompasses a broad spectrum of topics, including decision-making strategies, construction methodologies, an overview of available elements and systems, as well as aspects related to performance evaluation and inspection. Additionally, the book covers the design, detailing, and the intricacies of connections within the context of ABC for short-span bridges.

ABC – Definitions and Descriptions

Accelerated Bridge Construction (ABC) represents a construction methodology that significantly reduces on-site construction duration. This approach involves the adoption of novel materials, design techniques, and construction methods in both the development of new bridges and the rehabilitation or replacement of existing structures. A key strategy in ABC is the use of Prefabricated Bridge Elements and Systems (PBES), which are manufactured off-site. The processes of construction, reinforcement placement, concrete pouring, and curing are all conducted off-site under controlled conditions, enhancing the quality, safety, and durability of the bridge components. This off-site fabrication is less susceptible to weather-related delays and generally exerts minimal impact on traffic flow, in stark contrast to traditional construction methods (Mehrabi, Ali, & Baqersad, 2019).

Conventional bridge construction, predominantly executed on-site, is heavily weather-dependent and can be considerably time-consuming. This method often necessitates detours or temporary structures to mitigate its impact on traffic, and may require additional remote sites as supporting location, potentially compromising transportation network efficiency and safety. In comparison, ABC methods are typically more economical and safer (Mehrabi, Ali, & Baqersad, 2019).

Traditional construction methods, such as Cast-in-Place (CIP) decks, are characterized by extended construction periods and intensive on-site labour (Culmo, Lord, Huie, & Beerman, 2011), (Garber, Chitty, & Freeman, 2018). In contrast, ABC may incorporate strategies like "Fast Track Contracting" with incentive/disincentive clauses, nighttime or off-peak hour operations, or entirely off-line work to minimize mobility impacts. The use of rapid-set or early-strength-gain materials, including Ultra-High-Performance Concrete (UHPC) for closure pours, is also a feature of ABC to expedite construction (Culmo, Lord, Huie, & Beerman, 2011).

A notable aspect of ABC is the requirement for small closure pours to finalize some connections. Precast concrete construction, unlike cast-in-place methods, allows elements to cure with minimal restraint, reducing internal stress and the likelihood of cracking. This is particularly relevant in the context of transverse cracking in bridge decks, a common issue in cast-in-place construction due to the restraint imposed by girders. Since precast elements are placed post-shrinkage, the risk of shrinkage-induced cracking is significantly mitigated, thereby decreasing water infiltration, and positively influencing the long-term durability of the structures (Culmo, Lord, Huie, & Beerman, 2011).

For further detailed definitions and guidelines on ABC, the AASHTO LRFD (2018) - Guide Specification for Accelerated Bridge Construction provides an extensive resource (AASHTO, 2018).

Benefits of ABC

The Accelerated Bridge Construction (ABC) methodology presents several advantages over traditional construction techniques. While any construction method impacts the traveling public, ABC significantly reduces this impact through decreased on-site construction activities. Early in the planning phase, potential limitations can be identified and addressed, ensuring continuous progress. The primary benefits of ABC are:

- Minimized traffic disruption and congestion
- Enhanced safety for the public and construction workers
- Improved quality control for precast elements
- Lowered life-cycle costs and maintenance requirements
- Reduced environmental impact
- Better control over costs and schedules, with less weather dependency
- Improved constructability

Applications

ABC is versatile and can be applied in various bridge project scenarios:

- **New bridge construction**

While ABC is often associated with replacement of existing bridges, it offers substantial benefits in new bridge construction. Designers can select from a range of options to optimize project execution. ABC is particularly advantageous in environmentally sensitive areas, reducing construction time and environmental impact. When constructing over existing roadways, ABC minimizes disruption to traffic below (Culmo, Lord, Huie, & Beerman, 2011). The method also enhances safety and reduces weather-related delays compared to conventional methods.

- **Repair and Rehabilitation**

ABC is commonly used to minimize traffic disruption during bridge repairs and rehabilitation. The safety of the traveling public and the flow of the transportation network are directly impacted by on-site construction-related activities; therefore, reducing construction time will provide for better safety (Culmo, et al., 2013). The aging infrastructure in the United States necessitates efficient rehabilitation methods (Culmo, Lord, Huie, & Beerman, 2011). ABC applications in this context include:

- o **Deck Replacement**

Traditional methods for bridge deck construction are labour-intensive and time-consuming, necessitating extensive on-site work. In the case of concrete bridges, this typically involves the use of temporary formwork to support reinforcement and wet concrete until it achieves the required strength. Accelerated Bridge Construction (ABC) techniques, employing prefabricated precast deck elements, offer a solution to these constraints. ABC encompasses several deck replacement strategies, notably including partial depth and full-depth concrete deck panels. These panels are fabricated off-site in a controlled environment, allowed to cure, and then transported to the construction site as needed (Roddenberry & Servos, 2012). Additional types of prefabricated deck panels include open grid decks, concrete/steel hybrid decks, fibre-reinforced polymer decks, and timber deck panels.

Another ABC strategy involves the use of stay-in-place deck forms. These forms, typically made of corrugated metal panels, are designed to support both the reinforcing steel and the wet concrete of the deck. A key advantage of this approach is the elimination of the need to remove forms post-curing of the concrete. However, this method still requires the placement and curing of concrete and reinforcing steel, which may not substantially reduce construction time. Additionally, this approach precludes the possibility of future visual inspections of the deck's underside (Culmo, Lord, Huie, & Beerman, 2011).

- o **Superstructure Replacement**

Employing a prefabricated superstructure in bridge construction or replacement significantly accelerates the process compared to traditional methods. ABC techniques are particularly advantageous for superstructure replacement projects, as they eliminate the need for the typically lengthy process of constructing foundations and substructures (Culmo, Lord, Huie, & Beerman, 2011). Technologies such as Self-Propelled Modular Transporters (SPMT) and skidding/sliding methods facilitate the removal and installation of entire superstructures. These superstructures can be assembled offsite and then relocated to their final position in a considerably shorter timeframe. Additionally, ABC allows for the construction of modular bridge segments or the integration of various prefabricated bridge elements, further enhancing efficiency and reducing construction time.

- **Substructure Replacement**

The integration of prefabricated substructure elements in conjunction with ABC methods presents substantial opportunities for further reducing the overall duration of construction projects. Typically, these prefabricated substructure components are engineered to emulate the properties and functions of cast-in-place concrete structures concrete (Culmo, et al., 2013). The selection of specific substructure elements is influenced by a variety of factors, including project time constraints, associated risks and costs, environmental and geometric considerations, site conditions, accessibility, design requirements, and critically, the compatibility with the existing superstructure and foundation.

A practical application of this approach is the replacement of aged pier columns and caps with prefabricated pier elements, provided that the existing footings and foundations are structurally sound and adequate. To integrate the old and new structures, closure pours can be utilized at the base of the columns, effectively connecting the existing footings with the new prefabricated pier elements. In cases where an existing pier is supported by a spread footing, it is feasible to construct the new pier adjacent to the existing bridge on rails and subsequently jack it into position, similar to the lateral movement of a superstructure (Culmo, Lord, Huie, & Beerman, 2011).

- **Replacement of existing bridges**

The process of replacing entire bridges or constructing new ones presents distinct challenges compared to deck or superstructure replacement, primarily due to the necessity of replacing substructures and foundations. Additionally, these projects often involve managing existing traffic that traverses the current bridge, introducing an added layer of complexity (Culmo, Lord, Huie, & Beerman, 2011). In scenarios where an existing bridge requires replacement, accommodating ongoing traffic is a critical consideration. The implementation of ABC techniques can effectively mitigate traffic disruption. This can be achieved through strategies such as constructing a new bridge adjacent to the existing traffic flow or establishing a detour. ABC methodologies facilitate various replacement approaches, enabling a reduction in the duration of each construction stage.

Moreover, the adoption of ABC practices significantly enhances safety at the construction site.

ABC Bridge Elements

In the context of Accelerated Bridge Construction (ABC), bridge elements are typically categorized into superstructure, substructure, and foundation. The superstructure encompasses the deck, girders, and all components situated above the deck (Culmo, Lord, Huie, & Beerman, 2011). The substructure includes elements that support the superstructure, such as piers, abutments, and wing walls, essentially constituting the segment between the superstructure bearing and the foundation. The foundation, a critical part of the substructure, is responsible for transmitting the loads from the bridge to the underlying earth and geological strata. This can include various forms, either shallow or deep, such as footings, pile caps, and piles. An illustrative overview of ABC bridge elements is provided in Fig. 1-3.

Culverts and buried bridges, often integrating superstructure with substructure (like in 3-sided boxes or arches) or representing the entire structure (as in box culverts), can be classified as either complete bridge systems or subsystems. The various elements and components within ABC bridges are interconnected through joints and connections, typically established in-situ (Culmo M. , 2009), (Aktan & Attanayake, 2013), as shown in Fig. 1-2. Chapter 2 will offer a more comprehensive definition, classification, and discussion of the uses of these components, particularly in the context of short-span bridges.

Short Span Classification

This book focuses on ABC Bridge Systems specifically tailored for short-span bridges. The span length is a critical determinant in determining both the structural design and the economic aspects of a bridge. In this context, the book adopts a definition of short-span bridges as those with spans up to 70 feet and a maximum prefabricated bridge module weight of 90,000 pounds (Hntb Corporation, U.S. TRB National Research Council and U.S Second Strategic Highway Research Program, 2013). This definition aids in clarifying the constraints in selecting ABC components and provides a clearer framework for project scope.

Within this defined span range, structures spanning less than 20 feet are typically classified as culverts. These culverts, often embedded in soil, are primarily utilized to enable water passage under roads, railways, or similar structures, and are designed with hydraulic considerations in mind.