Overview of Accelerated Bridge Construction Techniques in Highway Bridge Construction in the United States

Amin K. Akhnoukh
Associate Professor, East Carolina University, Greenville, North Carolina, USA
Akhnoukha17@ecu.edu

Tarik A. Youssef
Assistant Professor, French University in Egypt, Shorouk City, Cairo, Egypt
Tarik.youssef@ufe.edu.eg

Chao "Luna" Xiao
Associate Professor, East Carolina University, Greenville, North Carolina, USA
Xiaoch17@ecu.edu

Abstract
The National Bridge Inventory (NBI) of the United States includes more than 600,000 highway bridges with spans exceeding 20 ft. Approximately one-fourth of the nation's inventory are structurally deficient or functionally obsolete, thus, repair, rehabilitation, or total replacement is required to maintain the highway bridges from collapse.

The total cost of required bridge maintenance activities requires a total annual budget of $15 billion compared to a $1 billion available budget at the Federal Highway Administration. The budget deficiency requires innovative techniques in bridge rehabilitation and replacement that provides the construction industry with sufficient savings in the direct and indirect cost of bridge maintenance activities. Accelerated Bridge Construction (ABC) techniques are introduced as a new-approach that uses innovative planning, design, and construction techniques in a cost-effective manner to reduce the onsite activities, utilize site-available topography and materials to reduce construction time and consumed materials, and minimize the use of heavy equipment. Recent studies by the Federal Highway Administration proved that ABC techniques has resulted in minimized detour time, and significantly reduced the overall bridge construction projects by months to years.

Keywords
Accelerated Bridge Construction (ABC), Structurally Deficient, Maintenance Activities, Detours

1. Introduction

The National Bridge Inventory of the United States includes more than 600,000 highway bridges with spans exceeding 20 ft. Approximately 12% of the bridge inventory is structurally deficient, which

needs immediate partial repair to bridge load-bearing members, and 14% of the bridges are functionally obsolete with improper alignment, small-sized lanes, unsafe approach inclination, or geometrical problems that result in increased accidents and/or traffic delays.
The 2017 Infrastructure Report Card published by the American Society of Civil Engineers (ASCE Report Card, 2017) shows that almost 4 in every 10 bridges in the United States are 50 years or older, and on average there are 188 million trips over a structural deficient bridge. The average age of bridges within the NBI is increasing resulting in a higher risk to the safety of commuters. The current overall rating of the bridge network is C+, which indicates that the infrastructure included in this network is in a fair condition with a general sign of deterioration. A recent study by the Federal Highway Administration (FHWA) stated that a budget of $15 billion is required annually to improve the bridge conditions versus a budget of $1 billion currently available at the FHWA. The budget deficiency requires different innovative approaches to the maintenance, repair, and replacement activities required to maintain or restore the deficient bridges. Among the possible approaches, the use of Bridge Management Systems as a tool to define the different problems, and prioritize the required maintenance activities (Akhnoukh and Morcous, 2005). To-date, the FHWA and Different State Departments of Transportation are adopting a new approach for bridge maintenance, repair, and replacement known as *Accelerated Bridge Construction* (ABC). ABC is defined as bridge construction that uses innovative planning, innovative design techniques, on-site materials, and construction methods in a safe and cost-effective manner to build new bridges and maintain, repair, or replace existing ones (Adams et al., 2012). The innovative ABC approach in planning, construction methods, and materials selection results in the construction of durable bridges with longer life spans at a reduced cost.

This paper presents different ABC technologies adopted by different State DoTs, the optimum site conditions and project constraints associated with each technology, and the attained advantages for adopting ABC technology in various bridge construction project. A Case study is presented to explain how the incorporation of ABC technologies and high strength construction materials result in material and labor savings.

2. Accelerated Bridge Construction (ABC) Technologies

Three different ABC technologies are currently adopted and promoted by the FHWA and State DoTs in various bridge construction and maintenance projects. These technologies are *1) Prefabricated Bridge Elements and Systems (PBES), 2) Slide-In Bridge Construction, and 3) Geosynthetic Reinforced Soil – Integrated Bridge System (GRS-IBS).* The implementation of each technology depends on specific project objectives, construction site topography, geotechnical conditions, type of the construction bridge and its intended use.

2.1. Prefabricated Bridge Elements and Systems (PBES)

Prefabricated bridge elements and systems is one of the main ABC strategies adopted in the construction of new bridges or the replacement of deteriorated elements of aging bridges. PBES are structural components that are fabricated off site and moved for the construction site for direct installations. PBES includes features that allow fast construction and are mainly fabricated using high performance materials for increased strength and better long-term performance of the constructed or repaired bridge. The fabrication of bridge elements off site enables the project contractors to operate in a controlled condition which improves the quality of the PBES, reduces construction time, and improves the overall safety of the project. PBES includes the following elements and systems:

- ***Deck elements*** that are fabricated off-site and transferred for direct erection, which eliminate activities associated with conventional deck construction including falsework, formwork, reinforcing steel placement, concrete pouring and curing, and formwork removal. Examples of deck elements include prefabricated deck panels, lightweight precast panels, and FRP deck panels, and fiber-reinforced polymer honeycomb "lightweight" panels.

- ***Girder elements*** including AASHTO girders, NU girder (Akhnoukh, 2008), bulb tee girders, and adjacent box girder. Girder elements fabricated for PBES are poured and cured off site using advanced curing methods, which results in high early strength of concrete, and lower permeability due to higher consolidation.
- ***Pier elem*****ents** that eliminates the time required for formwork, reinforcement placement, concrete pouring and curing. Pier elements include prefabricated caissons, pier caps, prefabricated footings and columns.

The afore-mentioned precast/prefabricated elements could be used in attaining a significant reduction in scheduled activities duration and minimizing the amount of critical activities within the construction project duration. In addition to prefabricated elements, prefabricated systems can be used as an ABC techniques to minimize or eliminate the use of temporary alignments or temporary bridge structures. Examples of prefabricated systems include full-width beam span with deck and girder-deck Pi-girder developed by researchers at the Massachusetts Institute of Technology (Keierleber et al., 2007). The MIT Pi-girder is shown in Figure 1.

Figure 1: MIT 2nd Generation (FHWA Report, 2009)

2.2. Geosynthetic Reinforced Soil-Integrated Bridge System (GRS-IBS)

The Geosynthetic Reinforced Soil-Integrated Bridge System (GRS-IBS) is an innovative approach that allows bridge contractors to execute their bridge construction project in a short construction period due to the use of on-site materials in bridge construction. The GRS-IBS approach depends on using layers of compacted granular fill, naturally available at construction site, alternatively with geosynthetic reinforcement that provides a stable seamless approach to the bridge span. The simple earth work results in a cost reduction up to 50% as compared to bridges constructed using conventional method.

The GRS-IBS bridges are durable due to the few man-made materials used in its construction. Aside of bridge durability, the required maintenance is minimal which results in fewer traffic disruption and lower life-cycle cost. The GRS-IBS construction technique provides the bridge with a seamless approach as it eliminates the bump at the bridge due to alignment issues at construction. The elimination of approach bump decreases the dynamic loads due to vehicle impact, which reduces the structure and vehicle maintenance. Additionally, elimination of approach bump eliminates the accidents occurring due to the driver loss of control, hence, improve the serviceability of the bridge. Typical GRS-IBS bridges are short one-span bridges that does not exceed 150 ft. in length and are constructed in a shallow terrain with a total depth that does not exceed 30 ft. as shown in Figure 2.

Figure 2: One Span GRS-IBS Bridge (FHWA, 2017)

2.3. Slide-In Bridge Construction (SIBC)

Slide-In Bridge Construction (SIBC) is one of the main ABC techniques adopted by the Federal Highway Administration to provide bridge constructors with a cost-effective tool to replace an existing bridge without impacting the traffic mobility or safety at the bridge construction location. Currently, the state highway agencies are working with the FHWA to develop their SIBC implementation guides and construction manuals through Every Day Counts initiative. The main objective of the FHWA collaboration with state agencies is to provide standard specifications to the SIBC technology and adopt SIBC technique as a part of the standard practices in bridge construction.

SIBC allows for the prefabrication of a new bridge at a precast facility or on-site using temporary supports adjacent to the aging bridge. Once the bridge construction is completed, a short-period full-traffic shut down is implemented to demolish the aging bridge and slide in the new bridge to occupy the same place before traffic restoration, as shown in Figure 3.

Figure 3: SIBC Construction Project by Washington State DoT (FHWA, 2017)

3. Accelerated Bridge Construction Current State of Practice

The implementation of ABC innovative approach has been increasingly incorporated in different bridge construction projects in the United States in the recent years to maintain and improve the US bridge network conditions given the FHWA budget deficit. Since 2010, 8 bridges were constructed using the *GRS-IBS* system. Current research is focused on the advantages of using short span metal and concrete arch bridges in rapid construction of GRS-IBS system bridges, with major emphasis on stream-crossing and railroad bridges. Similarly, more than 800 bridges have been designed or constructed using *PBES* system. Multiple research projects are currently investigating the potential of using ultra-high-performance concrete, high strength concrete, and larger prestress strands in the prefabrication of bridge girders with superior mechanical properties (Akhnoukh, 2010). In a relevant study, high strength concrete (compressive strength of 15 ksi) and larger 0.7 inch. Prestress strands were successfully used to design a 105 ft girder bridge panel with a 4 NU900 girders spaced at 12 ft. instead of a 6 NU900 girders spaced at 8.0 ft. for the same loading condition. The alternative design, shown in Figure 4, using high strength concrete and larger prestress strands resulted in a direct material saving of 14%. The use of fewer girders result in a lighter superstructure, shorter construction schedule, labor and equipment savings.

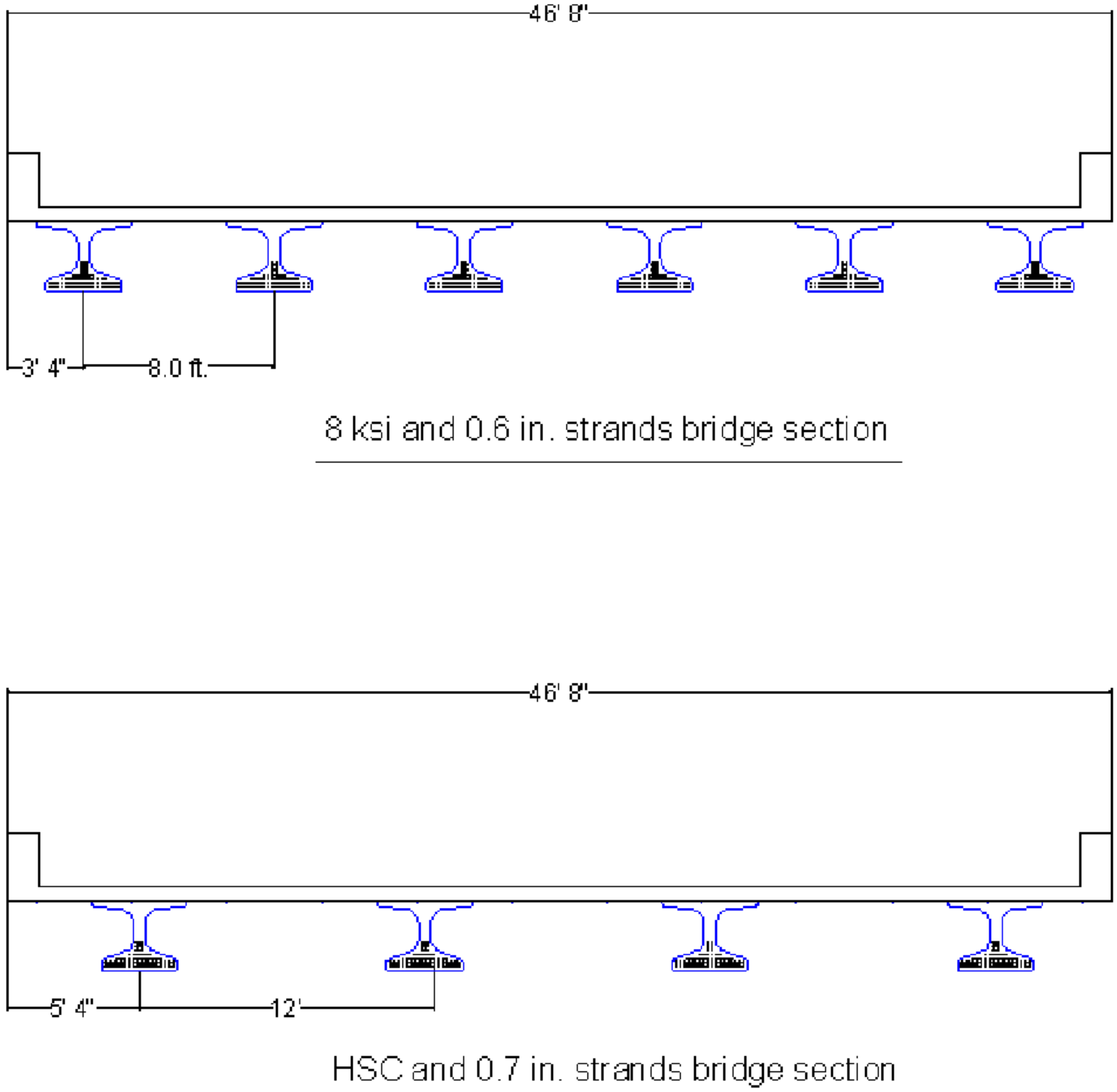

Figure 4: Superstructure Savings Using HSC and 0.7 Inch Prestress Strands (Akhnoukh, 2008)

4. Benefits of Different ABC Techniques

The overall benefits of ABC techniques include *reduced construction cost, reduced traffic interruption periods, higher quality control for bridge construction due to the fabrication of bridge elements on a controlled off-site environment, more durable bridges with lower life-cycle cost compared to conventionally constructed bridges, higher job site safety, and reduced impact on the surrounding environment*. The aforementioned advantages are generally associated with accelerated bridge construction. However, specific advantages are attributed to the specific bridge technique adopted by the bridge constructor. Specific advantages relevant to different ABC techniques are shown in Table 1.

Table 1: Specific Benefits of Different ABC Techniques

	GRS-IBS	PBES	SIBC	Remarks
Reduced Construction Cost	X	X	X	Shorter construction duration, reduced site conflicts, and minimized traffic interruption results in reduced project budget
Shorter Construction Schedule	X	X	X	Minimized on-site activities reduces construction time
Durable – Longer Bridge Life Span	X	X	X	Better quality control due to off-site construction
Reduced Environmental Impact	X	X	X	Minimized detours and minimized rerouting and stream mitigation activities
Eliminated Approach Bump	X			Integrated approach-deck construction using geo-synthetic fibers eliminates approach bump
Possible On-Site Changes		X		Possible activity and schedule changes due to limited critical activities (for off-site construction)
Easier Utility Installation		X	X	Utilities are fabricated off-site and inserted/tied after it is relocated to the construction site
Lower Life-Cycle Cost	X	X	X	Improved quality control results in a better construction and minimized maintenance activities

5. Summary and Conclusions

The Accelerated Bridge Construction Technique (ABC) is currently researched by the Federal Highway Administration and Different State Departments of Transportation as an innovative approach for new bridge construction and maintenance, repair, and replacement of aging bridges with noticeable deterioration. According to research findings, the main ABC technologies *Prefabricated Bridge Elements and Systems (PBES), Geosynthetic Reinforced Soil-Integrated Bridge System (GRS-IBS), and Slide-In Bridge Construction (SIBC)* are providing bridge owners and contractors with successful techniques for rapid construction with better quality control, higher job site safety while reducing the traffic interruption and minimizing the labor and construction equipment utilized during the project duration. In order to maximize the benefits of ABC approach, high strength construction material, innovative bridge systems are to be incorporated. Based on attained advantages, the Federal Highway Administration is currently working with state agencies to adopt ABC techniques as a standard way of executing bridge construction projects.

6. References

Akhnoukh, A., and Morcous, G. (2006). "Review of the State-of-the-Art Bridge Management Systems in North America" International Conference on Bridge Management Systems – Monitoring, Assessment, and Rehabilitation, Cairo, Egypt, March

Adams, M., Nicks, J., Stabile, T., Wu, J., Schlatter, W., and Hartmann, J. (2012). "Geosynthetic Reinforced Soil Integrated Bridge System Interim Implementation Guide". Washington D.C.: Federal Highway Administration Every Day Counts

Akhnoukh, A. (2008). "Development of High Performance Precast/Prestressed Bridge Girders". Ph.D. Dissertation, University of Nebraska-Lincoln, Nebraska, USA

Keierleber, B., Phares, B., Bierwagen, D., Couture, I., and Fanous, F. (2007). "Design of Buchanan County, Iowa, Bridge Using Ultra-High-Performance Concrete and PI Girders" Proceedings of Mid-Continent Transportation Research Symposium, Ames, Iowa, USA

Graybeal, B., (2009). "Structural Behavior of a 2nd Generation UHPC Pi-Girder" Federal Highway Report FHWA-HRT-09-069

Akhnoukh, A. (2010). "The Effect of Confinement on Transfer and Development Length of 0.7 Inch Prestressing Strands". Proceedings of Concrete Bridge Conference: Achieving Safe, Smart & Sustainable Bridges, Arizona, USA