

Accelerated Bridge Construction (ABC), A Better Approach to Bridge Construction?

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Abstract

Accelerated Bridge Construction (ABC) is a common term given to the combination of different procedures that help reduce the construction period of a project. Utilizing these different procedures on bridge replacement/rehabilitation projects presents several benefits, including reduced traffic congestion and improved on-site safety. The purpose of this paper is to recognize the difference between Accelerated Bridge Construction and Conventional Bridge Construction, and the process of deciding which approach is more suitable for a particular project. Specifically, this paper explores the desirable condition in which utilizing ABC would be most beneficial for the owner, builder, community, and environment. The methodology used in this paper is the content analysis method, which includes a large amount of textual information. The analytical constructs may be obtained from existing practices, experience, knowledge of experts, and previous research studies. Throughout this research, data and information was collected from different scientific articles, research papers, books, and journals. The results conclude that when a project is located in a critical area, and time is a vital factor, the ABC approach can be much more beneficial compared to the conventional approach. However, this method cannot be applicable unless owners have financial capability, skilled and competent workers, and the required specialized equipment for the job. Thus, utilizing prefabrication elements is greatly advantageous, but only when owners have the sufficient recourses.

Key words: Prefabricated Bridge, modular structure, precast concrete

Introduction

Bridges have always been an important part of our society, and they are essential and vital aspect for our day-to-day commuting. In transportation engineering, researchers and engineers have been developing different technologies and innovating different construction methods throughout the years in order to attain an economical, safe, and more convenient results in construction projects. There are many deficient bridges in the United States, and fixing them may cause many issues such as increasing the traffic congestion. Therefore, Accelerated Bridge Construction, or ABC, might be the best solution for bridge replacement/rehabilitation because it save time. The Accelerated Bridge Construction approach is one of the latest construction approaches that has been developed. In fact, prefabricating bridge elements offers

major time savings, cost savings, safety advantages, and convenience for travelers. The use of prefabricated bridge elements is also solving many construction challenges while enhancing bridge construction in the U.S. Further, over the past decade, the use of ABC has increasingly gained attention in the construction industry, especially in the United States. This unique bridge construction technique has brought many advantages in the construction industry because it can, if it is done properly, help to reduce construction time, decrease accidents, and improve safety. On the other side of the coin, however, the Conventional Bridge Construction method, or CBC, could be more beneficial, regardless of all the benefits that comes with new innovative method. Both, ABC implementation and other alternatives, will be studied in this paper.

Literature Review

History

The development of bridge technology can be divided broadly into two key eras. The first is the Arch Era, from 2 000 BC to the end of the 18th century, which was influenced by the Roman structures. During this period, stone arches were widely used in bridge construction and the historical reminiscence of this method can still be seen around the world today. The second is the Steel Era, which began when steel became commercially obtainable as a construction material in the mid-19th century. All contemporary bridge types, including beam bridges, truss bridges, cantilever bridges, arch bridges, tied arch, suspension, and cable-styled bridges (especially those with longer life spans) have been feasible and possible due to the great strength of steel in tension and in compression. Around a century ago, engineers started utilizing concrete, and the entire construction industry began to change. A new method, called prestressing, helped stop concrete from cracking after being built. In today's world, the majority of bridges are made of steel and prestressed concrete, which has allowed these methods to stand the test of time and become the building blocks of the modern built environment.(Tang, n.d.)

Conventional Method

The Conventional Bridge Construction method (CBC) is a process of construction that involves site activities which can be time consuming and weather dependent. Bridges, which can be categorized based upon how forces of tension, compression, shear, bending, and torsion are distributed through their structural elements,("untitled - LivingBridge.pdf," n.d.) come in many types - the most popular of which are briefly described below:

Beam Bridge

Beam bridges are not only considered one of the oldest type of bridges, they also one of the simplest to design and build. Approximately half of the bridges in the United States are beam bridges. As shown in Figure 1, the beam bridge's strength depends on the strength of the roadway and can be increased by constructing further piers.("National Building Museum," n.d.) While it is easy to build a beam bridge, one

major disadvantage is the fact that the distance between the piers is small, making it nearly impossible to build over water. This type of bridge can also be portrayed by its materials, such as concrete, metal, and stone, and may also have different types of spans, such as cantilever, continues, etc.¹

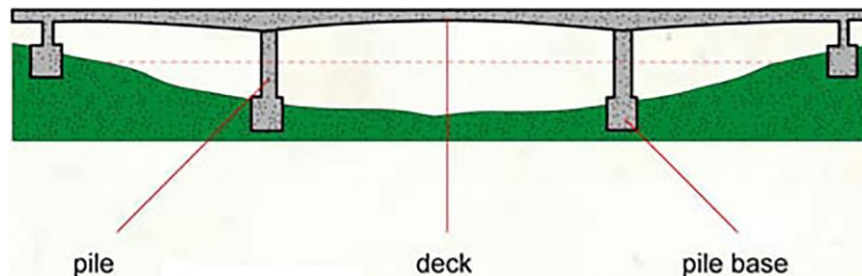


Figure 1 Beam Bridge (infovisual.info)

Truss Bridges

Truss bridges are one of the most popular forms of bridge in the construction industry due to its numerous advantages. Early truss bridges, as far back as the sixteenth century, were made of wood, with the first metal truss bridge was built in the mid-nineteenth century. Truss bridges are considered strong and can even be used as a drawbridge, or even as an overpass for railway trains. However, while it is sophisticated to build a truss bridge, this method's maintenance costs are extremely high (Figure 2). There are several types of truss bridges. The first is the thru truss, in which the road goes between the truss lines and is carried onto the deck. The second is a pony truss bridge, which is similar to the first type, although it does not have lateral bracing between the top chords. Finally, there is the deck truss bridge, which is different than the previews two forms because the road is situated above the trusses and its deck system is on top of the chords.²

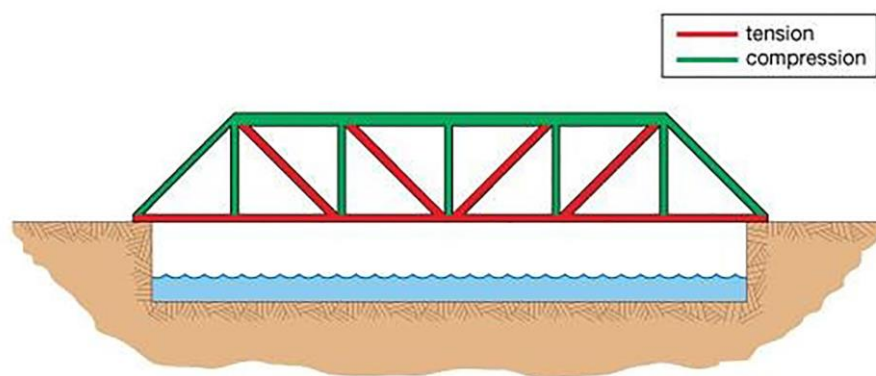


Figure 2 Truss Bridge (infovisual.info)

Arch Bridge

¹ Aggeliki K., ("Beam Bridge Construction & Design -Types of Beam Bridges," n.d.)

² ("truss.pdf," n.d.) DOT.

Arch bridges were primarily built by the Romans many centuries ago. This type of bridge can be built using different materials such as stone, concrete, and steel. The load on the bridge can be carried outward along the curve of the arch to the abutments, which is a structure built to support the lateral pressure at the ends of a bridge (Figure 3). Arches may be grouped upon the following parameters:

- The materials of construction
- The structural articulation
- The shape of the arch

Additionally, in terms of structural articulation, the arch can be fixed or hinged, with one, two, or even three hinges joined into the arch rib. (“Manual 11 Design Of Arch Bridges.pdf,” n.d.)

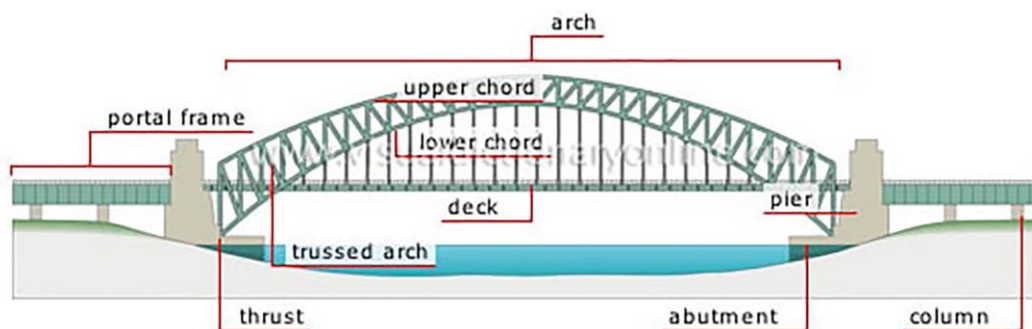


Figure 3 Arch Bridge (infovisual.info)

Suspension Bridge

When we think about suspension bridges, the first thing that comes to mind, compared to the other types of bridge structures, is the image of a strong bridge that has a much longer span, up to 7 000 ft. This unique structure is not only expensive, it takes a long time to build it and needs a large amount of materials. The main elements of this type of bridge are a pair of major cables stretching over a number of towers that are attached at the end to anchor, and smaller cables that are attached to the main cables to support the roadway. The load of the roadway is being carried by the cables, which transfers the force of compression to the towers of the bridge, while the tension force is acting on the cables (Figure 4). The main components of this kind of bridges are the stiffing girders/trusses, main cables, main towers, and anchorages. (“Chapter 18 - Suspension Bridges - Suspension-Bridge.pdf,” n.d.)



Figure 4 Suspension Bridge (infovisual.info)

Cable-stayed Bridge

This particular type of bridge is considered the newest form amongst the previous bridge types since it was first built in the mid-twentieth century in Sweden, and were created as an economical method to long-span bridges (500-2 800 ft). This type also contains one or more towers (Figure 5). The idea of the cable-stayed bridge is that the bridge carries largely vertical loads acting on a girder. The stay cables in the bridge gives an average supports for the girder in order to span a long distance. The basic structural shape of this type of bridge is a group of overlapping triangles involving the pylon, or the tower, the cables, and the girder. (“Chapter 19 - Cable-Stayed Bridges - ch19.pdf,” n.d.)

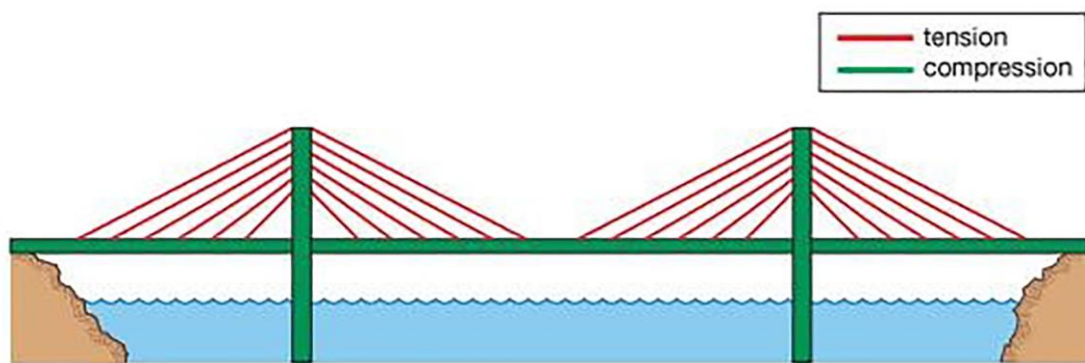


Figure 5 Cable-stayed Bridge (infovisual.info)

Accelerated Bridge Construction

At the beginning of the twenty-first century, it was noticeable that the use of the precast modular construction for ABC had started to gain popularity in the construction industry. Unlike the conventional construction method (Figure 6), this distinctive method seeks to reduce construction duration and the impacts on traffic by rapidly building bridges by building major bridge components close to their actual location and installing them speedily by utilizing heavy lifting equipment such as cranes or self-propelled transporters (Figure 7). ABC methods can greatly reduce the impact of construction work on both the environment and the community by working on the bridge's components away from the roadway.

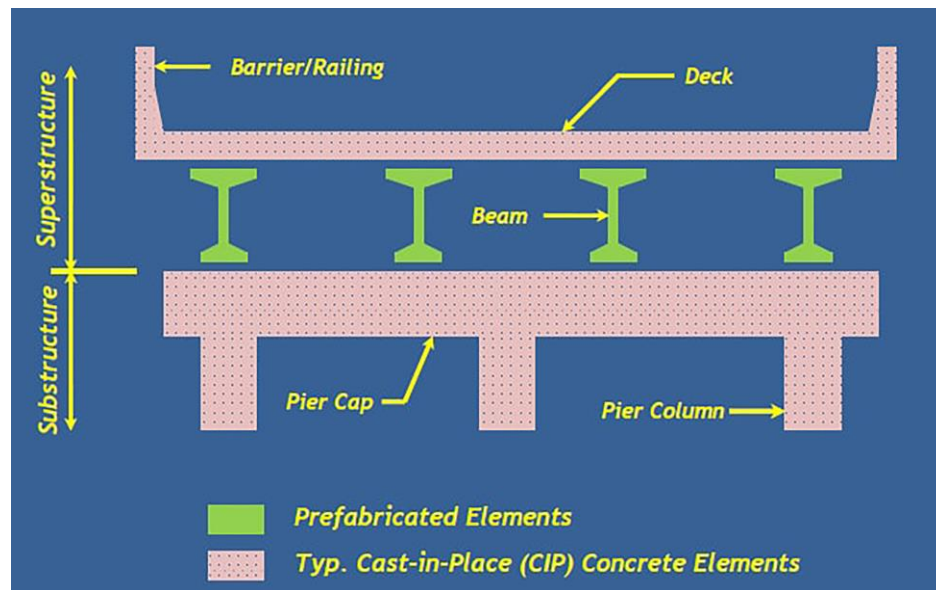


Figure 6 Conventional Bridge Construction (MnDOT)

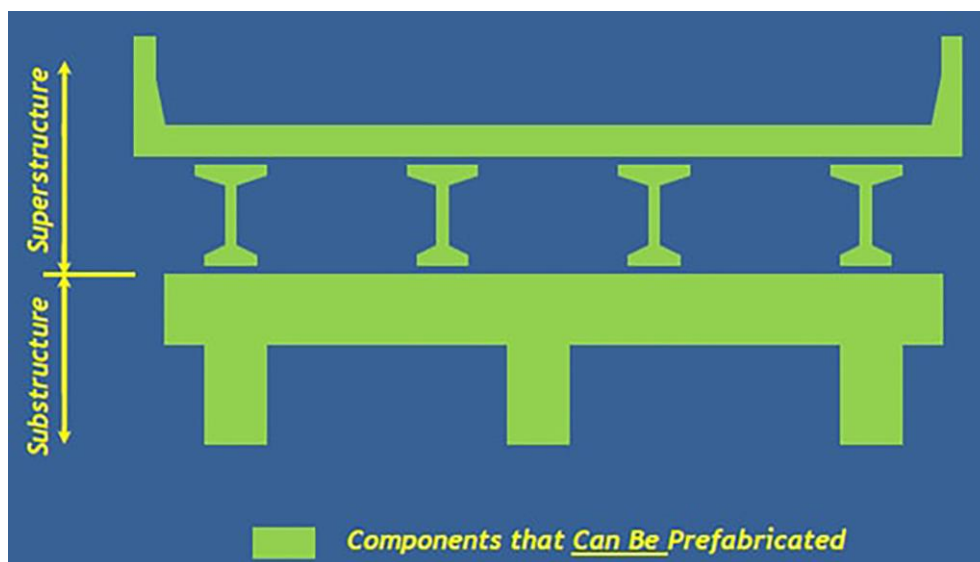


Figure 7 Accelerated Bridge Construction (MnDOT)

Problem Definition and Research Questions

Time, cost, quality, and safety are the four factors that play a significant role in the planning, constructing, and controlling of construction projects. Accelerated bridge construction is recognized as an important method for bridge owners to accelerate the delivery of highway bridge projects. However, while the potential advantages of accelerated bridge construction are recognized, there are many occasions that conventional construction method can be more beneficial for the project. Thus, the specific question to address is, “What are the optimum and most suitable conditions for utilizing Accelerated Bridge Construction (ABC) method, and how is it implemented to be time efficient?”. Expanding upon this question, another question emerges, “What are the desirable cases for utilizing the Conventional Bridge

Construction (CBC) Method over the Accelerated Bridge Construction (ABC) Method?”. This paper, however, will mainly focus on the superstructure replacement/rehabilitation projects.

Methodology

This research paper uses the “Content Analysis” method, which is a standard methodology in the social sciences for studying the content of communication. Earl Babbie, an American sociologist, defines communications as “the study of recorded human communications, such as books, websites, paintings and laws.”(Babbie, 2010) It is a highly flexible method that has been widely used in the library and information science studies. The research method is applied in quantitative, qualitative, and sometimes mixed modes of research framework and employs a wide range of analytical techniques to generate findings and put them into context. This method, however, will enable the study to include large amount of textual information and systematically identify its properties by detecting the more important structures of its communication content. The analytical constructs may be derived from existing practices, the experience or knowledge of experts, and previous researches. Throughout the research project, data and information will be collected from scientific articles, research papers, books, journals, and newspapers. Additionally, interviews with scholars and professional engineers who have a depth of experience in the transportation construction industry will be added as available.

Data Collection and Analysis

Decision Making

The conventional bridge construction methods are still the most prominent process used by the construction industry, and it will take a long time for the ABC to be fully adopted by state departments of transportation across the nation. The first step in conducting such approach is to identify whether ABC is suitable for a particular project. There are two different approaches for ABC decision making were specified in this literature:(NCHRP, 2011)

Decision-Making Flowchart

The first approach, which is a quick and simple procedure, is to answer the questions stated on the flowchart below (Figure 8), which was developed by The Federal Highway Administration (FHWA). A set of decision-making criteria are used to assist decision makers select the ideal method, whether ABC or CBC, and also choose whether using a prefabricated bridge is a more economical and effective choice or not. (“Framework for Decision-Making - ABC - Accelerated - Technologies and Innovations - Construction - Federal Highway Administration,” n.d.)

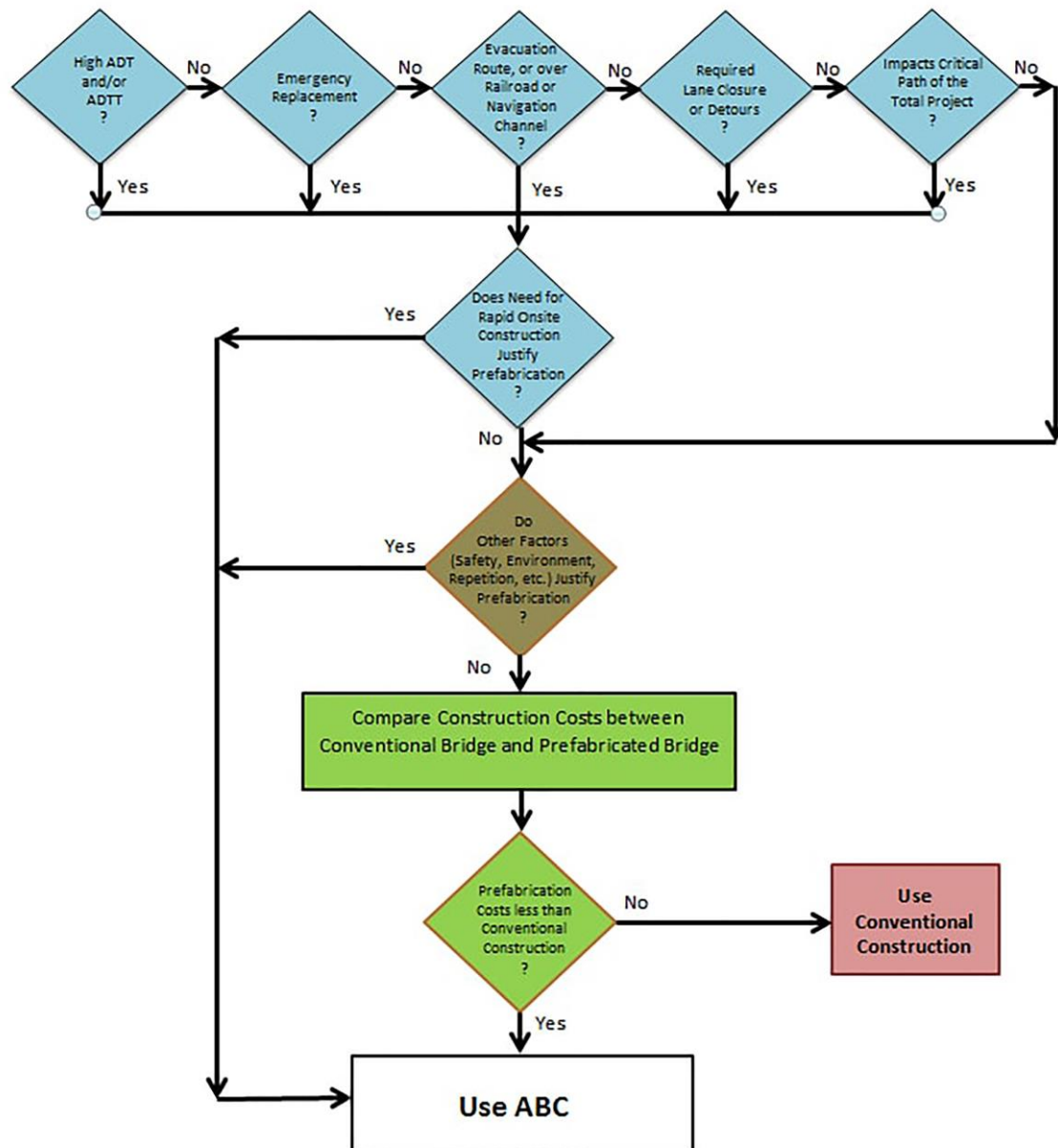


Figure 8 Decision-Making Flowchart (The Federal Highway Administration)

The Table of Important Considerations

These two unique tables (table 1 and 2) were developed by the author of Accelerated Bridge Construction, Best Practices and Techniques, Prof. Mohiduddin Khan.(Khan, 2014) Each of the below items earn points and are eventually compared with the other construction methods.

Table 1 Primary consideration for selection of suitable projects for ABC in terms of benefit

Important Primary Considerations for Selecting ABC	Maximum Points Based on Project Features	Advantage Point Using ABC	Advantage Points (Traditional Method)
Estimated duration and importance of early completion	15		
Complexity, river location, or seismic vulnerability	15		
Located on interstate/inter-country/local route	15		

Feasibility of D-B management	15		
Estimated cost of bridge & availability of funds	10		
Bridge replacement or new bridge	10		
Contractor's experience on similar projects	10		
Span length, deck width, and number of traffic lanes	10		
Total	100		

The list of items in table 1: A+B+C+...+H (out of 100) for initial screening

Table 2 Secondary consideration for selection of suitable projects for ABC in terms of benefit

Important Primary Considerations for Selecting ABC	Maximum Points Based on Project Features	Advantage Point Using ABC	Advantage Points (Traditional Method)
Shallow foundation/piles/drilled shaft from soil report	7.5		
Impact of construction on environment	7.5		
Type of deficiencies outlined in inspection reports for rehabilitation	7.5		
Demolition easy/difficult	7.5		
Deck geometry straight/skew/curved	5		
Feasibility of detour/kkane closure/use of temporary bridge during construction	5		
SPMT length of girders	5		
Maximum crane capacity	5		
Precast deck panel sizes	5		
HPC concrete strength	5		
HPC girder strength	5		
Precast concrete substructure strength	5		
Mechanically stabilized earthwork (MSE)			
wing walls/precast retaining walls	5		
Easy access to site	5		
Site office/easy mobilization	5		
Availability of labor	5		
Present/projected average daily truck traffic (ADTT)	5		
General/extreme weather conditions	5		
Total			

The list of items in table 2: A+B+C+...+H (out of 200) for final screening

The recommended points allocation are listed as follows:

- Small advantages/impacts (30%)

- Medium advantages/impacts (70%)
- High advantages/impacts (100%)
- Total Maximum points = 200

Seismic Considerations

The majority of projects using ABC are in the U.S. regions of low-seismicity. (“ABC - Accelerated - Technologies and Innovations - Construction - Federal Highway Administration,” n.d.) In the presence of seismic forces, the connections between the bridge components should withstand the seismically-induced forces. This part provides information on the current standards for seismic details. (“nchrp20-68a_11-02.pdf,” n.d.)

General Standard

All design and components details in ABC are generally similar to the details of the conventional bridge construction method that must be applied in any bridge, according to the American Association of State Highway and Transportation Officials (AASHTO).

Connection of Superstructure to Substructure

There are several techniques to connect bridges to the substructure. Most often, those designs are made to transfer lateral seismic forces from the superstructure of the bridge to its substructure.

Pinned Connections

In the majority of the ABC projects in the U.S., the connection between the superstructure and the substructure is detailed as a pinned connection. The most widespread type of pinned connection is over the bearing device (Figure 9) in which forces can be transferred from the superstructure over the bearing device then finally into the substructure of the bridge.



Figure 9 Bearing Device (<http://www.archiexpo.com/>)

Moment Connection

In order to provide further stability to the bridge in case of an earthquake, it is crucial to use moment connections between the superstructure and substructure of the bridge. These connections, however, can also minimize lateral movement of the structure and minimize forces in the foundation.

Columns

In case of an earthquake, columns are considered the most heavily loaded components. Hence, exceptional care must be taken to fairly detail connections in precast column components. In high seismic zones, columns are designed to shape plastic hinges and help to remove the possible seismic forces (Figure 10). Further, it has been observed that due to the lack of seismic performance data for prefabricated element connections, ABC application is limited in high seismic regions.³

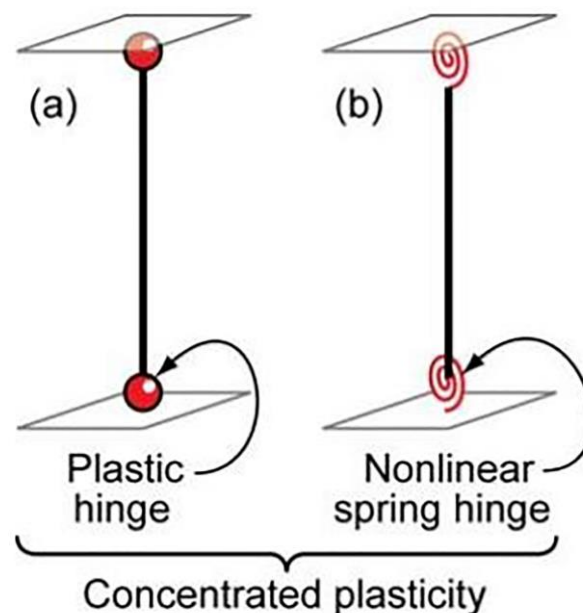


Figure 10 Columns reaction to Seismic Forces (<https://www.researchgate.net>)

Footings and Foundations

Similar to the process of cast-in-place, the design of precast footings should go through the same regular procedures. In deep foundations, however, when precast piles are utilized, additional details might be required in order to provide pile uplift and moment capacity in the precast footings (Figure 11).

³ Mostafa Tazarv, M. Saiid Saiidi, ("UHPC-filled duct connections for accelerated bridge construction of RC columns in high seismic zones," n.d.)

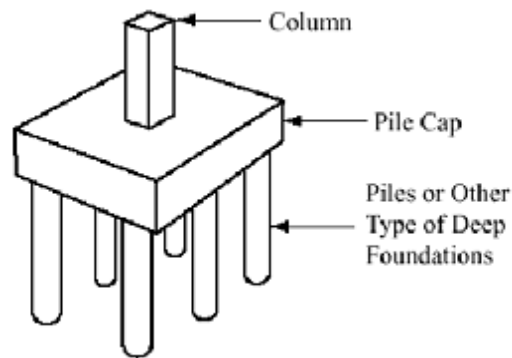


Figure 11 Foundation⁴

Materials

This section gives a general review of the various types of materials utilized in prefabrication and covers the effect of the materials on ABC procedures.

Concrete

Concrete is the most used material for ABC projects. This material, in fact, is the first choice for designers due to the fact that its elements can be built off site in different shapes. Prevalent concrete elements include beams, deck slabs, and piers. Further, concrete can be utilized for making connections between the various bridge elements. These different type of connections, more likely, require high early strength concrete.

Structure Steel

Steel elements, such as steel decks or steel beams, are very suitable for ABC projects. There is a great control over the tolerances of fabrication, hence, connections that are complex can be employed utilizing structural steel. Just like any other material, steel has advantages and disadvantages in ABC projects. One of its positive aspects is the fact that steel weighs less than an equal concrete element. On the other hand, steel has greater flexibility, and therefore, it is crucial, when steel components are being transported to the project site, to insure that internal stresses and deflection of the steel components are not exceeded.

Superstructure Systems

Superstructures are designed based on the American Association of State Highway and Transportation Officials (AASHTO) as “Structural parts of the bridge that provide the horizontal span.” In CBC, however, the superstructure is usually known as the part above the bridge bearings.

Prefabricated Deck Systems

⁴ Harbun Subekti (“Building Foundation Types for Construction Engineering,” 2015)

Deck systems are probably one of the most important elements of ABC. In fact, it is very beneficial because in the conventional way of constructing a bridge, deck erection can be time-consuming. While, on the other hand, when ABC is implemented, the time that workers spend forming and placing concrete is no longer wasted. There are many types of prefab deck panels. A summary of these different types of decks are shown in Table 3(“Prefabricated/Precast Bridge Elements and Systems (PBES) for Off-System Bridges - BDK83_977-13_rpt[1].pdf,” n.d.-a), however, the two major types of precast deck panels are the partial-depth (Figure 12) and full-depth (Figure 13). (“Home | Federal Highway Administration,” n.d.)

Table 3 Deck Systems (The Federal Highway Administration)

System	Time: Days/Span	Comments
Full-depth Precast Concrete Deck Panels	2	This includes longitudinal post-tensioning and closure pours. Deck Replacements have been completed during a single weekend closure
Open Grid Decks	1	The lack of post-tensioning needs for these systems can lead to very fast installations.
Concrete/Steel Hybrid Decks	2	Some of these systems are similar to full-depth precast decks. They require grouting in order to make the connection to the beam framing.
FRP Deck Panels	2	Adhesive connections and grouting are the major installation tasks.
Partial Depth Precast Deck Panels	7	The panels install quickly (1 day); However, replacement of the top mat of reinforcement and concrete is needed to complete the deck.
Timber Deck Panels	1	This system is simple and requires no grouting or post-tensioning.

Summary of deck systems and their minimum installation times



Figure 12 Partial-depth Deck Panels (https://www.fhwa.dot.gov/bridge/abc/prefab_def.cfm)



Figure 13 Full-depth Deck Panels (https://www.fhwa.dot.gov/bridge/abc/prefab_def.cfm)

Full-Depth Deck Panels

In ABC, using the full depth panels can be greatly beneficial since it eliminates the need of formwork, reinforcing steel placement, concrete placement, and curing. This type of deck can be used in different sizes and shapes, and not only transversely, but also longitudinally. Most frequently, the components are built with transverse joints. Furthermore, these components can be simply prestressed and are usually post-tensioned longitudinally after placement since these components are being pre-casted elsewhere.

A typical Full-depth precast deck system that usually consists of precast concrete panels is shown in (Figure 14)(Yamane, Tadros, & Baishya, 1998). These panels, however, are about eight inches thick that are placed close by each other on the bridge girders. There are various methods of connecting those panels to each other. The most popular one is what's called a “grouted shear key” connection (Figure 15)(“Design Guide for Precast UHPC Waffle Deck Panel System, including Connections | Federal Highway Administration,” n.d.)

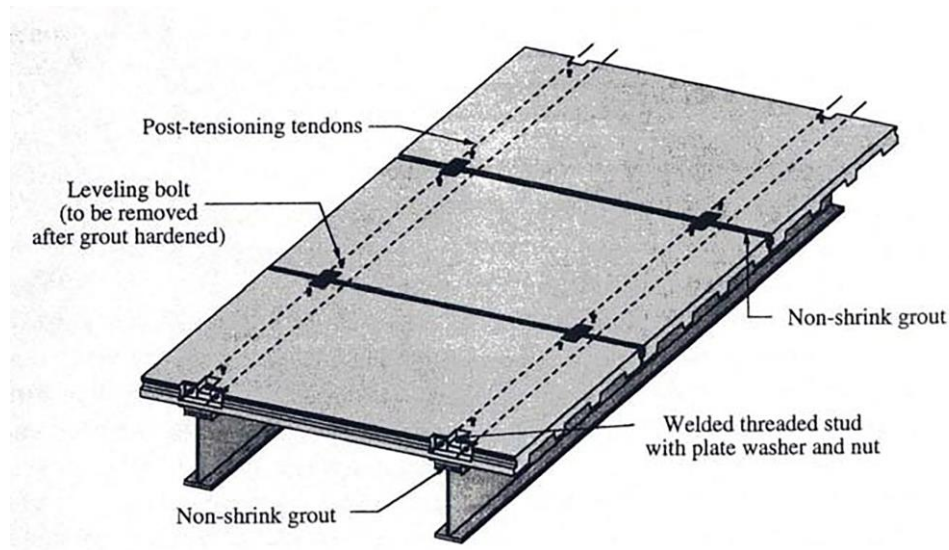


Figure 14 Typical full-depth precast concrete deck panel application on steel girders⁵

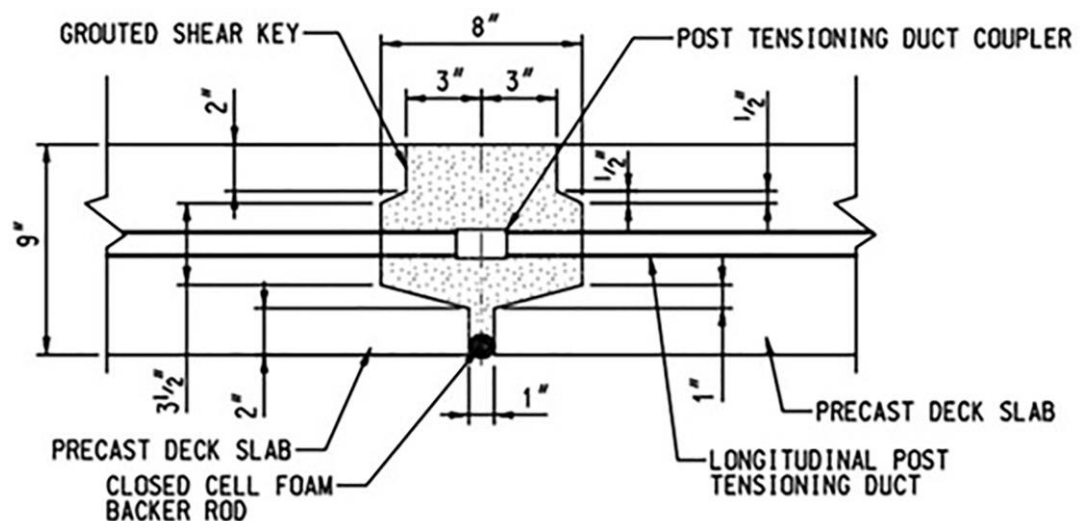


Figure 15 Grouted Shear Key (U.S. Department of Transportation)

Construction Sequence

The typical procedure for constructing a full-depth precast panels on steel girder are listed as shown below:

1. First, girders are properly placed and difference in elevation are fixed with shims.
2. Carry the panels and put them onto the girders.
3. Difference in elevation of panels are corrected using shims.
4. Fill the joints between the panels with grout and allow the grout to gain the required compressive strength.
5. If longitudinal post-tensioning is involved in the design of the bridge, then, tendons are fed into ducts in the panels and stressed. ("Post Tensioning Manual - hif13026.pdf," n.d.)

⁵ Missouri Transportation Institute ("or11005.pdf," n.d.)

6. Shear connectors, like shear studs for instance, are welded to the girders inside the shear pocket openings in the panels. Without them, the beam and slab will bend. (“Shear connection in composite bridge beams,” n.d.)
7. The shear pockets, which is the empty area between the panels, and the post positioning ducts are filled with grout and left to cure.
8. Place an overlay in order to have a smooth surface.

It is crucial, however, to apply the longitudinal post-tensioning after the grouting of joints and before the group of panels are attached to girders in order to prevent any unwanted stress into the girders. Moreover, the same approach and steps explained earlier can be used for placing panels on prestressed concrete girders.

Partial-Depth Deck Panels

This type of precast concrete panels, as shown in Figure 16 and 17, are thin prestressed concrete panels that spread between girders and act as stay-in-place forms for bridge construction. These panels are usually 3.5 inches thick and eight feet long. (“Prefabricated/Precast Bridge Elements and Systems (PBES) for Off-System Bridges - BDK83_977-13_rpt[1].pdf,” n.d.-b)

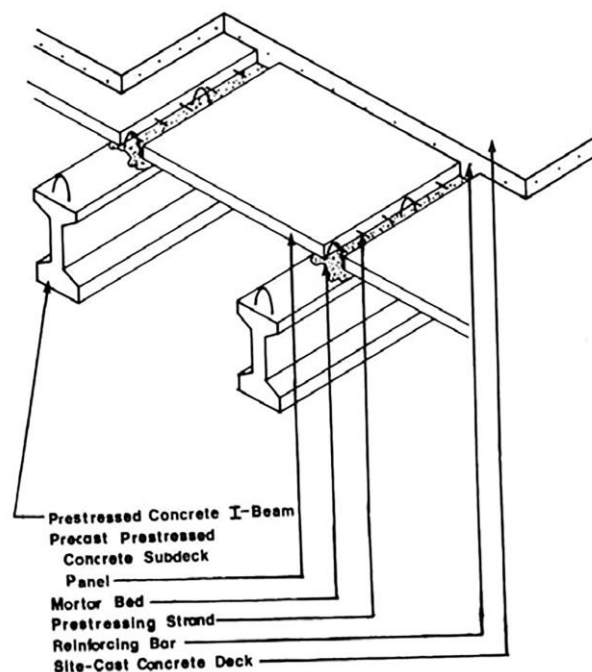


Figure 16 Typical precast/prestressed partial-depth deck panel (Sprinkel 1985)

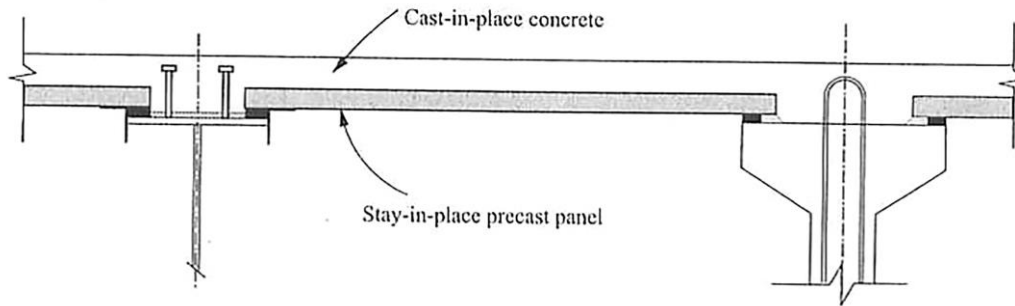


Figure 17 Typical partial-depth precast panel system (Tadros 1998)

Construction Sequence

Typical procedure for constructing a partial-depth precast panels are listed as shown below:

1. Grout are placed on the top of the girders' flange.
2. Use momentary supports to locate the panels until they are all grouted into place.
3. The panels are laid on top of girders (Figure 18).
4. A grout layer is placed between the bottom of the panels and the top of the girders' flange.
5. All previous steps can be done simultaneously with the deck overhangs formwork.
6. On top of the panels, the upper layer of reinforcement for the composite deck is being positioned (Figure 19).
7. Place concrete for the deck and allow it to cure.
8. Remove the formwork after reaching the required strength.

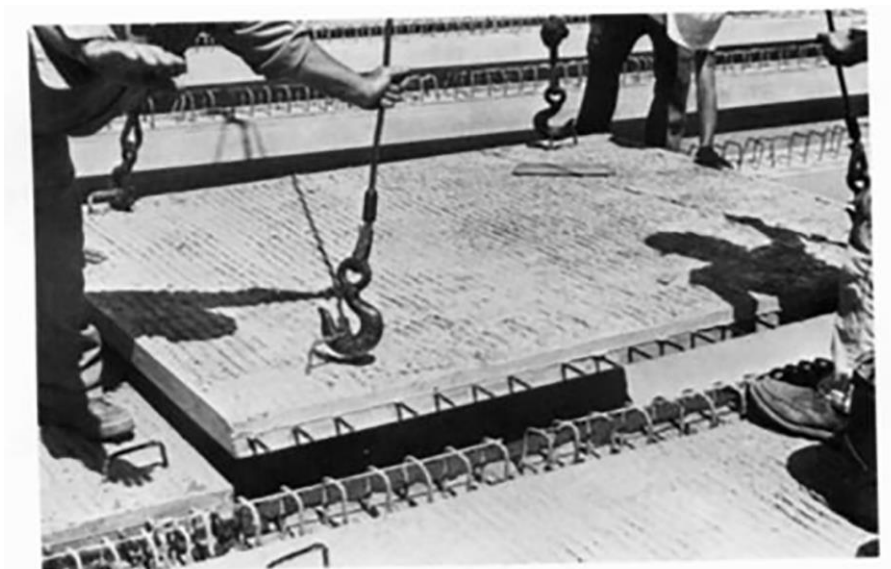


Figure 18 Typical partial-depth precast panel installation (Sprinkel 1985)



Figure 19 Top layer of reinforcing steel in place on top of partial-depth panels (WSDOT)

Substructure System

Precast Concrete Pier System

The precast pier system uses the collection of precast columns and the precast cap beam elements to basically make piers, whether it is a single-column or multiple column type of piers. Pier systems, however, are suitable for different type of foundations. The single elements in the pier system are attached to the other with mild reinforcing steel. Figure 20 displays an example of a single-column pier. In ABC, prefabricated pier components are used since it can be extremely challenging to form and place concrete on site. As a result, great amount of both time and money will be saved, which is one of the important traits of utilizing ABC. (“SPR-687: Analysis of the State of the Art of Precast Concrete Bridge Substructure Systems - AZ687.pdf,” n.d.)

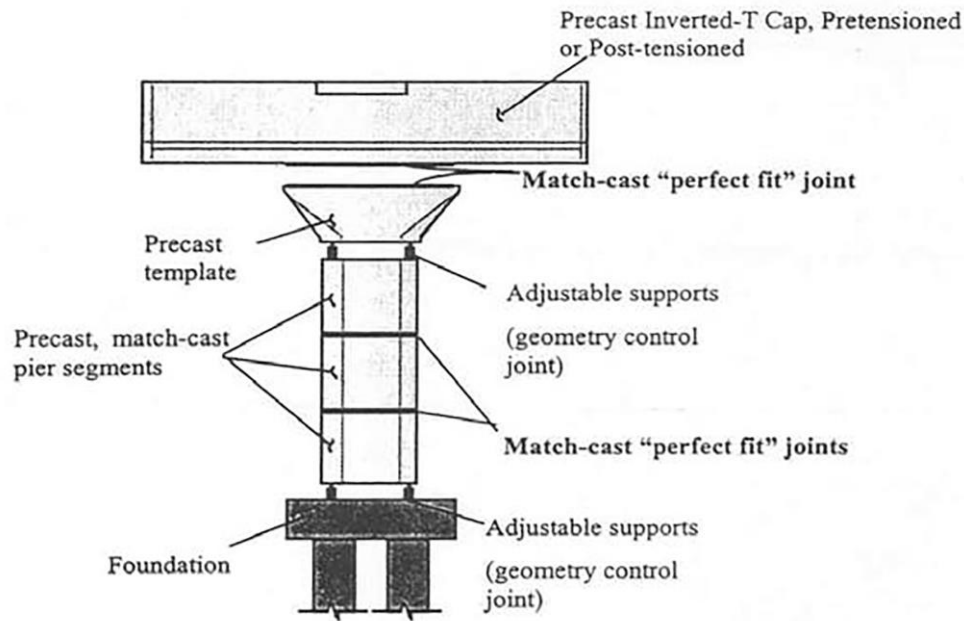


Figure 20 Single-column pier composed of precast concrete components (Billington et al. 1999)

Open Frame Bents

A precast pier caps and column is depicted in Figure 21. There are various types of connections used, however, components of open frame piers are usually joined utilizing grouted sleeve reinforcing bar couplers (Figure 22). ("Insecure Connection," n.d.)

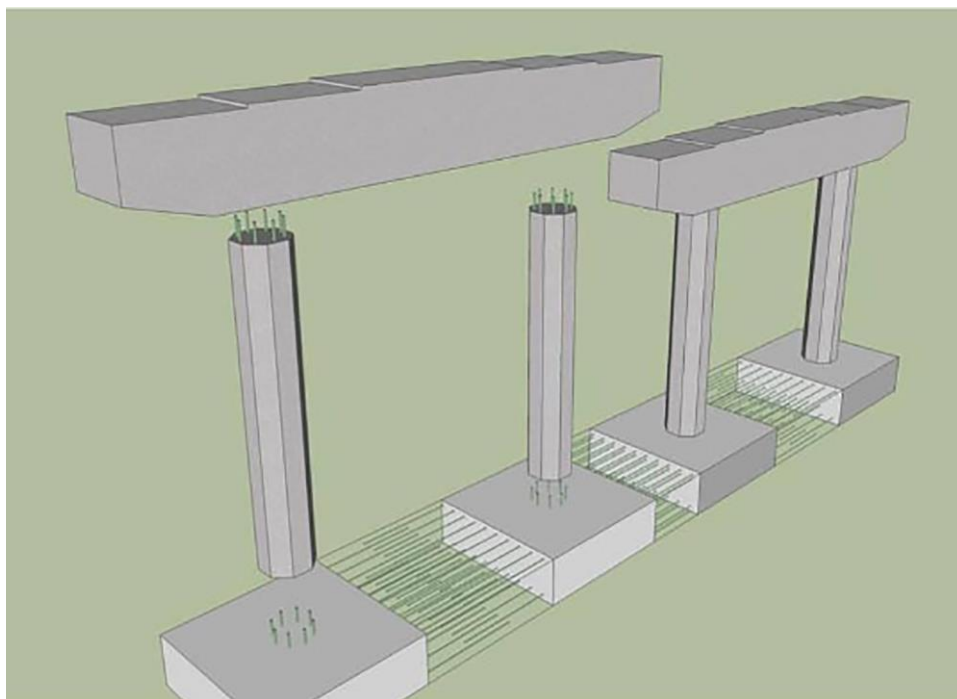


Figure 21 Precast Open Frame Bents (Federal Highway Administration)

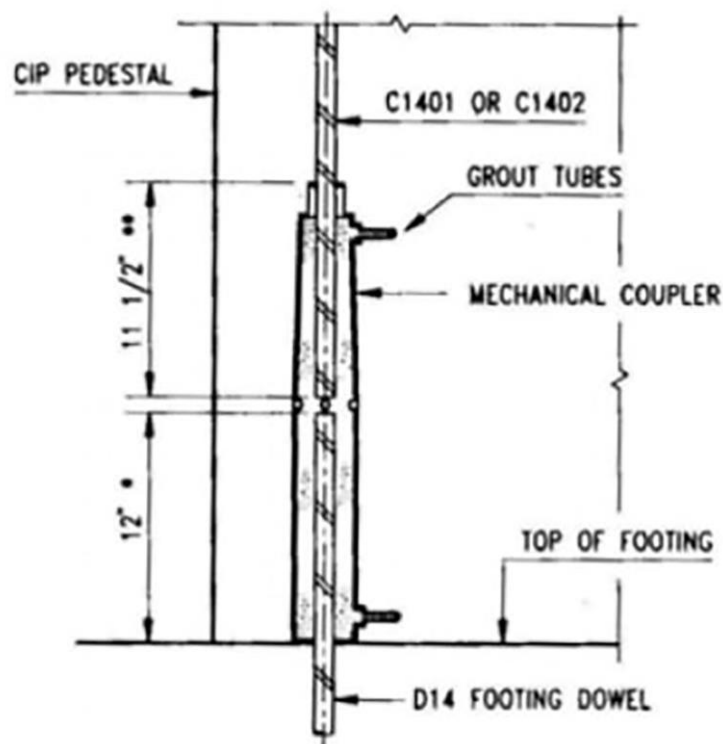


Figure 22 Grouted sleeve reinforcing bar couplers (IOWA DOT)

Building of precast concrete pier can be achieved fast. Utilizing precast concrete connection technology, a regular pier bent can be built within two days when the footings are in place.

Installation of Prefabricated Elements

There are various methods used to assemble the prefabricated elements of a bridge, depending upon its location and structural system. However, the most common methods used for ABC are the "Lateral skidding/Sliding" and "Self-Propelled Modular Transporters (SPMTs)". (Mahmoud, 2011)

Lateral Skidding/Sliding

When using this approach, a new superstructure is built on a temporary support alongside the old existing bridge. This technique allows the existing bridge to remain in service without causing any traffic jam in the area while the new one is being constructed. This method can be executed in two stages. The first stage includes building the substructure elements under the old existing bridge, as well as constructing the superstructure on the temporary support beside the old bridge (Figure 23) ("Garver - Engineering, Planning, and Environmental Services," n.d.)

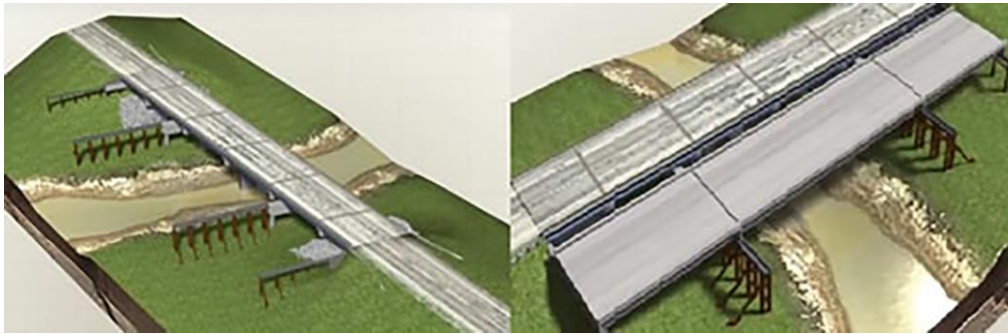


Figure 23 the First Stage of the Sliding Approach (GarverUSA)

The second stage requires closing the existing bridge in order to remove it, then pushing the new bridge onto the support structures, and finally implementing the needed pavement connections (Figure 24). (“An inside look at designing for Accelerated Bridge Construction (ABC) - YouTube,” n.d.)



Figure 24 the Second Stage of the Sliding Approach (GarverUSA)

Self-Propelled Modular Transporters (SPMTs)

SPMT is a collection of multi-axle platforms that works through a computer controlled system that can rotate 360 degrees as needed that can be utilized to lift, transport, and install the prefabricated bridges from an adjacent or off-site location to its final location (Figure 25). In case of bridge replacement, SPMTs can be used to remove the existing bridge.



Figure 25 Self-Propelled Modular Transporters (Federal Highway Administration)

SPMTs are motorized vehicles that move at walking speed. Using this unique technique can greatly reduce traffic disruption and improve work place overall safety. A typical SPMT unit has a total of four or six axle lines with four to eight number of tires per line. SPMTs can be pushed by an on-board hydraulic power pack, or as it is called, "Jack up System", that is connected to the hydraulic drive motors on several axes. Its capacity, however, is approximately 40 tones/ axle line. The most important requirement to use this distinctive method is not only having skilled workers, but also availability of location so it can be convenient to construct a bridge near location, it also requires a feasible route from the off-site location to its final location. ("Microsoft Word - Snabba brobyten och brobyggnationer_Final_II.docx - SBUF 12691 - Slutrapport Snabba brobyten och brobyggnationer.pdf," n.d.) Table 4 shows the traffic impact comparison between Conventional Bridge Construction and SPMT.

Table 4 The difference between CBC and SPMT ("AASHTO - AASHTO Innovation Initiative - Self Propelled Modular Transporters," n.d.)

Conventional Bridge Construction		
Work Operation	Duration	Traffic Control Method
Bridge Demolition	2-3 days per span	Detour
Beam Placement	25-90 minutes per beam	Rolling Roadblocks or detour
Form Placement	Varies	Lane shifts/closure
Deck Concrete Placement	1-2 days per span	Lane shifts/closure
SPMT		
Complete Span Removal or Placement	25 minutes to a few hours	Detour or single rolling roadblock

Traffic impact comparison between CBC and SPMT

Case Study: Accelerated Bridge Construction in Saudi Arabia

The construction industry in Saudi Arabia is one of the largest, if not the largest, markets in the Middle East. In fact, the Kingdom's construction sector contributes about 8% of the country's total GDP. ("Top 10 Saudi Arabian infrastructure projects," n.d.) The Saudi Government has invested billions of dollars throughout the years in upgrading its transport infrastructure.



Figure 26 the Location of Jeddah on the Map (<http://global.yamaha-motor.com>)

Jeddah is the second largest city in Saudi Arabia that is located on the West Coast of the country (Figure 26). People living in Jeddah are constantly burdened by traffic jams every day, especially during rush hours, as Jeddah's streets become gridlocked during heavy traffic times. These traffic jams, reflect not only on population growth, but also poor urban and transportation planning.(Saudi, n.d.) Therefore, Jeddah Municipality has been undergoing a series of bridge and tunnel projects all around the city in order to mitigate the suffocating traffic jams.(Nadim, 2014) Furthermore, and according to the Jeddah Municipality websites, there over ten bridges around the city that either need rehabilitation or replacement. Unfortunately, since the municipality has been using the conventional bridge construction in a crowded city like Jeddah, it can take months or even years to complete such projects. In fact, some bridge projects tend to be delayed for months due to various reasons. Consequently, utilizing the Accelerated Bridge Construction approach in this case is extremely vital. As a result, the municipality will be able to speed up the construction of bridges and greatly reduce traffic delays. One such case is Briman Bridge (Figure 27), which is considered to be one of the most important bridges in Jeddah since it is located on the road that connects Jeddah to the nearby city of Makkah, while additionally connecting the east and west sides of the City. This Jeddah-Makkah road is basically the artery road to thousands of commuters every day.



Figure 27 Briman Bridge in City of Jeddah (Google Map)

CBC vs. ABC of Briman Bridge

As the municipality of Jeddah traditionally prefers to work on the project, using the conventional bridge construction, the company responsible for the Briman Bridge replacement (which is about 131 feet long), will have to make a three-lane detour around the bridge. This is a very ineffective technique for that particular road since the main road is a four-lane road that becomes extremely congested during the rush hours.

Decision-making Methods

Implementing the decision-making flowchart procedures shown in Figure 8 to see whether prefabricated bridge approach is more economical and effective choice for the Briman Bridge in comparison to CBC. Note that the “Red” lines are the positive answered questions.

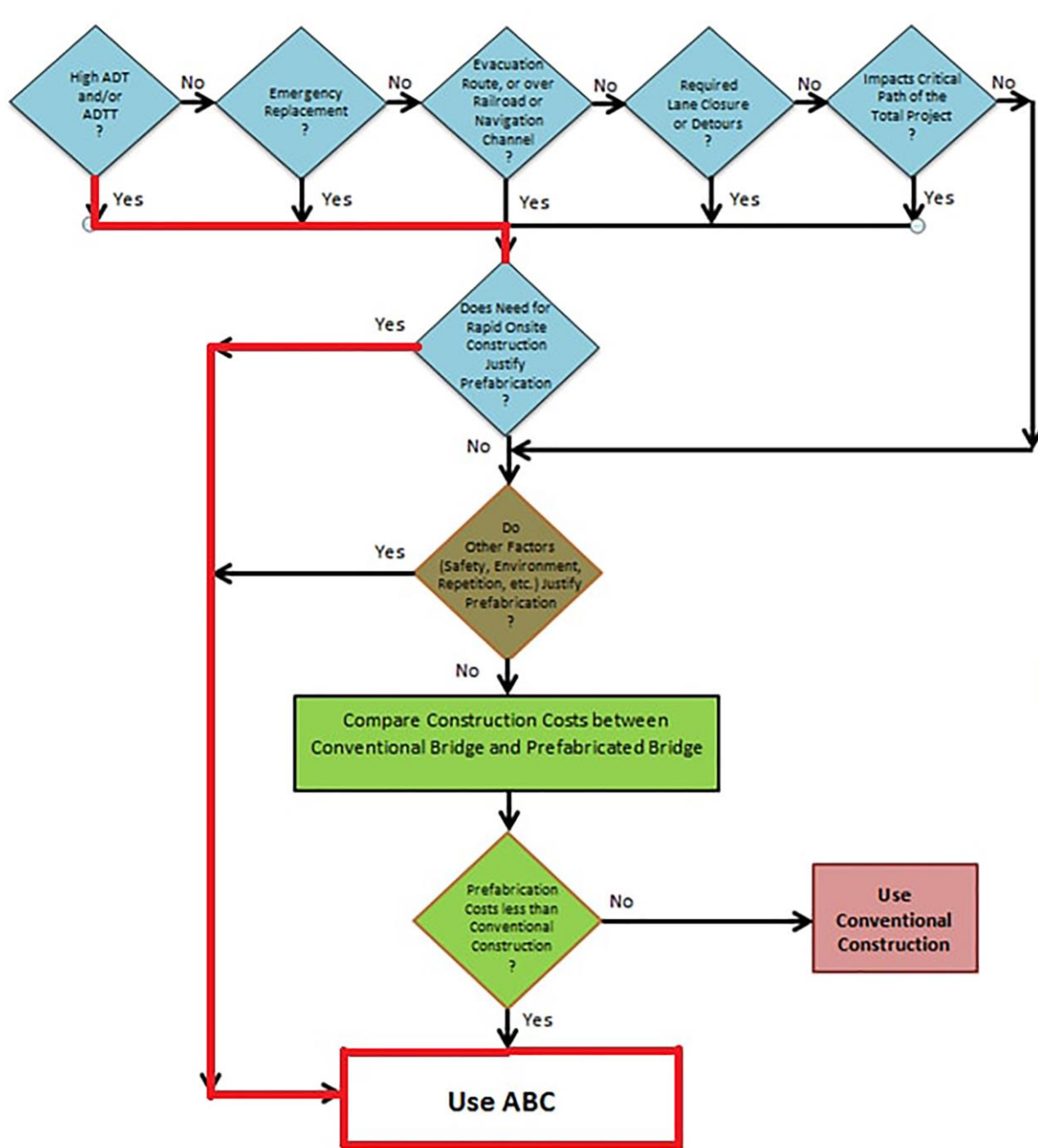


Figure 29 Decision-Making Flowchart for Briman Bridge

Applying the second method, as seen on the following table is important to consider (Table 1 and 2).

Table 5 Primary consideration for selection ABC for Briman Bridge

Important Primary Considerations for Selecting ABC	Maximum Points Based on Project Features	Advantage Point Using ABC	Advantage Points (Traditional Method)
Estimated duration and importance of early completion	15	15	5
Complexity, river location, or seismic vulnerability	15	8	8
Located on interstate/inter-country/local route	15	10	4
Feasibility of D-B management	15	14	14

Estimated cost of bridge & availability of funds	10	10	10
Bridge replacement or new bridge	10	10	4
Contractor's experience on similar projects	10	5	10
Span length, deck width, and number of traffic lanes	10	10	9
Total	100	82	64

Based upon the location, conditions, and criteria of the project, the ABC wins with a total of 82 points

Table 6 Secondary considerations for selection ABC for Briman Bridge

Important Primary Considerations for Selecting ABC	Maximum Points Based on Project Features	Advantage Point Using ABC	Advantage Points (Traditional Method)
Shallow foundation/piles/drilled shaft from soil report	7.5	7.5	7
Impact of construction on environment	7.5	7.5	2
Type of deficiencies outlined in inspection reports for rehabilitation	7.5	7	7
Demolition easy/difficult	7.5	7	4
Deck geometry straight/skew/curved	5	5	5
Feasibility of detour/kkane closure/use of temporary bridge during construction	5	4	3
SPMT length of girders	5	4	7
Maximum crane capacity	5	5	5
Precast deck panel sizes	5	4	3
HPC concrete strength	5	5	5
HPC girder strength	5	5	5
Precast concrete substructure stregh	5	5	3
Mechanically stabilized earthwork (MSE) wing walls/precast retaining walls	5	4	3
Easy access to site	5	3	3
Site office/easy mobilization	5	3	3
Availability of labor	5	2	5
Present/projected average daily truck traffic (ADTT)	5	5	4
General/extreme weather conditions	5	4	4
Total		87	78

Based upon the location, conditions, and criteria of the project, the ABC wins with a total of 87 points

Results

Thomas Kuhn, a prominent American physicist and philosopher of science, says “shifting one's paradigm requires personal change, and personal change requires hard work”⁶. Many people in the industry are just accustomed to the Conventional Bridge Construction (CBC) approach. In many cases, CBC could be

⁶ Thomas S. Kuhn (“The Structure of Scientific Revolutions,” n.d.)

much more preferable depending upon the site conditions. However, applying the Accelerated Bridge Construction (ABC) method can be beneficial for owner, builder, users, and the environment, especially in cases where the location of the project cannot stand long months of obstruction.

The following points are the results found:

- **Cost:** In terms of cost, the ABC method is the preferable approach. In many cases, owners do not have adequate capital to finance a project utilizing the ABC approach. In this case, the ABC would be the only reasonable choice.
- **Speed:** With regards to speed, ABC is considerably faster than CBC. In this case, if owners are capable of funding a bridge project utilizing ABC just to finish it fast, then this would be the perfect choice. For instance, the Briman Bridge in the City of Jeddah, which is located in a very critical area in the City. Jeddah municipality has the financial liquidity to fund this type of project. Therefore, selecting this approach would be ideal to avoid the impacts on people and the environment that will undoubtedly occur when utilizing the conventional approach.
- **Safety:** When working on transportation projects, it is crucial to have a comprehensive strategic highway safety plan in order to reduce potential accidents. Hence, it is very clear that when shortening the construction time we would greatly protect workers and will greatly help to reduce work-zone accidents. Therefore, ABC would be the best choice for the project.
- On top of prefabrication, ABC requires skilled labor who have experience in ABC projects and are able to get the job done from the start to end, as well as having the specialized equipment, without them, it is impossible to select ABC as an option for a project. In the example given above on the Briman Bridge project, Jeddah municipality may have not considered ABC in their projects due to lack of skilled labor and specialized equipment. However, this problem can be solved if they had reached out for international specialized corporations.

Conclusion

People involved in the transportation construction industry frequently seek safe, economical, and durable construction methods. Being stuck in traffic, losing time, gas, and money are all issues experienced daily by travelers during bridge rehabilitation projects that cause disturbance. These issues, however, have become some of the CBC method's traits. The majority of bridge replacement projects are located in heavy traffic areas, which often make it necessary to create detours or close bridges, which could negatively impact the flow of vehicles, and effect the community and the environment. Therefore, one of the most common methods to accelerate bridge construction projects is by utilizing prefabricated bridge components. These components can be constructed off-site or close by the site before placing it to the final bridge location. As a result, the traffic congestion will be greatly reduced, as well as saving time and money. Time, cost, quality, and safety are four significant factors in the planning, constructing, and controlling of any bridge project. Ultimately, when owners have the financial capability as well as skilled workers to conduct bridge replacement/rehabilitation projects in heavy traffic prone areas, using ABC would be the best option. On the other hand, when owners do not have the financial capability to pay extra cost for ABC, do not have skilled workers who are capable and highly competent of doing the work, or

when the location closure will not affect the traffic flow, then using the CBC method would be the ideal approach to use for optimal project success.

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Dedication

To my parents, whom I owe everything in life. There are no words that can truly express the level of gratitude and appreciation I have for you. I hope I always make you proud.

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