DEVELOPMENT OF GUIDE FOR SELECTION OF SUBSTRUCTURE FOR ABC PROJECTS

Quarterly Progress Report

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Submitted by:
PIs - Armin Mehrabi, Hesham Ali
Graduate Students - Mohamadtaqi Baqersad, Saman Farhangdoust

Department of Civil and Environmental Engineering
Florida International University
Miami, FL

ABC UTC

ACCELERATED BRIDGE CONSTRUCTION
UNIVERSITY TRANSPORTATION CENTER

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ABC-UTC
Florida International University
Miami, FL

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1 Background and Introduction

While much attention has been paid to means and methods of accelerated construction of the bridge superstructure, little has been done to provide proper guidance to designers and bridge owners on the selection of type, design and construction of the substructure. The primary objective is to provide guidelines for decision making by the designers and bridge owners for the selection of substructure and foundation for new bridges and replacement of existing bridges using the ABC methods, including evaluation, retrofitting, design, and construction. The project will include a comprehensive review of the current practice and compilation of available ABC methods for substructures and superstructures. This review should result in categorization of sub- and superstructures that are best match. Efforts will be divided into two major categories: new bridge construction and existing bridge replacement. An attempt will be made to identify issues and obstacles preventing the adoption of ABC substructures for bridge projects, and exploring solutions for facilitating a wider use of ABC substructure. Development of the Guide would rely on information from various sources including open literature, survey of experts and stakeholders, input of ABC-UTC Advisory Board members, and other domain experts nationally and globally. Information obtained from these sources will be reviewed and synthesized carefully and organized systematically. Gaps in the knowledge will be evident from this synthesis. This research project is a collaborative project between Florida International University and the Oklahoma University. FIU will focus its work on substructure and lead the development of the guideline, and OU will focus its activities on foundation related subjects and provide support to FIU on other tasks.

2 Problem Statement

The aim of accelerated bridge construction (ABC) is to reduce the impact of bridge construction on the public and bridge usage by reducing the construction time, especially when replacement of an existing bridge is involved. In addition to reducing construction time significantly, ABC has been found to enhance safety and reduce congestion. Although much work has been done in the past to investigate the design, configuration, and erection methods for bridge superstructure, very limited studies have addressed substructures and foundations (in this proposal "substructure and Foundation" and "substructure" are used interchangeably). Often, it is assumed that the bridge substructure and foundation are ready to receive the superstructure. Based on field experience, site-specific testing, design and construction of foundations and substructures can be the most time-consuming part of bridge construction. An informed and educated decision on the type of foundation and substructure may define the viability and economic feasibility of the entire ABC project. In the proposed study, the research team seeks to develop a Guide that can be readily used by practitioners for the selection of substructures and foundations for different ABC projects. The Guide will include parameters in design and construction of substructure and foundation including type, geometry, location, superstructure and bridge configurations, and design methodology. Issues related to construction of new bridges and replacement of existing bridges will be addressed including evaluation and strengthening of existing substructure and foundation for potential reuse. In addition to developing the Guide, the proposed study will identify gaps in existing knowledge and practice and make recommendations for future studies to address these gaps.

3 Research Approach and Methods

The primary objective of this project is to provide guidelines for decision making by the designers and bridge owners for the selection of substructure and foundation for new bridges and replacement of existing bridges using the ABC methods, including evaluation, retrofitting, design, and construction. The decision will depend strongly on the type and configuration of the superstructure intended for the bridge. From compatibility and conformity considerations, the decision on the type and design of both substructure and superstructure needs to be done concurrently. Geometric parameters such as span length, bridge width and bridge clearance are also important parameters in the selection of substructure type. This study may also review new types of substructures and/or closure joints and connection types for better performance and service life of the bridge. As noted in the Problem Statement, the evaluation of substructure and foundation of existing bridges for their structural capacity and functional adequacy and decision on reuse or replacement will be an important part of this study.

4 Description of Research Project Tasks

An overview of the study tasks is given below. The project is a collaborative effort with active participation of Florida International University (FIU) and Oklahoma University (OU).

4.1 Task 1 – Draft Outline

A draft outline of the Guide for the selection of substructure and foundation for ABC projects was developed collaboratively by the research teams at FIU and OU.

4.2 Task 2 – Conduct Literature Search on Topics Identified in the Draft Outline

A comprehensive literature search is underway on the topics identified in the guideline. To date, different component of ABC bridge components has been identified. A summary describing these components is as follows.

4.2.1 Definitions

ABC bridge components, in general, includes superstructure, substructure, and foundation subsystems (Figure 1). Superstructure refers to deck and girders and everything above the deck [1]. The substructure refers to elements that hold the superstructure like piers, abutments, and wing walls, basically, everything below the superstructure bearing and above the foundation. Foundation is a part of substructure that transfers loads from the bridge to the earth and strata, it can be shallow or deep, and includes footings, pile caps, piles, etc. The ABC bridge elements and components are connected to each other using joints and connections which normally are established in-situ [2, 3].

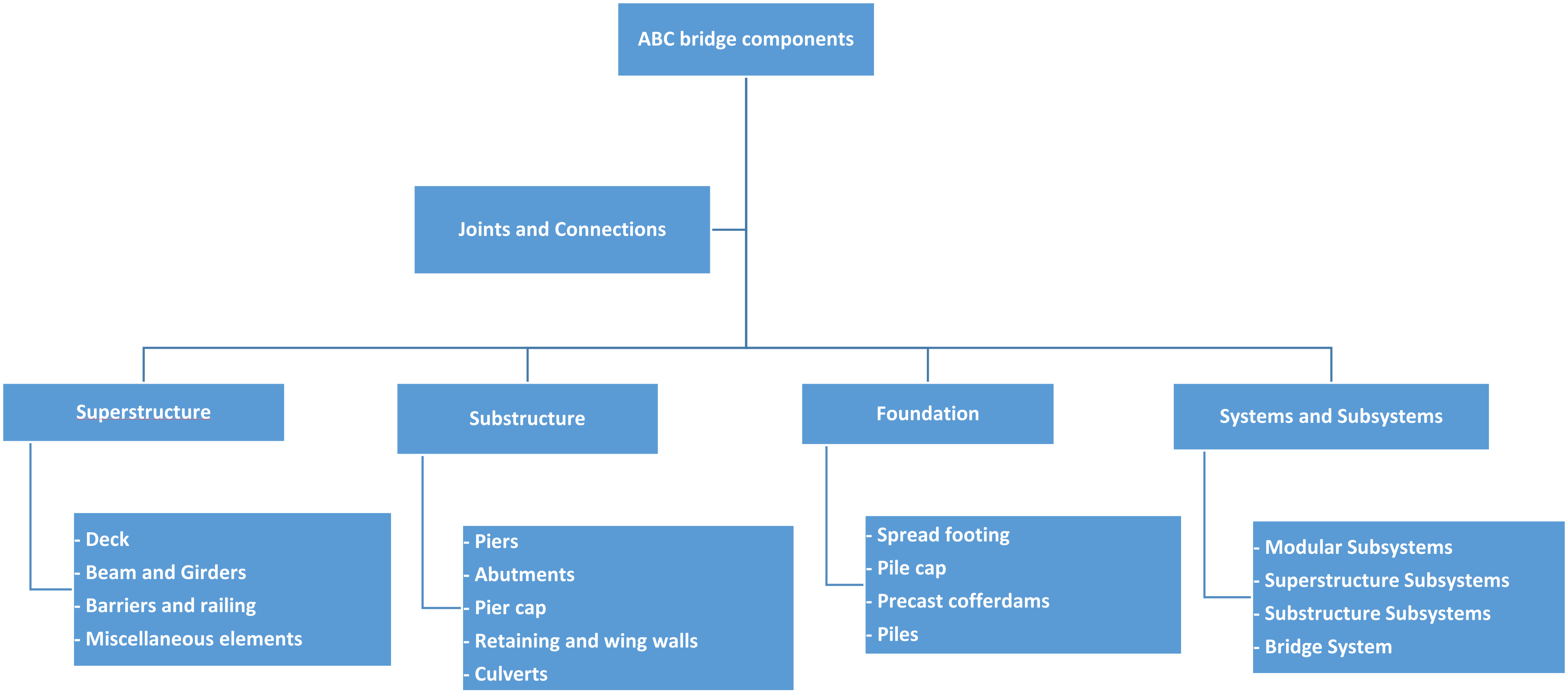


Figure 1: ABC bridge elements

4.2.2 Superstructure

The superstructure referes to all the parts that are above the bridge bearing and provide horizontal span. These elements carry loads from the deck span and provide the riding surface [4]. Superstructure includes girder and deck slab, miscellaneous elements, barriers, and railing. ABC bridge superstructure elements are listed in Table 1.

Table 1: Different ABC bridge superstructure elements

Element	Type	Comment
Precast Concrete Deck	Full-depth Precast Decks	Panels can be installed on steel or concrete girders
	Partial-depth Precast Deck	Panels can be installed on steel or concrete girders also to act as stay-in-place forms as well as part of the deck. Upper part of deck still needs to be cast-in-place
Cast-in-place Concrete Deck	Normally with Stay-in-place metal forms	Forms are supported by girders and facilitate casting without the need for scaffolding, therefore accelerating the construction
Other Deck Panel Types	FRP, Steel Grid, Exodermic, and Timber	Normally used for reducing dead weight for deck replacement projects.
Superstructure girders	Steel girders	Steel girders can have different shapes Main advantages is light weight
	Precast concrete girders	Different shapes of precast concrete girders includes I beam, U beam, Single and Double-tee beam, rectangular beam, voided slab, and box-shape beam
Modular systems	Modular steel systems	Different modular steel systems include multi-beams unit, modular steel folded plate girder system, and orthotropic steel deck system
	Precast concrete modular systems	Different precast concrete modular systems include double tees and decked bulb tees.
	Modular timber system	All the elements are prefabricated. The laminated girder deck system is installed on the top of timber or steel beam.
Other Systems	Entire width of superstructure w/wo miscellenous elements	The superstructure can be entirely fabricated off-site and moved to be installed on site
	Superstructure with part or entire substrcuture	The entire width of superstructure can be constructed along with part or entire substructure and moved or slid on footing

4.2.3 Substructure

Substructure elements transfer vertical and horizontal loads from superstructure to the foundation. Piers, pier cap, abutments, culvert, wing walls, and retaining walls are the substructure elements [1]. Substructure elements are summarized in Table 2.

Table 2: Different ABC bridge substructure elements

Element	Type	Comment
Substructure Piers or columns	Piers and pier bents	Vertical elements that support deck span Piers that consist of more than one column are called pier bent
	Wall piers	Used when the pier is affected by the errant vehicles
Abutments	Fully integral abutment	Whole portion of abutment is constructed with superstructure Abutment connection to the superstructure is a full moment connection
	Semi-integral abutment which	A portion of the abutment is constructed with the superstructure, Abutment connection to the superstructure is a pin connection
	Cantilever abutment	Constructed separately from superstructure
	Spill-through abutment	Constructed separately from superstructure It is a cantilever abutment with a large void in its stem
	Retaining wall and wing wall	Abutment extension to maintain the earth pressure in the approach embankment
Pier cap	Rectangular pier cap	Used when there is a precast girder or steel girder that can sit directly on top of the pier cap
	Inverted-tee pier cap	Used when there are precast girders
Culverts	Three sided culvert	Have a rectangular cross-section with varying wall thickness or have an arched structure.
	Box culvert	Has a rectangular cross-section
	Arched culvert	The precast strips are placed side by side to create the bridge span The arch culverts can be slid under the existing bridge without closing the bridge

4.2.4 Foundation

Foundation function is to transfer load from the abutment, pier, and wing wall into the earth and strata [1]. When the soil near the surface is adequately stable and can provide bearing for the bridge load, spread footing can be used as the bridge foundation. However, when the surface soil is not stable enough, deep foundation such as piles should be used under the footing to transfer the load under the surface of the soil to provide enough support to bridge loads. This section will be covered in more details by Oklahoma University.

4.2.5 Joints and Connections

In an ABC bridge construction, joints and connections are needed to attach the prefabricated elements to each other and between foundation, substructure and superstructure. The design and details of joints and connections in bridges that use prefabricated elements should at a minimum satisfy the same conditions as connections in cast-in-place bridges to provide enough durability and integrity for the structure [5].

Connections between Superstructure elements

Joints connecting deck elements are normally referred to as closure joints. “Emulating connection detailing” and design is used to make the precast structural elements behave as they are monolithic [6]. In summary, according to the joints configuration, the most common closure joints are categorized into five types [7]. These five categories are shown in Table 3. The first four shapes cover “linear” joints, and the last shape covers “blockouts”. Linear joints refer to longitudinal and transverse joints for connecting deck panels or decked beams to each other and to the girders, and connecting deck panels to the abutment/piers. Blockouts are pocket-type joints mostly for connecting deck panels to the girders [3].

In addition to the above common joints, other connecction types are also used for specific cases. For example, mechanical joints including welded and bolted connections are sometimes used for connecting panels to steel girder.

Connections between Substructure elements

Within a substructure, joints are used to connect columns, piers, or walls to a cap beam [3]. It is easy to access this connection for inspection. It can experience high shear and bending moment, especially during lateral loading, e.g., earthquake. In the longitudinal direction, it may experience high deformation due to thermal expansion of the deck slab. Connection of piers to pier cap can be accommodated using slots or sleeves in the cap to receive the extended reinforcing bars from pier, or a complete opening (socket) can be left in the cap to receive the bars [8]. Different types of connection between cap beam and column and between column and footing are summarized in Table 4 and Table 5, respectively. Also, the connections that can be used in between abutment elements and systems are listed in Table 6.

Table 3: Different type of closure joints [7]

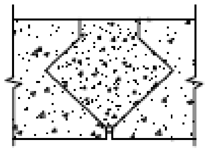
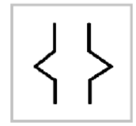
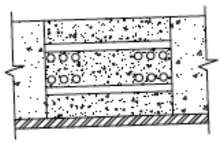
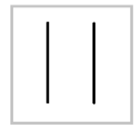
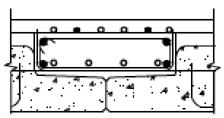
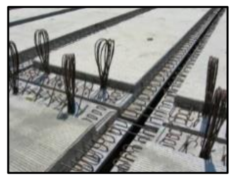
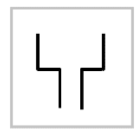
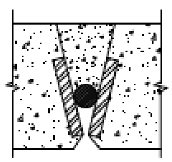
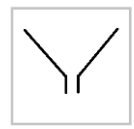
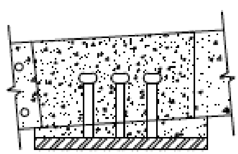
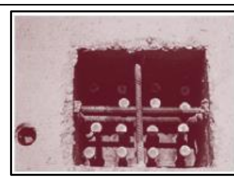
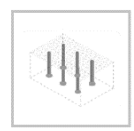
Group	Sample		Symbol
Type 1			
Type 2			
Type 3			
Type 4			
Type 5			

Table 4: Connections of cap beam and column

Type	Connection method	Usage
Formed in cap beam	Grouted sleeve	-Connect precast cap beam to cast-in-place or Precast (PC) concrete column
	Grouted pocket	-Connect precast cap beam and precast/cast-in-place concrete column -Connect precast cap beam and steel pile or column
Formed along the Columns	UHPC column segment	-Connect precast cap beam and precast concrete column
	Grouted sleeve	-Connect precast cap beam and precast concrete column
Other types	Welding	-Connect precast cap beam and steel pile/column
Cap beam segments	Closure pour	-Connect precast cap beam segments

Table 5: Connections of column and footing

Type	Connection method	Usage
Formed along the column	Grouted sleeve	- Connect precast concrete column and cast-in-place or precast footing
	Mechanical couplers	- Connect cast-in-place footing and precast column
Formed in footing	Grouted Pocket	- Connect precast column and precast or cast-in-place footing
Column segments connection	Closure pour Grouted sleeves mechanical couplers	-Connect precast column segments

Table 6: Abutment systems connections

Connection type	Comment
Closure pour, grouted pockets or sleeves	-Connect abutment elements -Connect abutment to superstructure
Grouted Sleeve/Splice couplers	-Connect all types of abutment elements
Grouted Pocket Connection	-Connect abutment stem or cap directly to steel piles or precast concrete piles
Welded Plate Connection	Connect steel piles to abutment
Steel bar dowels connection	-Connect pile cap and integral abutment
Small closure pour	-Connect abutment segments

Connections between foundation elements

This section will be covered by OU.

4.3 Task 3 – Identify Stakeholders and Conduct Survey

The FIU and OU research team members will work collaboratively among themselves and with the ABC-UTC leadership to identify stakeholders for this study. The stakeholders would include, but not limited to, state DOTs (bridge divisions, construction divisions, and maintenance divisions), bridge designers, contractors, academic institutions, and TRB committees. A survey of the stakeholders will be prepared and conducted to identify existing practices that are not available in the open literature (Task 2). Online instruments such as Survey Monkey and Google Frame could be used in conducting the survey. Statistical analyzes of results (for multiple choice questions) are automatically conducted by these instruments. This task will be performed collaboratively by FIU and OU.

4.4 Task 4 – Analysis of Literature Search and Survey Results

Information from the literature search (Task 2) and the survey (Task 3) will be analyzed carefully to document existing practices, best practices, issues, and other important factors such as cost, service life, construction/retrofitting time, and durability. Outcomes of this task will be instrumental to the development of the Guide. FIU will focus on substructure and OU on foundation.

4.5 Task 5 – Identification of Issues and Potential Solutions

Findings of Tasks 3, 4 and 5 will be used to identify the issues related to design and implementation of ABC substructures and foundations and the knowledge gaps. They will also help identify issues hindering the design and use of ABC substructures. To the extent permitted by the scope of this project and the limited budget, solutions to these issues will be explored by the FIU and OU research teams. FIU will focus on substructure issues and OU on foundation issues.

4.6 Task 6 – Develop Draft Guide

Based on the outcomes of Tasks 1 through 5, a draft Guide will be compiled and submitted for review by the Advisory Panel. The draft will be revised based on the review comments. FIU will lead this task with the support from OU.

4.7 Task 7 – Final Report

A comprehensive final report will be prepared and submitted. In addition to discussing the Guide, the process used in the development of the Guide will be included. FIU will lead this task

5 Expected Results and Specific Deliverables

5.1 ABC-UTC Guide for Selection of Substructure and Foundation for ABC Projects

The main deliverable for this project is a Guide for selection of substructure and foundation for ABC projects.

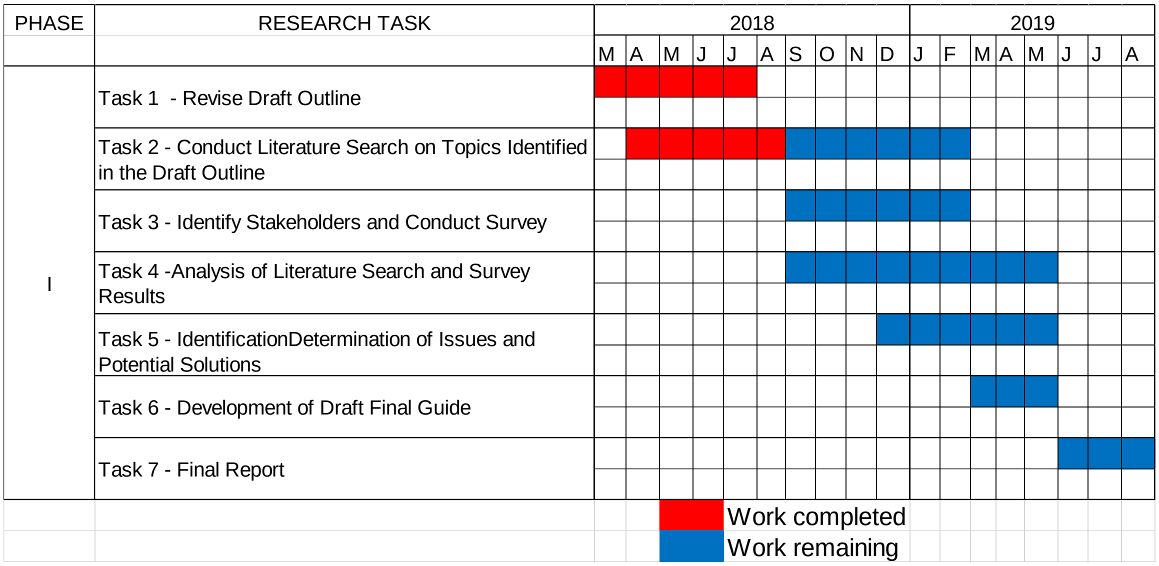
5.2 A five-minute Video Summarizing the Project

A short video will be prepared describing the guide developed in this project.

This research work and the Guide to be developed are directly applicable to the selection, design, and construction of ABC projects, including new bridges and replacement of existing bridges. Designers, bridge owners, and other stakeholders should be able to use this Guide to determine the substructure that best serves their purposes.

6 Schedule

The bar-chart below shows the schedule and work progress.



7 References

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