DEVELOPMENT OF GUIDE FOR SELECTION OF SUBSTRUCTURE FOR ABC PROJECTS

Quarterly Progress Report

For the period ending February 28, 2019

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ACCELERATED BRIDGE CONSTRUCTION
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Submitted to:

ABC-UTC
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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 and flowcharts to help selecting the substructure elements for construction of new bridges using ABC technique has been developed as reported in the previous progress report. Also, the methods and procedure using in evaluation of existing bridge foundation and substructure has been reviewed and a summary describing the evaluation methods is as follows.

4.3 Existing Bridge Replacement

According to the National Bridge Inventory data for bridges in the US in 2016, 9% of the bridges were in poor condition, 15% had service life older than average design life of the bridge, and 9% of them needed urgent strengthening or rehabilitation [1]. These data is indicative of the necessity of bridge maintenance, construction, and rehabilitation. One common method in improving the bridge performance is demolishing the existing bridge and construction of a new bridge. However, this method is expensive and is not a favorable option in urban areas where there is high congestion. New bridge construction can cause significant mobility and traffic problems. To address this issue, other options become more attractive that include retrofitting or strengthening of existing bridges, reuse, or partial replacement of existing bridges. To select the proper method to improve the life and performance of an existing bridge, a precise and comprehensive evaluation of existing bridges is needed. The bridge evaluation may well discover that some parts or subsystems of the bridge, such as foundation and/or substructure, are in good condition and only replacement of superstructure is necessary. The benefit of foundation and substructure reuse is the time and cost saving especially in urban and populated areas.

The Federal Highway Administration publication on the "Foundation Reuse for Highway Bridges" has defined the reuse of bridge substructure or foundation as "use of existing foundation or substructure in whole or part, when existing bridge has been evaluated for new loads" [2]. FHWA definition for reuse of foundation includes reuse of substructure and foundation above and below ground, or rehabilitation of existing substructure and foundation when superstructure has been determined to be replaced or otherwise optimized by reduction of superstructure dead load with the use of lightweight elements or other methods. Also, the foundation reuse may occur when widening of bridges or strengthening and retrofitting of foundations are included among the options. Following sections related to replacement of existing bridges are adopted from FHWA Foundation Reuse for Highway Bridges, let it be with some modifications. Figure 1 shows four options introduced by the FHWA publication [2] that may arise when considering bridge replacement;

- Option 1, existing foundation is discarded, and a new foundation with new alignments is constructed.
- Option 2, existing foundation alignment is kept, but a new foundation/substructure is installed. In this case, the demolition of substructure is needed.
- Option 3, existing foundation is reused with no or minor modification or strengthening.
- Option 4, foundation is reused with some form of modification, retrofitting, or strengthening.

As described, Options 3 and 4 are foundation reuse.

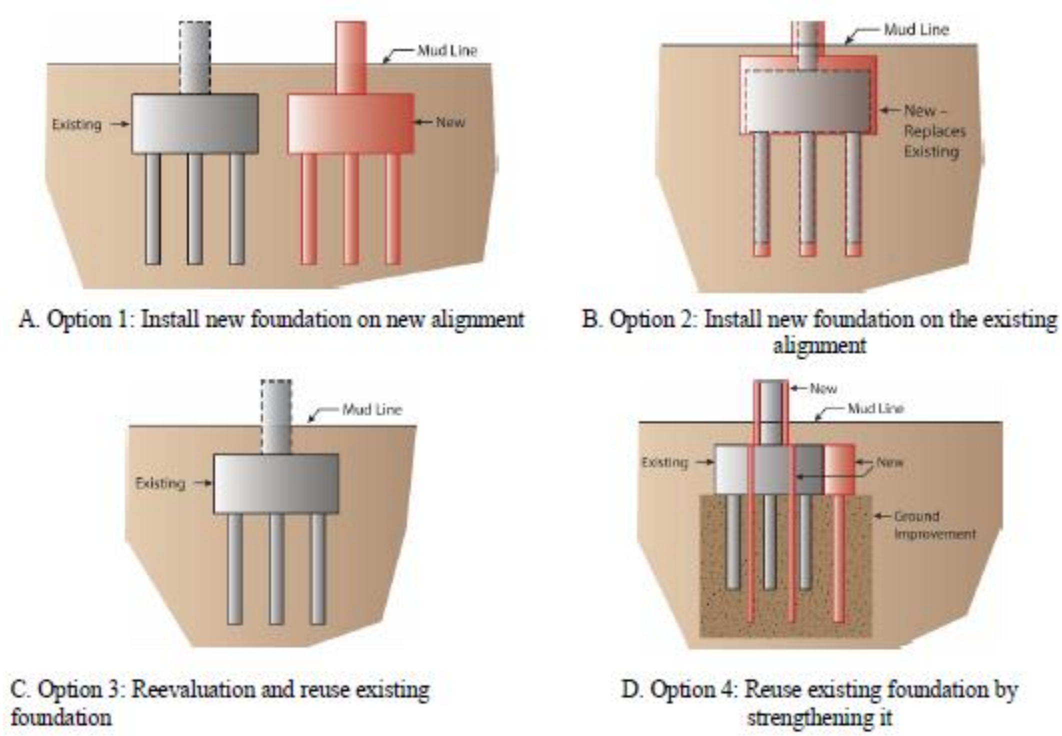


Figure 1: Foundation replacement and reuse options [2]

According to the Sustainable Project Appraisal Routine (SPeAR®) study, eight factors should be considered to decide whether reuse of foundation is an option [3]. These factors are;

- Site location,
- Archeology and historical constraints,
- Geological constraints and conditions,
- Material reuse and sustainability,
- Land value and cash flow,
- Construction cost,
- Consistency in location, and
- Risks.

4.4 Evaluation of Existing Substructure for Potential Reuse

An exhaustive bridge evaluation should be conducted to first determine the remaining service life of bridge components. The substructure components of bridges are wall piers, columns, abutments, wing walls, and pier caps. These elements can be constructed from reinforced concrete or steel. The durability and remaining service life assessment of bridge components is categorized in three stages as shown in Figure 2.

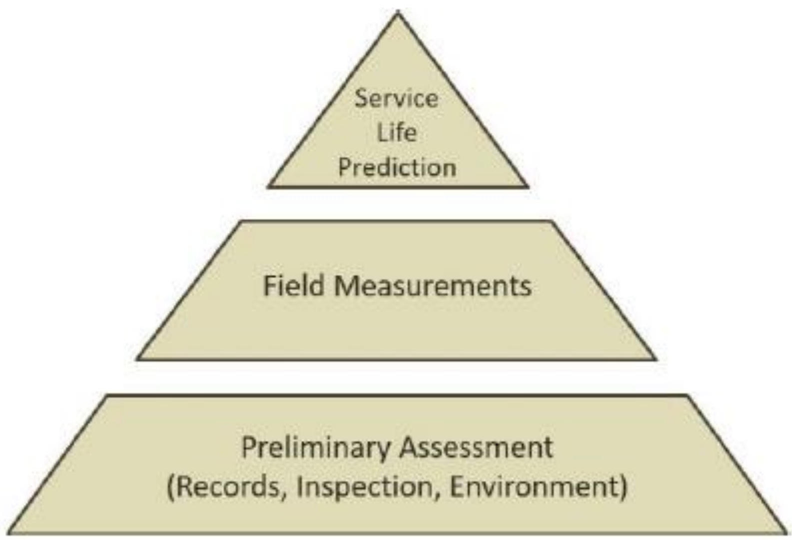


Figure 2: Durability and residual service life assessment of bridge substructure [2]

In the preliminary assessment, the previous performance issues, environmental conditions, and concerns related to the durability of a bridge are investigated. This assessment is playing an essential role in providing an appropriate plan for further inspections and tests as well as repair type and extent. The preliminary assessment and procedure are summarized in Table 1.

Table 1: Preliminary assessment procedure [2]

Evaluation Procedure	Reason/Outcomes
Records Review	Review of past inspection history allows for assessment of the time history of bridge performance
Environmental Conditions	Environmental conditions at the bridge dictate the types of deterioration expected. Important aspects to consider are: exposure to deicing salt, exposure to salt water, fresh water, contaminated soil or water, humidity, stray currents, or freeze/thaw conditions
Visual/Physical Survey	Document extent of cracking, signs of rust staining or efflorescence, erosion of concrete paste, and extent of spalling. Locate delaminated areas using hammer sounding and physical methods. Generally, overlaps with integrity assessment in finding the current condition of the concrete.

4.4.1 Concrete Elements Testing

The aim of durability testing plan for reinforced concrete members is to identify the extent and depth of cracks, reinforcement's corrosion, extent of carbonation and chloride penetration into the concrete cover. The typical factors need to be evaluated to define the durability of concrete elements are summarized in Table 2. Also, the tests to be conducted to assess the concrete elements degradation factors are listed in Table 3.

Table 2: Field testing related to the concrete elements [2]

Available Testing	Issue identified during preliminary evaluation	Notes
Cover Measurement	Corrosion, chloride exposure, carbonation	Determine cover thickness important to evaluation of other durability issues.
Chloride Testing	Exposure to chlorides	Determine profile of chloride diffusion into cover concrete. Initial chloride testing can be limited to surface and depth samples, to ascertain the magnitude of bound and unbound chlorides
pH testing	Carbonation	Perform pH testing on extracted cores to determine depth of carbonation penetration
Half-cell potentials	Active corrosion	Perform half-cell potential testing in areas of suspected corrosion
Electrical Resistivity	Potential for corrosion	Useful for finding areas of corrosion or areas susceptible to corrosion

To evaluate a concrete element susceptibility to chloride, carbonation, corrosion, and other degradation substances, cover depth of concrete elements is needed to be measured [2]. It is possible to find the cover depth of an element from the drawing design plan. However, there are differences between the actual depth and design plan. Also, it is possible that the cover depth of element may change along with the length of element. In this case, the actual cover depth can be detected using ground penetration radar (GPR) or covermeters. These tests should be conducted in different parts of member length to define the rebar location and the minimum cover depth along the member length (Table 3).

Table 3: Durability tests of concrete elements

		Comment
Cover depth	Ground Penetration Radar (GPR)	Radar reflection, Cover more area,
	Covermeters	Eddy current detection, Less affected by moisture and voids
Concrete cover delamination	hammer sounding, steel rod off the surface, impact-echo, ultrasonic pulse responses, wall climbing robots, infrared thermography	Delamination survey, ASTM D4580
Corrosion	Half-cell	Location of corrosion ASTM C876
Porosity	90-day ponding test	AASHTO-T-25
Chloride ingress	Electrical method	ASTM C1202
	Acid-soluble test	ASTM C1152
	Water-soluble test	ASTM C1218
Carbonation Susceptibility	SHRP-S-329	Air permeability CO^2 ingress resistance
	phenolphthalein test	Ph indicator
Freeze/Thaw	Petrography	
	Temperature measurement	

Furthermore, the commonly used NDT technics for concrete elements are summarized in Table 4. As shown, these are the Ground Penetration Radar (GPR), Ultrasonic Pulse Velocity (UPV) and tomography, infrared thermography, Electrical Resistivity (ER), radiography, rebound hammer, Impact Echo (IE), Spectral Analysis of Surface Waves (SASW), Sonic Echo (SE), Impulse Response (IR), Bending wave, and Ultraseismic (US).

Table 4: NDT technology for concrete elements

NDT Method	Issues Investigated
Ground Penetrating Radar	Rebar layout, voids, cover depth
Ultrasonic Pulse Velocity and tomography	Location of voids, weak zones, honeycombing, and cracks
Infrared Thermography	Location of voids and delaminations
Electrical Resistivity (ER)	Presence of water, chlorides, and salts
Radiography	Location of voids and condition of tendons and strands
Rebound Hammer	Surface strength of concrete
Impact Echo/Ultraseismic/Parallel Seismic	Location of defects and voids in piles

4.4.2 Testing for Steel Elements

Most of steel member evaluation is based on physical assessment and inspection that are conducted periodically. When field evaluations for steel members or portion of them that are underwater or underground is performed, test pit excavation is needed to drive a core and evaluate the exposure of steel members directly. Care should be taken not to damage the foundation during excavation and coring [2].

Furthermore, the commonly used NDT technology in steel elements to detect flaws are Dye Penetration Testing (PT), Magnetic Particle Testing (MT), Eddy Current Testing (ECT), Ultrasonic Testing (UT) and Phased Array Ultrasonic Testing (PAUT), and Acoustic Emission (AE) [2]. The usage of these technologies is summarized in Table 5.

Table 5: NDT technology for steel elements

NDT Method	Comment
PT	Detect cracking and surface flaws
MT	Detect surface breaking cracks
ECT	Detect flaws, material, and coating thickness
UT and PAUT	Detect surface and undersurface flaws
AE	Monitor cracks grow

4.5 Structural capacity

The structural capacity of foundation and substructure of bridges are assessed based on the durability and integrity evaluation and is required to ensure safety and capacity for reusing them in the construction of a replacement bridge. The capacity assessment of bridges determines the available capacity of foundation and substructure and follows the updated AASHTO LRFD standard and state DOT guideline [2].

In the structural capacity assessment, the following should be addressed [3]:

- Verifying the original design capacity
- Determining LRFD capacity for foundation originally designed using ASD or LFD
- Determining if increased nominal capacity is available
- Determining whether the capacity has been reduced due to deterioration

4.5.1 **Modeling and Analysis**

Different approaches of modeling and numerical simulation is used to determine the forces, moment, and stresses that a bridge structure experience, including determination of loads that the substructure/foundation should carry. The available methods are listed in Table 7. As shown, for purposes of approximate analysis, Finite Element (FE) analysis, p-y curve, and wind tunnel testing can be carried out to identify the behavior of structures [2].

Table 6: Modeling methodologies for bridge structures [2]

Modeling Methodology	Advantages	Disadvantages	Notes
Approximate analysis	Simple, based on basic engineering knowledge, finds forces/moments in the substructure elements	Cannot account for non-linear soil contributions, or complex geometry	Generally good as a first estimate of loading on the structure and soil. Can be difficult to account for behavior of soil.
Finite element analysis	Allows input of entire system, including soil and wind, can be non-linear, allows input of structure to help determine actual forces going into substructure elements	Can be computationally expensive for large bridge, may require many hours of input, requires knowledgeable staff to create model, requires knowledge or estimation of many material properties	FEA models can be of entire bridge system, or individual substructure elements. Can include non-linearities if needed, although at increased model complexity.
P-y curves (and T-Z, T-Θ, Q-Z)	Simplistically includes soil behavior, can be applied to FEA models, reduces computational cost while approximating soil behavior	Requires experience, difficult to apply to large diameter piers in deep soil	Simplifies input of soil behavior through non-linear springs. Linear springs can be used if they appropriately approximate the soil behavior in the load case being considered.
Wind tunnel testing	Accurate estimation of wind forces acting on superstructure and substructure	Expensive, time consuming	Allows determination of wind forces transferred to substructure using scale models. Generally, only used for signature bridge with unique profiles and complicated wind analysis.

4.5.2 **Functional adequacy**

The decision regarding demolition, replacement, or rehabilitation of an existing bridge should be conducted according to the structural capacity and functional adequacy of the bridge. Engineering analysis is performed to support the design expectations. The engineering analysis may verify the bridge integrity and capacity structurally. However, the bridge may be still functionally obsolete and fail to serve its main purpose. Several factors may make the bridge functionally obsolete for traffic demand. These include insufficient number of lanes, narrow lane widths, inadequate vertical clearance for traffic on the bridge and crossing under the bridge, and inadequate shoulder width. Bridges that are occasionally flooded can be classified as functionally obsolete [4]. This situations may require major improvements in bridge function including retrofitting and modification such as widening of bridges to accommodate its future needs.

4.6 Integrity and remaining service life

The geotechnical and structural stability and integrity check for bridge components are required to assess for potential reuse. Figure 3 illustrates the required integrity assessment steps for components of bridges constructed from concrete or steel [2]. The integrity assessment of steel and concrete components are reviewed in this section.

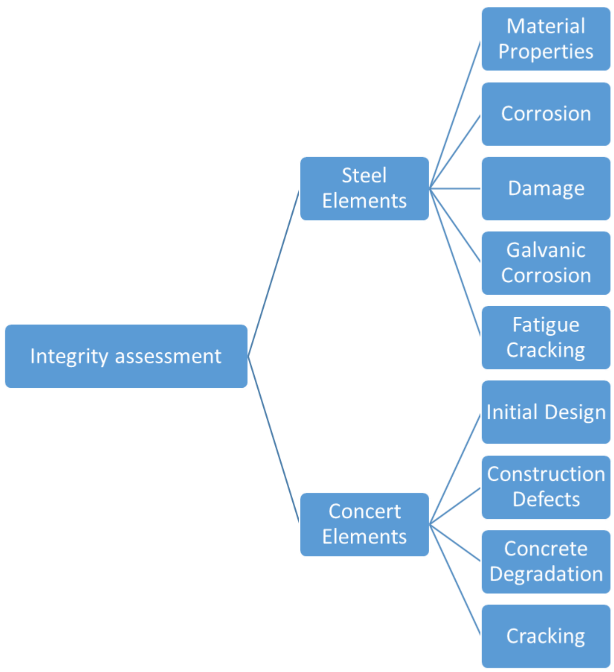


Figure 3: Aspects of Integrity assessment

4.6.1 Integrity of concrete elements

The reinforced concrete is commonly used in the construction of pier wall, abutment wall, column, pier cap, piles, and shafts. Since concrete can bear very low tensile strength, the reinforcing bars are used in the concrete elements to increase the tensile strength of the elements. Concrete can provide compressive strength as well as providing cover for the rebar to prevent their corrosion. Due to loads or deterioration, the concrete cracks which can expose the rebar and cause corrosion. In fact, the rebar corrosion is the main control factor for the service life of the concrete elements. This factor was discussed in the evaluation of service life of reinforced concrete. Another aspect of concrete elements is integrity evaluation. Concrete elements integrity assessment is summarized in Table 7 and includes, initial design, construction defects, degradation, damage, and cracking of concrete elements.

Table 7: Concrete elements integrity assessment

Concrete elements integrity	Aspects	Comment
Initial Design	Mix properties	W/C ratio, aggregate details porosity, etc.
	Compressive strength	Unconfined compressive strength Test to ensure strength Core test or NDT tests
	Reinforcement layout	Bar size, lap splice length, transverse reinforcements, GPR, radiography, or covermeter tests
	Reinforced strength	Detail from design drawing or perform test on samples removed
Construction issues	honeycombing	Mixing problem, poorly sized aggregate, decrease in paste bonding
	Weak zones	Improper mixing, higher w/c rate, lower compressive strength
	Cold joints	Discontinues plane
	voids	Flowing of cement around rebar, decrease in nominal capacity of element
Concrete degradation and damage	Freeze-thaw	Trapped water freeze, expand water in element
	ASR	Sufficient ASR cause durability and integrity problem
	DEF	Cause cracks, poor construction quality
	Sulfate attack	Submerge elements problem
	Paste erosion	Exterior face erosion
	Calcium leaching	Loss of cement paste
	Fire damage	Cracks, buckling of rebar
Cracking	Early age cracking	Cracks during curing process
	ASR, DEF, freeze-thaw	Cracks due to improper mix design
	Flexural and shear cracks	Initiated in tensile area of members
	Foundation movement	Create tensile stress
	Seismic events	Create ground movement and overload
	corrosion	Rebar corrosion

4.6.2 **Integrity of steel elements**

The steel elements integrity assessment summarized in Table 8. Design drawing can provide enough information about different aspect of steel elements including yield and ultimate strength. However, if there is uncertainty about the design drawing report, the yield and ultimate strength of sections should be obtained by testing.

Table 8: Steel elements integrity assessment

Steel elements integrity	Aspects	Comment
Material properties	yield and ultimate strength	Design drawing information, Test for uncertainty
Corrosion	Capacity problem	Where and how much corrosion, in wet areas
Galvanic corrosion	Capacity problem	Where two metals connect to each other
Damage	Permanent stress	Seismic loads
Fatigue cracking	Prone to failure	Shera or tensile stress in connections

4.6.3 **Hydraulic issues**

The changes in the hydraulic condition of bridges can induce or change the loads to the existing bridge substructure and foundation during its service life, and their impacts should be considered when reuse option is being considered. These changes may impose certain loading to the bridge never experienced in the past. The hydraulic changes can be related to rise in the sea level or precipitation. Hydraulic changes may also stem from changes in the code, such as consideration of a different flood return period. Aside from changes in the hydraulic loading, bridge scour is the main consideration for damages to the foundation and changes in the loading [2].

4.6.4 **Seismic considerations**

The seismic evaluation of a bridge structure is conducted using C/D (capacity/demands) ratio. When this ratio is over or equal to 1, it shows that the element and structure have sufficient seismic capacity to resists seismic displacement and force [2]. The demands consist of displacement demand and force/moment demand. The displacement demand is evaluated using pushover analysis by considering the nonlinear behavior of materials and elements to define the ductility of bridges and elements. The force/moment demand estimates the actual forces and loading that the bridges and elements experience.

4.6.5 **Other Considerations**

Other consideration and hazards that should be considered in evaluation of existing bridges for potential reusing include wind loads, impacts loads, fire damages, ice and debris flow, and blasts. These potential hazards need to be considered depending on the condition and location of the bridge.

5 Task 3 – Identify Stakeholders and Conduct Survey

A survey was prepared and was distributed among state departments of transportations through AASHTO Committee on Bridge and Structures. The survey was designed to identify existing practices, selection processes, parameters affecting selection, and issues and challenges that are not available in the open literature (Task 2). Online instrument named Cualtrics was used in preparing the survey. Statistical analyzes of results (for multiple choice questions) can be automatically conducted by this instrument. This task is ongoing collaboratively by FIU and OU. The summary of survey questions are attached in the appendix.

6 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.

7 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.

8 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.

9 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

10 Expected Results and Specific Deliverables

10.1 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.

10.2 A five-minute Video Summarizing the Project

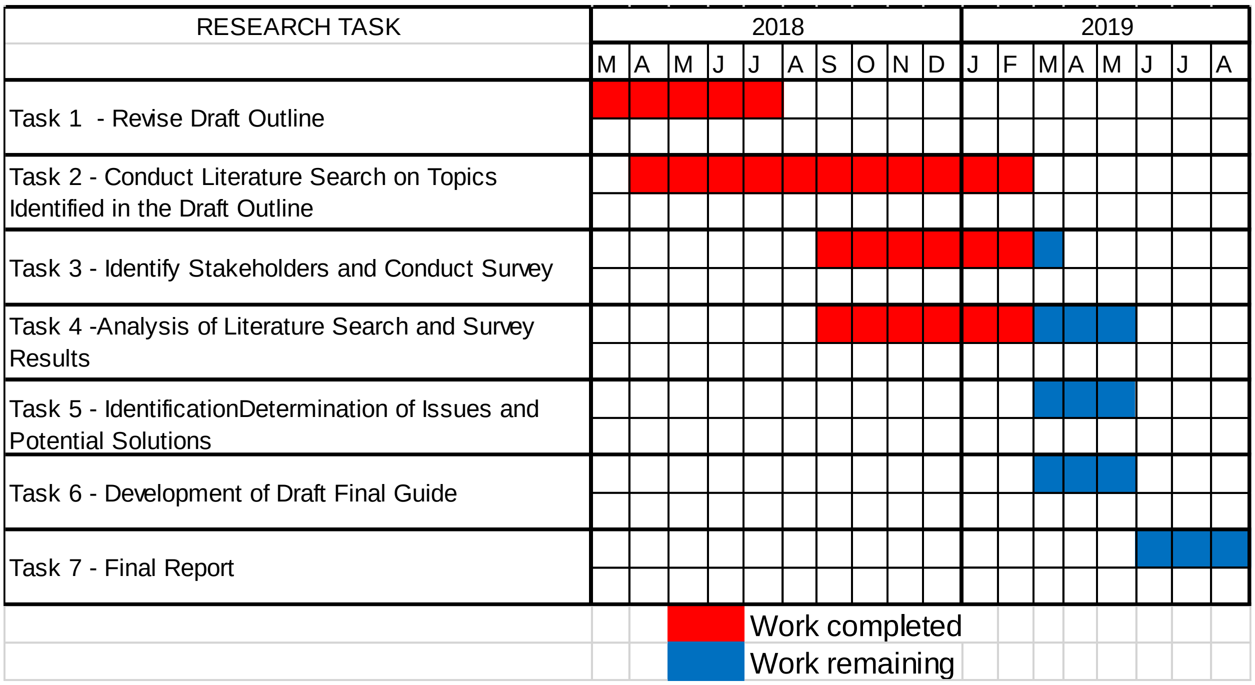
A short video will be prepared describing the guide developed in this project.

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.

11 Schedule

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



12 References

1. AASHTO, *Manual for Bridge Evaluation*, in *American Association of State Highway and Transportation Officials*. 2016: Washington, D.C.
2. FHWA, *Foundation Reuse for Highway Bridges*, in *Infrastructure Office of Bridges and Structures*. 2018, Federal Highway Administration, FHWA-HIF-18-055,.
3. Strauss, J., et al., *Drivers Affecting the Frequency of Foundation Reuse and Relevance to US Cities*, in *Contemporary Issues In Deep Foundations*. 2007. p. 1-10.

4. Bridge Inspection Definitions, VDOT, http://www.virginiadot.org/info/resources/bridge_defs.pdf

Appendix A

Survey Outline and Questions

DEVELOPMENT OF GUIDE FOR SELECTION OF SUBSTRUCTURE AND FOUNDATION FOR ABC PROJECTS

DEVELOPMENT OF GUIDE FOR SELECTION OF SUBSTRUCTURE AND FOUNDATION FOR ABC PROJECTS

FIU FLORIDA INTERNATIONAL UNIVERSITY

ABC UTC ACCELERATED BRIDGE CONSTRUCTION UNIVERSITY TRANSPORTATION CENTER

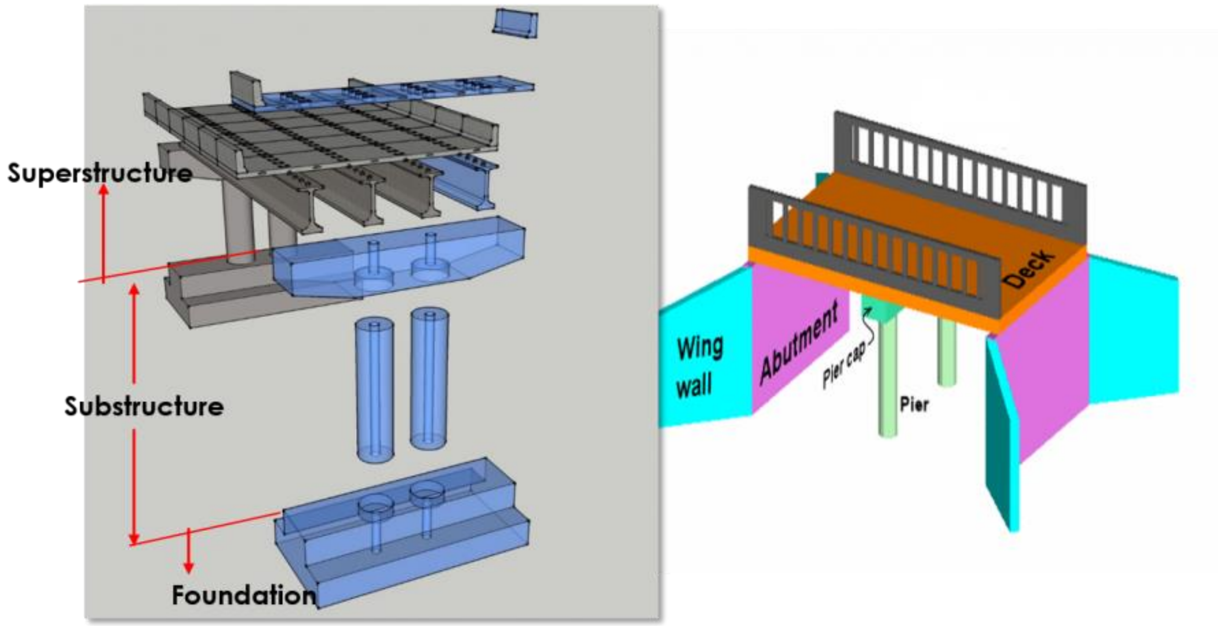
The UNIVERSITY of OKLAHOMA

Administrative Information

- ☐ Name ____
- ☐ Agency ____
- ☐ Title ____
- ☐ Email ____
- ☐ Tel. ____
- ☐ Address ____

-This survey is related to a project titled "Development of Guide for Selection of Substructure and Foundation for ABC Projects" as a part of the research program at Accelerated Bridge Construction University Transportation Center (ABC-UTC).
(Link to the project: https://abc-utc.fiu.edu/research-projects/fiu-research-projects/development-of-guide-for-selection-of-substructure-for-abc-projects/)
-In this survey, your experience in implementing the ABC techniques in the construction of new and existing bridges will be used to provide input for developing the guideline. As there are different definitions for identifying superstructure, substructure, and foundation components,

our definition is as follows. 1- Superstructure refers to deck and girders and everything above the deck. 2- Substructure refers to elements that hold the superstructure like piers, abutments, and wing walls, basically, everything below the superstructure bearing and above the foundation. 3- 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.- If you have supporting files to upload, you can upload them at the end of the survey.



Q2.1 Has your agency had any experience in application of ABC technique in the construction of a bridge?

- ◯ Yes
- ◯ No

Q2.2 For which of the bridge components the ABC method has been used?

- ◯ Superstructure only
- ◯ Superstructure, Substructure, and/or foundation

Q2.3 What type of superstructure system and elements and construction method have you used?

Q2.4 What is necessary, in your opinion, for preparing your or other agencies to adopt and fully utilize ABC?

____

Q2.5 which of the following options your experience is related to? (please select all that applies). Subsequent questions will be based on the options you select here.

- ☐ New bridges
- ☐ Replacement or retrofitting of existing bridges with an option to reuse, extend or modify the substructure/foundation

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ABC Techniques in Construction of NEW BRIDGES

Q3.2 Please describe/identify the specific system(s) or elements you have used for substructure and foundation.

____

Q3.3 Please provide input for the following questions;

- ☐ a) What factors have you considered in selection of substructure and foundation systems and elements? ____

- ☐ b) What guideline or procedure, if any, have you used to select the substructure and foundation systems and elements? please upload any applicable file at the end of the survey (e.g. written guideline, procedure, etc.). ____

- ☐ c) Has there been any interrelation between superstructure, substructure, and foundation that effected or limited your selection of the type of bridge elements? please explain. ____

Q3.4 Please describe if you have used any type of ABC technology in the construction of the bridge foundation (eg., continuous flight auger piles, Micro-piling, Screw piling, Geosynthetic reinforcement soil-integrated bridge system, etc.).

____

Q3.5 What type of superstructure system and elements and construction method have you used?

____

Q3.6 Did you consider the seismic effect for designing prefabricated substructure and foundation elements and connections? Please specify.

____

Q3.7 Do you know of any maintenance problems or other issues that impact the life-cycle performance of the prefabricated substructure and foundation elements or ABC technology? Please specify.

____

Q3.8
What is necessary, in your opinion, for preparing your or other agencies to adopt and fully utilize ABC?

____

Q3.9 If you have a supporting file, please upload it.

Q3.10 If you have a supporting file, please upload it.

ABC Techniques in Construction of

EXISTING BRIDGE

Q4.2 For potential reuse, retrofitting, extension or modification of existing substructure and foundation:

a) what factors have you considered to evaluate the existing substructure and foundation?

____

☐ b) Do you follow an established procedure to decide whether to replace or reuse the existing substructure/foundation? Please explain methods used for the evaluation of capacity and service life of existing substructure/foundation. please upload any applicable file at the end of the survey (e.g. written guideline, procedure, etc.).

____

Q4.3 If you used retrofitting, modification, or extension of existing substructure/foundation (not a complete reuse or replacement), please explain the methods and elements you used.

____

Q4.4 If substructure/foundation replacement was the option you used,

☐ a) What factors have you considered to select the substructure and foundation elements and systems? ____

☐ b) Please describe/identify the specific systems or elements you have used for substructure and foundation system(s).

____

☐ c) What guideline or procedure, if any, do you use to select the substructure and foundation systems and elements? please upload any applicable file at the end of the survey (e.g. written guideline, procedure, etc.).

____

☐ d) Did any interrelation between superstructure, substructure, and foundation affect or limit your selection of the type of bridge elements? please explain.

____

Q4.5 What type of superstructure system, elements, and construction method have you used for your projects involving replacement, reuse, retrofitting, or extension of substructure/foundation of existing bridges?

____

Q4.6 Did you consider the seismic effect for designing prefabricated substructure and foundation elements and connections? please specify.

____

Q4.7 Do you know of any maintenance problems or other issues that impact the life-cycle performance of the prefabricated substructure and foundation elements or ABC technology? please specify.

____

Q4.8 What is necessary, in your opinion, for preparing your or other agencies to adopt and fully utilize ABC?

____

Q4.9 If you have a supporting file, please upload it.