DEVELOPMENT OF GUIDE FOR SELECTION OF SUBSTRUCTURE FOR ABC PROJECTS

Quarterly Progress Report

For the period ending May 31, 2019

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ACCELERATED BRIDGE CONSTRUCTION
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Submitted to:

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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 attempt to 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 that are used in evaluation of existing bridge foundation and substructure for potential reuse has been reviewed and is available in the previous progress report. The literature review is underway to summarize the design specifications related to the ABC projects. A survey was also conducted and the analyses of the survey results was performed. The summary of survey results are reported below.

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 Qualtrics was used in preparing the survey. Statistical analyzes of results (for multiple choice questions) can be automatically conducted by this instrument.

The survey had four sections (Figure 1). Appendix A also provides the entire survey questionnaire.

Section 1: Administrative questionnaire

Section 2: Type of bridge construction questionnaire

Section 3: New bridge construction questionnaire

Section 4: Existing bridge construction questionnaire

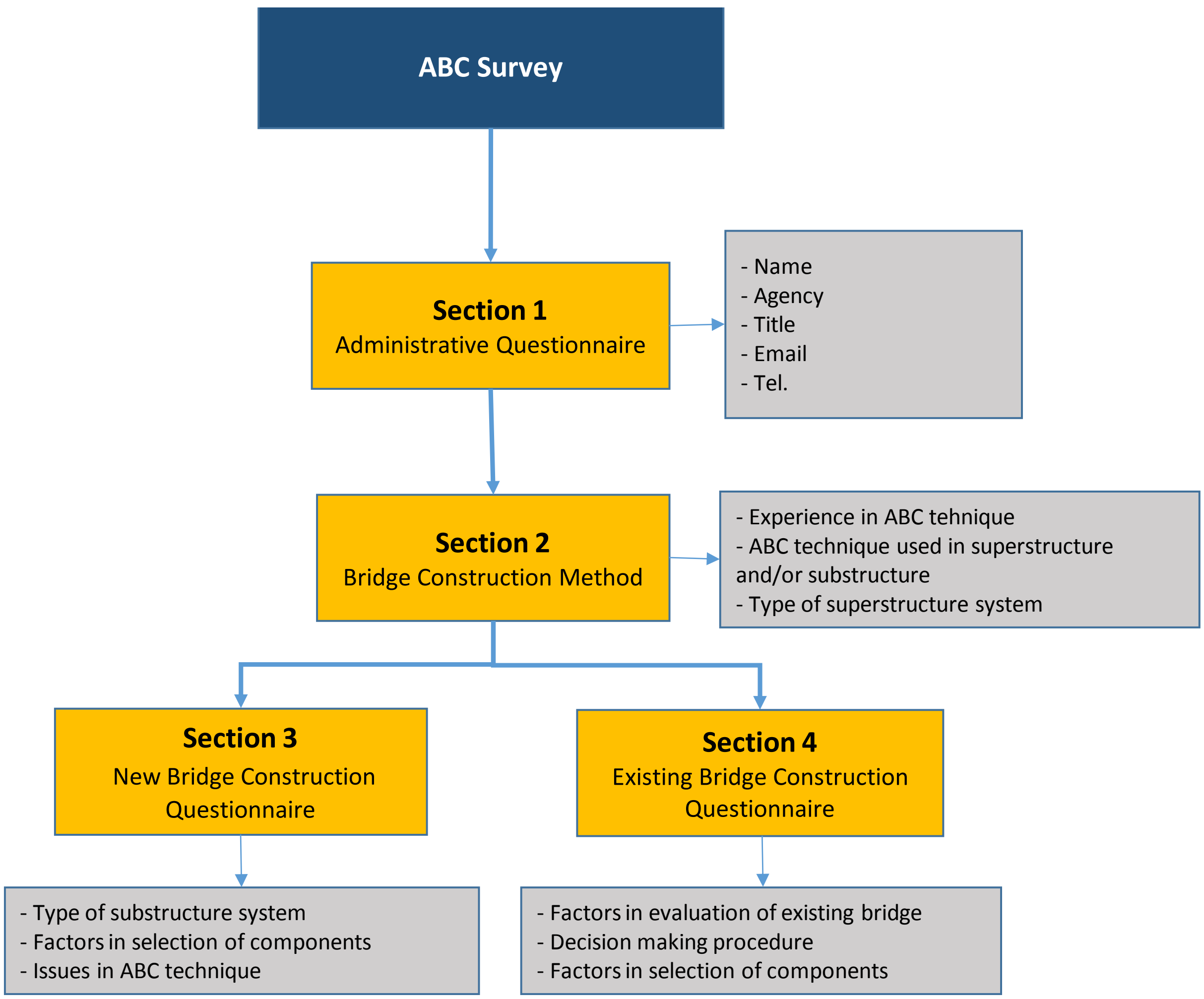


Figure 1: Survey sections

5.1 Survey Participants

20 respondents from eighteen State DOTs participated in the survey (Figure 2). These departments were located in different parts of the United States. Figure 2 shows the distribution of agencies in the United States.

5.2 Survey Results

Ninety percent of the survey participants who had experience in the application of ABC technique, had their experience in the construction of bridge superstructure, substructure, or foundation (Figure 3). 10% of respondents with ABC experience implemented the ABC technique only in construction of bridge superstructure.

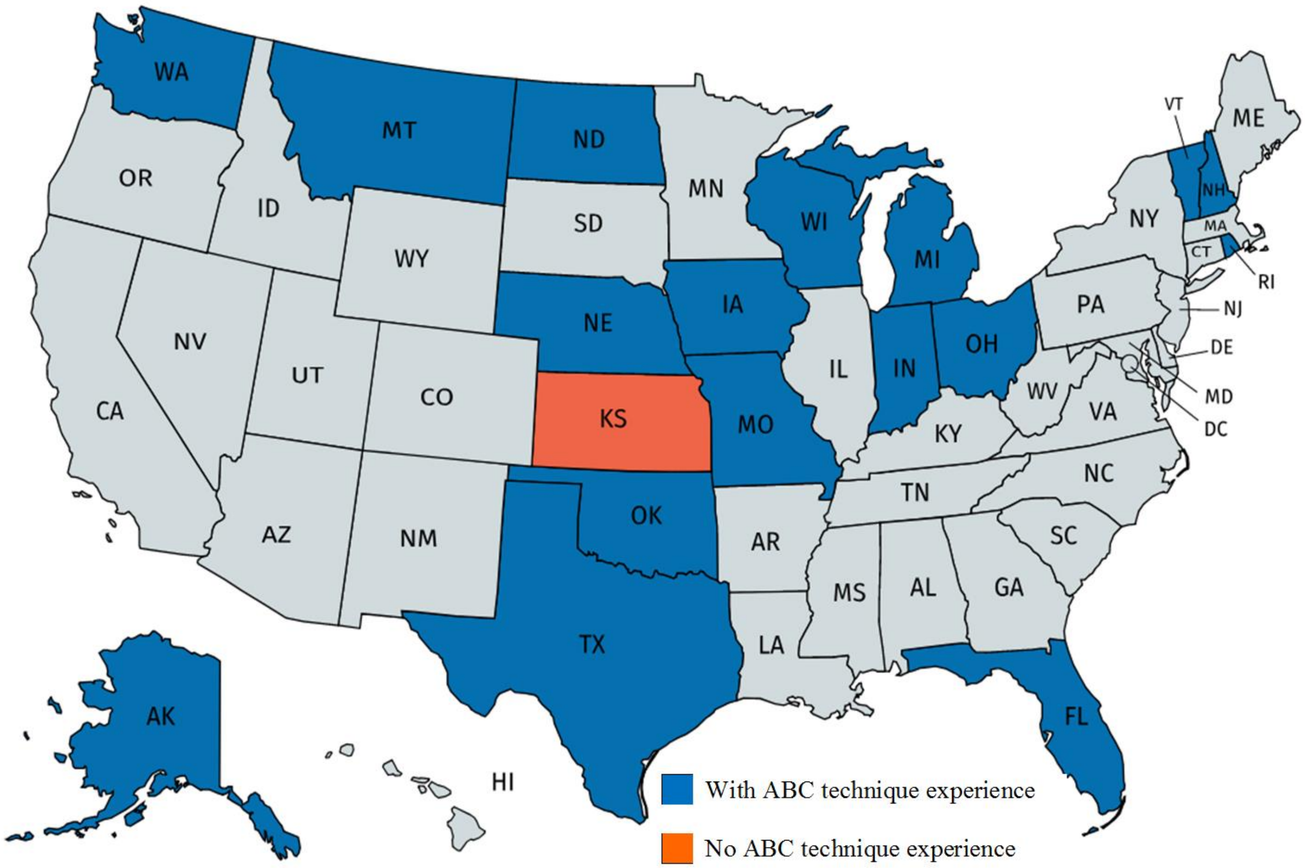


Figure 2: Distribution of participants in the survey

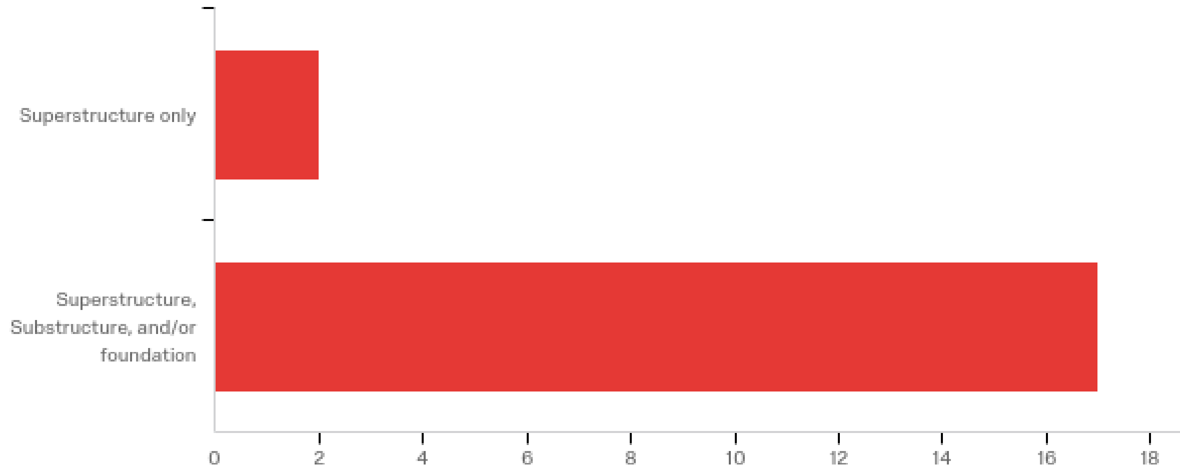


Figure 3: Application of ABC technique in bridge construction

The results also showed that 75% of participants had experience in implementing the ABC technique in constructing new bridges, where, 25% of participants had experience in applying the ABC technique in replacement or retrofitting, of existing bridges with an option to reuse, extend, or modify the substructure/foundation (Figure 4). Michigan State DOT was the only state had experience in implementing ABC technique in construction of both new and existing bridges.

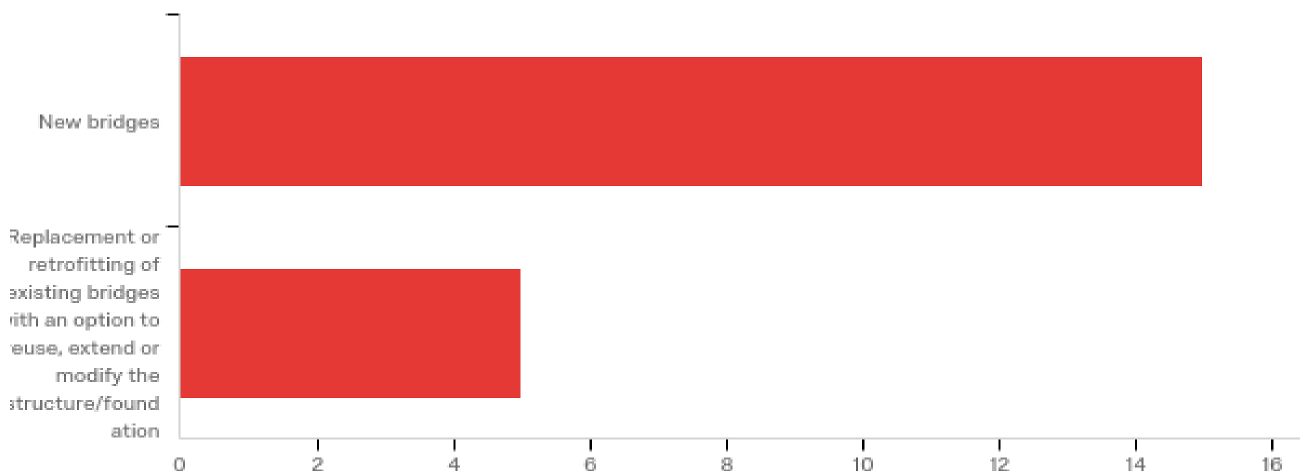


Figure 4: Implementation of ABC in the construction of new bridges or existing bridges

5.2.1 ABC Construction Method

SPMT and lateral sliding, along with the use of crane for prefabricated elements have been identified by the participants as construction methods used in their projects.

5.2.2 Superstructure Elements

Prefabricated superstructure elements were used commonly. The most common elements used in the ABC projects are listed below.

- Partial and full precast deck,
- Butted box beams,
- Precast and prestressed beams with topping slab and modified shear key,
- Side-by-side box beams or cored slab superstructures,
- Spliced curved, U-beams,
- Voided slab superstructures

5.2.3 What is needed to prepare agencies to adopt the ABC Technique?

In this section, participants were asked to describe what the agency needed to better implement ABC. Their response is summarized below:

1. Training of contractors, agencies and DOT staff about ABC. There is a lack of knowledge about how, where and why ABC technology can be implemented.
2. Designers need to be educated about the type of elements, connections and shapes they can fabricate to support ABC type construction.
3. Having a guideline for designers and agencies that help them to select the best method in the construction of a bridge based of construction duration, construction cost, and the reason for choosing a specific method can help to facilitate the use of ABC technology.
4. Case study details are required to quantify the road user cost and ABC benefits to give ideas on how to implement ABC. This can also can address the unfamiliarity of owners and agencies to address this issue.

5.2.4 Substructure elements

The common substructure elements used by the participants included:

- Precast caps on precast piles supporting precast superstructure elements (side-by-side box beams/or cored/hollow slabs)
- Precast concrete pier cap
- Precast concrete columns
- Precast concrete backwalls
- Precast concrete approach slabs
- Approach slabs with integrated concrete rail, concrete-filled steel pipe, and
- Pile extension bents that can be constructed without a cofferdam and the pipe pile serves as a permanent

5.2.5 Foundation Elements

The most common foundation elements indicated by the participants are:

- Steel piles,
- Spread footings,
- Drilled shafts,
- Precast grade beams
- Precast abutment
- Pile caps

5.2.6 Factors in Selection of Substructure and Foundation Systems

The most important factors affecting the selection of substructure and foundation bridge systems and components were described by the respondents as:

- Cost and speed,
- Bridge span
- Soil condition and location of rock under the surface of ground
- Stream crossing
- Critical path of bridge that determines amount of precast substructure need
- Equipment
- Traffic restrictions
- Precast elements transfer issues
- Risk mitigation
- Contractor familiarity
- Constructability
- Design compatibility
- Seismic performance
- Long-term durability
- Quality and safety of work

5.2.7 Guideline for selection of bridge components

Participants did not mention a particular written guideline for selection of substructure elements for ABC projects. However, Florida DOT stated that it is often useful to know the traffic restrictions and consider what operations are restricted to night-work and what operations can be constructed during day-time that usually gives the best clues of where to target the precast elements, specialized equipment, etc. Alaska DOT also stated that Alaska Bridges and Structures Manual addresses the design of concrete-filled steel pipe pile bents including the cold climate effects. They added that updates are forthcoming that provide additional design guidance on this type of substructure.

5.2.8 Interaction between Superstructure, Substructure, and Foundation in the Selection of Components

The following restrictions were reported by the participants.

In some cases, the superstructure type may lend itself to working well with certain substructure types. For example, prestressed tri-deck beams can be cast with integral backwalls. Or, the foundation type will drive whether the abutments are semi-integral or integral. It was reported that the use of semi-integral abutment complicated the details since it was required to pour the abutment diaphragms in place. The precast backwall was used to connect the abutment to the end of floor and the approach slab.

5.2.9 Seismic Considerations in Design of Foundation and Substructure

Most agencies reported that seismic issues were not their concern because they are not located in seismic potential regions. However, seismic considerations were considered for substructures and connections in states that are located in seismic region. Montana DOT stated that Seismic effects were considered for the substructures and connections, but most of their ABC structures are relatively small, single-span bridges. As a result, the seismic considerations are typically not significant.

Washington State DOT used integral connections at intermediate piers for seismic applications. Also, Alaska reported that pushover analyses of the pier were conducted according to the AASHTO LRFD and Alaska DOT manual to consider seismic effects.

5.2.10 **Issues in Using ABC Technology**

The reported issues and concerns from agencies are summarized below.

Ohio DOT stated that they need to make sure the details allow roadway drainage to get where it is supposed to go. If a closed drainage system is required, details have to be consistent with obtaining the drainage to the catch basin. Example - precast concrete elements have joints between the elements. If these joints open up, will the roadway drainage go to places not intended. This applies to the bridge and immediately off the bridge. Too many times, roadway drainage is an afterthought. Where the roadway drainage does not function as designed and the drainage ends up in a place not intended, there will be deteriorated components. Also, Montana DOT stated seal the joints between precast elements such as backwalls to prevent water or soil intrusion is in concern. PBES connections and demonstrations through full-scale mock-ups was another reported concern.

TX DOT "incorporates provisions meant to minimize the need for maintenance into our prefabricated elements. In particular, TxDOT relies heavily on the use of High-Performance Concrete in precast elements. Although there are several options for achieving the HPC requirements, in almost all cases that are accomplished by replacing some portion of the Portland cement with Class F fly ash."

5.2.11 **Decision making procedure in selecting, replacement, reuse,**

Participants reported that there was no procedure to decide whether to replace or reuse the existing substructure/foundation. There were some rare and specific exceptions. For example, it was stated by Rhode Island that retrofit of or replacing a column is an option if there is 60% spalled, cracked or hollow areas. It was reported that bridges are evaluated on a case-by-case basis.

5.2.12 **Retrofitting/strengthening**

Few responses to this question indicated that for majority, each bridge is considered and evaluated separately. TxDOT frequently extends existing caps on bridge widening projects.

6 Task 4 – Analysis of Literature Search and Survey Results

Information from the literature search (Task 2) and the survey (Task 3) was analyzed carefully to document existing practices, best practices, issues, and other important factors such as cost, service life, construction/retrofitting time, and durability. A series of procedures and flowcharts for selection of substructure and foundation are under development that incorporates the results of literature and survey. These procedures and flowcharts will be presented in the next report.

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. 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.

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.

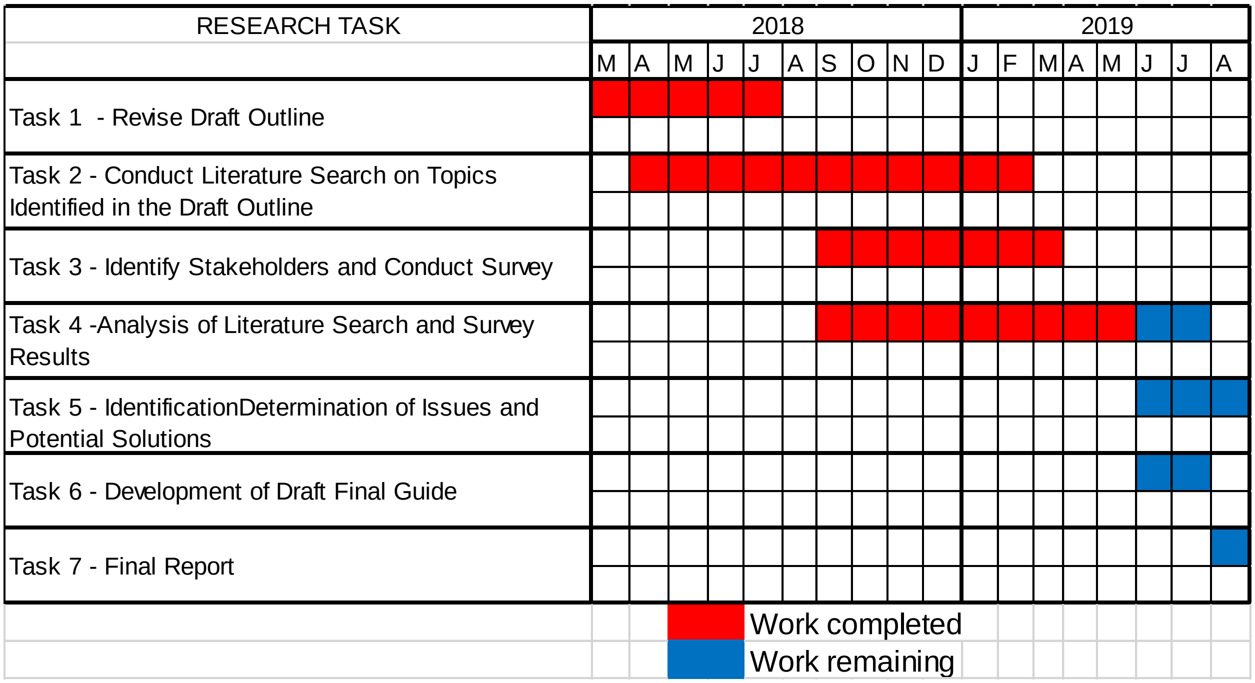
10.2 A five-minute Video Summarizing the Project

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.


RESEARCH TASK
2018
2019
M A M J J A S O N D J F M A M J J A
Task 1 - Revise Draft Outline
Task 2 - Conduct Literature Search on Topics Identified in the Draft Outline
Task 3 - Identify Stakeholders and Conduct Survey
Task 4 -Analysis of Literature Search and Survey Results
Task 5 - IdentificationDetermination of Issues and Potential Solutions
Task 6 - Development of Draft Final Guide
Task 7 - Final Report
Work completed
Work remaining