PROJECT TITLE: DEVELOPMENT OF GUIDELINES 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

The concept of Accelerated Bridge Construction (ABC) using precast and prefabricated bridge elements are gaining popularity among transportation agencies primarily to minimize traffic delays and costs. Some other benefits associated with the ABC techniques are reduced on-site construction time, reduced impact on mobility, better work zone safety and improved quality. Previously, the focus of the ABC techniques was limited to specific prefabricated bridge elements such as bridge decks and pier caps. However, with the recent advancement in construction methods, many projects are using precast and prefabricated elements for other bridge elements such as substructures and foundations. In case of a new bridge construction, substructure design by ABC technique will allow rapid construction to accommodate superstructure installation. For replacing an existing bridge, the substructure construction by ABC technique will cause minimum interference with existing bridge operation. Currently, a number of potential ABC technologies are available to design and construct bridge substructures and foundations. A guideline will help the transportation agencies to select the suitable techniques for their specific need.

2. Problem Statement

A number of previous studies are available focusing on the use of precast, prefabricated bridge superstructure elements. On contrary, only few studies can be found focusing on the design and construction of substructure and foundation by ABC method as most of the time it is assumed that the substructure already exists and ready to receive the load from superstructure. However, substructure construction can be the most time-consuming work for a bridge construction. There is a need to have specific guidelines for design and construction of substructures and foundations for new bridges to obtain full benefits of ABC method. Also, guidelines are needed for consideration of reusing, strengthening, and modification of substructure and foundations of an existing bridge. In addition, new, innovative and non-interruptive substructure and foundation design methods need to be explored and documented.

3. Research Approach and Methods

The overall approach of this project is to conduct an extensive literature search and document the ABC technologies available for design and construction of substructure and foundation. The current evaluation techniques of an existing substructure and foundation and problems associated with the evaluation techniques will also be investigated for replacing an existing bridge. Also, methods for strengthening or modifying an existing substructure will be discussed. The issues with the state-of-the art practices of ABC techniques for constructing a new bridge will be identified and potential solutions will be proposed based on the literature review. Attempts will be taken to present few examples of new and innovative techniques of substructure and foundation construction. A survey will be conducted to find out the challenges faced by stakeholders during construction of bridge. The acceptability of new practices such as installation of prefabricated foundation elements, retrofitting etc. will be investigated through this survey.

4. Description of Research Project Tasks

The following is a description of tasks carried out to date.

Task 1 – Develop Outline for the Guideline

Proposed task description:

An outline will be proposed as a first step of developing a guide for substructure and foundation by ABC method. The outline will broadly encompass the topics related to substructure and foundation by ABC method such as ABC definitions, design methodologies for new and existing bridges, materials for bridge construction by ABC method, evaluation techniques of existing bridge elements and new methods of substructure and foundation construction. The outline will be updated periodically to prepare a comprehensive guide.

Description of work performed up to this period:

An initial outline has been developed. The outline will be updated periodically, as needed.

Task 2 – Conduct Literature Search on Pertinent Topics.

Proposed task description:

A comprehensive literature review will be conducted focusing on the design and construction of substructure and foundation by ABC techniques. Sources of literature include, but not limited to TRB, FHWA, NCHRP, and DOTs. Other sources such as society journals will be consulted. Moreover, national and international conferences, symposia and workshops will be reviewed. The literature review will be continued throughout the duration of this project.

Description of work performed up to this period:

The following articles are examples of the reviewed papers during the reporting period.

i. The objective of the study conducted by Kamel et al. (1995) was to evaluate the design practices for using integral abutments supported on precast concrete piles. For this purpose, a survey was conducted among highway agencies to identify current foundation practices for integral abutment bridges. It was found that, most of the agencies use steel H-piles and predrilled oversized holes filled with granular soil. Load-deflection tests were conducted to compare the flexibility of one steel and two concrete piles to determine the suitability of concrete piles in integral abutment bridges. It was observed that the steel pile can accommodate higher amount of lateral deflection than the concrete pile. Also, a new pile abutment joint, consists of a neoprene bearing pad with a Teflon layer, was proposed for concrete piles. The joint was found to allow the prestressed concrete piles to accommodate higher lateral deflection.

ii. Fam et al. (2003) explained the application of concrete-filled glass fiber reinforced polymer (GFRP) circular tubes as composite piles in Rout 40 bridge in Virginia. Two full-scale specimens with GFRP tubes identical to proposed piles were tested in bending under four-point loads. Axial and lateral loading tests were conducted in the field on a full-scale precast composite pile and a prestressed conventional square concrete pile. The GFRP tube was found to act as a permanent formwork and reinforcement at the same time. Both the composite and prestressed concrete piles performed similarly during pile driving. The flexural strength of the GFRP was found to be similar to the flexural strength of prestressed square concrete pile. Also, GFRP and square concrete beam exhibited similar behavior in axial and lateral load tests. Considering the low-maintenance cost, the use of GFRP tubes for bridge piers was suggested to be a feasible option.

iii. The objective of the study conducted by Suleiman et al. (2010) was to evaluate the performance of driven ultrahigh-performance concrete (UHPC) H-Pile with reference to steel H-pile. For this purpose, two instrumented H-shaped UHPC piles and one steel piles were driven in the field. The experimental results obtained during driving as well as vertical and lateral load tests were compared with the behavior of a steel H-pile subjected to vertical loads. It was found that H-shaped UHPC piles can be driven successfully without a pile cushion through hard soil layers without causing any damage to the UHPC piles. Also, it was observed that the H-shaped UHPC piles resisted applied load by both skin friction and end bearing, whereas steel H-piles mostly resisted applied load by skin friction. It was suggested that the total number of piles required for a bridge foundation might be reduced as the axial load capacity of the UHPC pile was found to be 86% higher than that of the steel pile.

iv. Fouad et al. (2006) conducted a study to examine the existing practices in prefabricated bridge construction using precast concrete components, and to recommend a totally prefabricated concrete bridge system for use on the Alabama highway system. For this purpose, the current trends and practices in prefabricated bridge construction used by different state agencies were reviewed. Also, prefabricated superstructure and substructure systems were examined and ranked based on the suitability to use in Alabama. Based on the findings of this study, a totally prefabricated precast concrete system, known as the University of Alabama at Birmingham (UAB) precast bridge system was developed. Several foundation construction methods were observed from the investigation conducted during this study. It was found that, bridge abutments were typically founded on driven piles, spread footings, or drilled shafts, whereas, cast-in-place columns were typically founded on pile caps, spread footings, or drilled shafts. Also, driven pile foundations were found to be used for short span bridge. However, no attempt was made to devise new foundation construction methods for UAB precast bridge system due to constructability issues.

Task 3- Identify Stakeholders and Conduct Survey.

Proposed task description:

A survey will be conducted to find out the state of the art practices of foundation design and construction methods by ABC method. Also, the challenges faced by engineers during construction of foundation will be investigated. The acceptability of new practices such as installation of prefabricated foundation elements, retrofitting etc. will be investigated through this survey. The questionnaire will be disseminated among DOTs and personals involve in research using ABC method.

Description of work performed up to this period:

A survey questionnaire form has been prepared with consultation with FIU team members. The stakeholders for this survey was finalized. The survey questionnaire was disseminated with the help of AASHTO Committee on Bridge and Structures. A total of eighteen responses were received while this report is being prepared. Following questions and options were included in the survey questionnaire to obtain information related to Bridge Foundation:

Survey Questions:

- ❖ *Have you used any precast/prefabricated foundation elements or employed any ABC technology in constructing foundation for a new bridge? Why?*
    - ☐ *To minimize construction delays*
    - ☐ *To minimize lane closure*
    - ☐ *To improve quality and durability*
    - ☐ *To improve safety*
    - ☐ *To minimize cost*
    - ☐ *To minimize environmental impact*
    - ☐ *Other (please specify)*

a) *Please specify where precast/prefabricated foundation elements were used.*

- ☐ *Spread Footing*
- ☐ *Pile cap*
- ☐ *Pile foundation*
- ☐ *Caisson foundation*
- ☐ *Sheet piles*
- ☐ *Prefabricated full height wall panels around foundation elements*
- ☐ *Other (please specify)*

b) *Please specify what type of ABC technology was used.*

- ☐ *Continuous Flight Auger Piles (CFA)*
- ☐ *Geosynthetic Reinforced Soil-Integrated Bridge System (GRS-IBS)*
- ☐ *Micro-piling*
- ☐ *Screw piling*
- ☐ *Other (please specify)*

c) *What factors have you considered to select the Foundation element?*

- ☐ *Superstructure type*
- ☐ *Subsurface soil properties*
- ☐ *Economic considerations*
- ☐ *Site accessibility*
- ☐ *Time constraint*
- ☐ *Compatibility between substructure and foundation elements*
- ☐ *Transportation of precast/prefabricated elements*
- ☐ *Other (please specify)*

d) *What guideline or procedure to have you used to select the Foundation for a new bridge?*
e) *What type of connection have you generally used for the following:*
    - *Foundation to column*
    - *Foundation elements*
f) *In what way, if any, the superstructure impacted your selection of foundation?*
g) *Did you consider seismic effect for designing precast/prefabricated foundation elements and connections? (Please specify)*
h) *Do you know of any associated maintenance problems or other drawbacks that might impact the life-cycle cost of these precast/prefabricated foundation elements or ABC technologies? If yes, please specify.*

Task 4- Analyze Literature Search and Survey Results

Proposed task description:

The literature reviewed for this project will be summarized and analyzed in order to prepare the guidelines for this project. A report will be prepared on the survey feedback and will be included in the final guideline.

Description of work performed up to this period:

The literature review conducted for this project is being analyzed to prepare the construction and design guidelines for bridge foundation by ABC technique. Different ABC techniques and components for bridge foundation have been identified. Different components of ABC include, but not limited to:

- Prefabricated Caps for Caisson or Pile foundation
- Sheet Piling (Steel or Precast Concrete)
- Prefabricated Full Height Wall Panels around Foundation Elements
- Prefabricated Spread Footings

Different ABC Techniques that can be used for bridge foundations are:

- Continuous Flight Auger Piles
- Geosynthetic Reinforced Soil Integrated Bridge System (GRS-IBS)
- Bored Piling-Cased Secant Pile (CSP)
- Self-Drilling Hollow Bar Nailing and Miro piling
- Screw piling

The details of these techniques and components are now being documented. The summary of the continuous flight auger piles (CFA) and precast spread footing are presented in the following section.

- **Continuous Flight Auger Piles (CFA):**
  The advantage of using CFA is that these piles are drilled and cast in place rather than driven into the ground. CFA is suitable for a wide range of cohesive and cohesionless soil conditions. Also, CFA does not produce shocks, vibrations, noise which makes it suitable

for work in urban areas. Typical diameter of CFA ranges from 12 to 36 in. and length of up to 100-ft. CFAs are less time consuming as drilling a hole in a continuous process is faster; than driving piles. However, the structural integrity and pile bearing capacity of CFA was found to be difficult to verify. Figure 1 present the construction sequence of CFA.

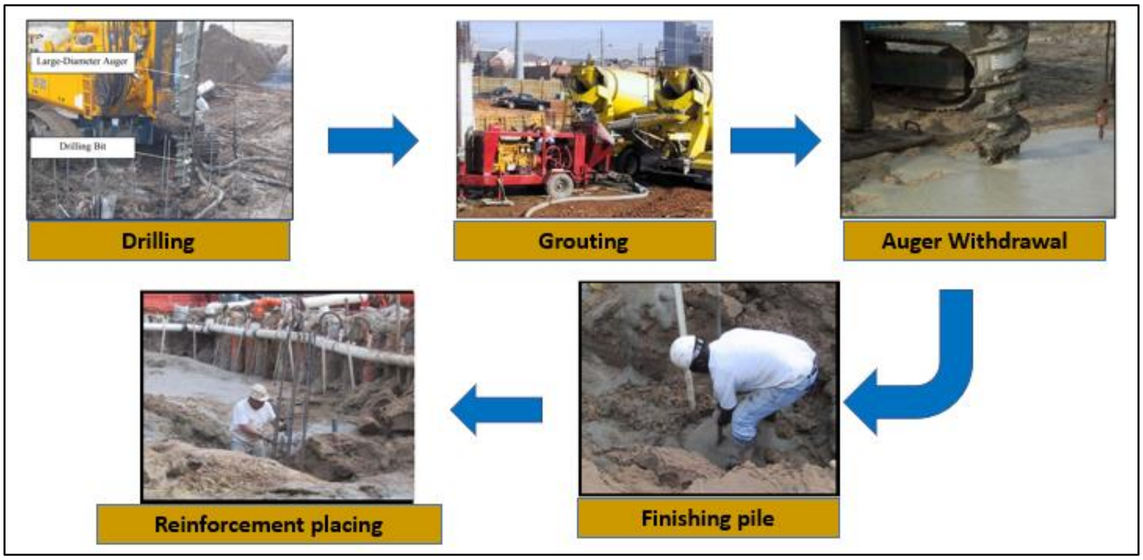

Figure 1 Construction sequence of continuous flight auger piles

- **Precast Spread Footing:**

  The precast spread footings are precast off-site, transported to the construction site and placed on a prepared subgrade and then grouted into place. Spread footings are connected to piers or columns by placing fill over the footings and then compacted. Also, reinforcing bars can be extended from the precast footings, and a cast-in-place closure pour can then be completed during the erection of the remaining portions of the bridge.

- **Footing Column Connections:**

  Literature were reviewed to identify different footing column connections currently used by different agencies. Three different types of connections were observed to be used most frequently. These are:

  - Embedded Column Ends
  - Grouted Couplers
  - Grouted Ducts

Figure 2 (a), (b) and (c) presents embedded column ends, grouted couplers and grouted ducts types of connections for bridge foundation, respectively.

(a) (b) (c)

Figure 2 (a) embedded column ends, (b) grouted couplers and (c) grouted ducts connection for footing column connection

Literatures were reviewed to compare the benefits of using different bridge foundation systems, equipment, and ground improvement methods for accelerated construction of bridge. Based on the findings from a geotechnical engineering scan tour to Europe in June 2002 (organized by FHWA and AAASHTO), Dumas et al. (2003) presented the following comparison (Table 1) between bridge foundation systems, equipment, and ground improvement methods for poor subgrade.

Table 1 Bridge Foundation Systems, Equipment, and Ground Improvement Methods for Accelerated Construction on Poor Subgrades

Technology or process	**Anticipated accelerated Construction Performance**	**Related Potential for Accelerated Construction**	**Applicable conditions for Accelerated Construction**	**Relative Cost**	**Improvement in Quality**	**Comments**
Continuous Flight Auger Piles (CFA)	Rapid pile installation for vertical or batter piles	High	Best in weak to medium soil	Medium	Low	Automated control, Not suitable for difficult drilling
Bored Piling-Cased Secant Pile (CSP)	Rapid Pile installation for vertical piles	High	Cut situations, temporary excavations	Medium	Medium	Casing assists in some soil conditions
Self-Drilling Hollow Bar Nailing and Miro piling	Self-drilling and grouting for one-step installation	High	Difficult ground for drilling/driving	Low	High	Confined condition with difficult ground for drilling

Task 5- Identify Issues and Potential Solutions

Proposed task description:

Based on the literature review and survey results, issues with the state-of-the art practices of ABC techniques for constructing bridge foundation and substructure will be identified and potential solutions will be proposed.

Description of work performed up to this period:

Not pursued during this reporting period.

Task 6- Develop Draft Guideline

Proposed task description:

One of the deliverables from this project will be a draft guideline on design and construction of bridge foundation and substructure by ABC techniques. The guidelines will be based on the literature search and survey results. The guidelines will cover the topics mentioned in the Task 1.

Description of work performed up to this period:

Not pursued during this reporting period.

Task 7- Prepare Final Report

Proposed task description:

A final report will be prepared based on the outcome of the project. the final report and the draft guideline will be submitted to the ABC-UTC and other professionals for further review.

Description of work performed up to this period:

Not pursued during this reporting period.

5. Expected Results and Specific Deliverables

At the end of the project a user-friendly guideline on design and construction of bridge foundation and substructure by ABC techniques will be available for transportation authorities, engineers and other stakeholders. The specific deliverables from this project will be:

i. Progress reports at the end of every quarter
ii. A draft guideline on design and construction of bridge foundation and substructure by ABC techniques
iii. A final report

6. Schedule

Progress of tasks in this project is shown in the table below.

Research Task	2018												2019							
	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A
Task 1 – Develop Outline for the Guideline																				
Task 2 – Conduct Literature Search on Pertinent Topics																				
Task 3- Identify Stakeholders and Conduct Survey																				
Task 4- Analyze Literature Search and Survey Results																				
Task 5- Identify Issues and Potential Solutions																				
Task 6- Develop Draft Guideline																				
Task 7- Prepare Final Report																				
		Work Performed							Work to be Performed											

7. References

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v. Dumas, C., Mansukhani, S., Porbaha, A., Short, R. D., Cannon, R. R., McLain, K. W., ... & Brown, D. A. (2003). Innovative Technology for Accelerated Construction of Bridge and Embankment Foundations in Europe (No. FHWA-PL-03-014).