# PROJECT TITLE: DEVELOPMENT OF GUIDELINES FOR SELECTION OF SUBSTRUCTURE FOR ABC PROJECTS

**Quarterly Progress Report**
**For the period ending November 30, 2019**

Submitted by:
PI- Dr. Musharraf Zaman
Graduate Student- Syed Ashik Ali

**Affiliation: Department of Civil Engineering and Environmental Science**
**University of Oklahoma**
**Norman, Ok**

ACCELERATED BRIDGE CONSTRUCTION
UNIVERSITY TRANSPORTATION CENTER

Submitted to:
ABC-UTC
Florida International University
Miami, FL

# 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 was 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:*

Based on the literature reviewed during the reporting period, “Chapter 4: Existing Bridge Replacement” was prepared. The following sections presents the OU part of “Chapter 4: Existing Bridge Replacement”.

**Strengthening techniques for Reuse of Bridge Foundation**

The assessments of integrity, durability and capacity help to identify the deficiencies associated with the substructure and foundation elements. The selection of foundation strengthening techniques depends on the issues identified during these assessments to produce an acceptable reuse design. Different substructure and foundation strengthening options based on NCHRP Synthesis 505 (Boeckmann and Loehr, 2017) are as follows:

i. **Increased footing size:** applicable for shallow foundations

ii. **Additional deep foundation elements:** installing micropiles, drilled shafts, driven piles, ground anchors, stone columns or other deep foundation elements.

iii. **Ground improvement:**

- ***Global ground modification techniques:*** techniques for improving the strength and stiffness of the overall soil or rock mass into which the existing foundation is installed.
- ***Local ground improvement techniques:*** techniques that are more narrowly targeted

iv. **Strengthening of above ground foundation elements:** Increase in loading capacity of above ground elements can be obtained through pier stem widening, addition of tiebacks, replacing backfill with lightweight fill to reduce loading on abutment, soil nails, encasing of pile bents by concrete or FRP, wall encasement of piers/pile bents.

A total of seven different foundation strengthening methods were found to be used by State DOTs and other agencies from a survey conducted for NCHRP Synthesis 505 (Boeckmann and Loehr, 2017). Figure 1 presents the results of this survey. Addition of driven piles was found to be the most commonly used strengthening method among DOTs. Table 1 presents commonly used substructure and foundation repair options for concrete, steel and timber elements obtained from a survey conducted by Wan et al. (2013).

Table 1 Different repair techniques for substructure and foundation elements (Wan et al., 2013)

| | Repair Methods | Timber | Steel | Concrete | Service Life (Years) |
|---|---|---|---|---|---|
| Pile Repair | Pile Posting | x | | | |
| | Concrete Encasement | x | | x | 20 |
| | Pile Restoration | x | | | |
| | Pile Augmentation | x | | | |
| | PVC Wrap | x | | | |
| | FRP Wrap | x | | x | 50-75 |
| | Pile Shimming | x | | | |
| | Adding Steel | | x | | |
| | Pile Jacket | | x | x | 20 |
| | Anodes | | x | x | 15 |
| | Anode Embedded Jacket | | x | x | 10-35 |
| Supplemental Piles | Steel Piles | | x | | |
| | Timber Piles | x | | | |
| | Concrete Piles | | | x | |

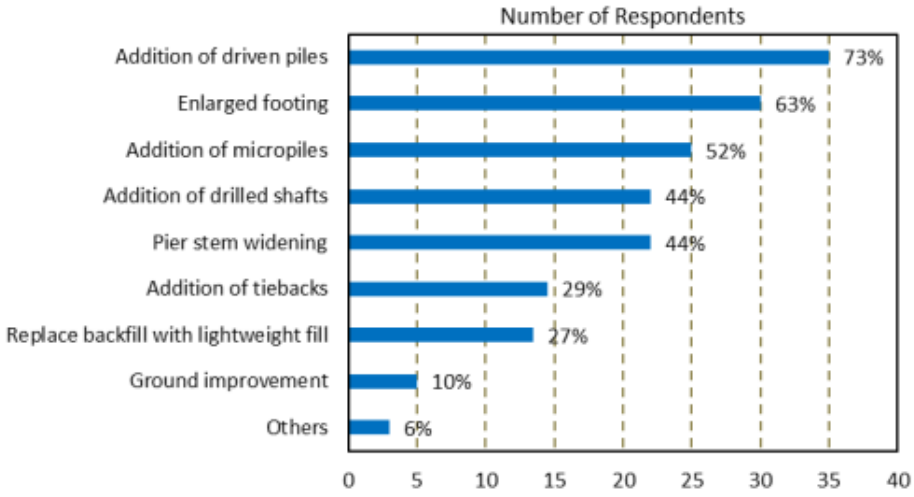



Figure 1 Commonly used foundation strengthening methods used by DOTs and other agencies (Boeckmann and Loehr, 2017

## Repair of Structural Elements

### *Concrete Elements*

A number of different techniques are available for reinforce and repair concrete members. Table 2 shows some of the most commonly used strengthening and repair techniques for concrete foundation elements (Agarwal et al., 2018).

Table 2 Strengthening and repair option for concrete foundation elements

| | Identified issue | Strengthening Measures Available |
|---|---|---|
| Integrity issues | Concrete Damage | Demolition and replacement of impacted concrete |
| | Alkali Silica Reactivity | Removal and replacement of impacted concrete, replacement of ASR impacted members |
| | Corroded Reinforcement (loss of rebar area) | Doweling, external rebar placement, FRP wrapping |
| Durability Issues | Chloride Ingress | ECE, removal and replacement of affected concrete, cathodic protection |
| | Spalling/delamination | Repair of spalled areas, placement of anodes in repair to prevent corrosion, wrapping of affected areas, addressing primary issue causing spalling |
| | Freeze-Thaw | Removal of impacted concrete and replacement with HPC, wrapping of vulnerable concrete with moisture barriers |
| | Carbonation | Remove/replace carbonated concrete, wrapping with barriers to prevent moisture and $CO_2$ exposure, cathodic protection to prevent corrosion |
| Capacity Issues | Increased Load | Addition of new elements, encasement of existing concrete sections, addition of external reinforcement cage, FRP wrapping, doweling of additional bars |
| | Low Concrete Strength | Replace/add elements, encase with new concrete |
| | Under-reinforcement, detailing issues | Doweling, encasement with additional reinforcement cage, FRP wrapping of low capacity sections |

***Steel Elements:***

Due to the exposure to exposure to aggressive environment, steel piles can be subjected to corrosion and as well as excessive section loss. These steel sections will require repair to prevent corrosion. Table 3 presents different repair options for deteriorating steel recommended by Brown et al. (2010).

Table 3 Different repair options for underwater steel piles (Brown et al., 2010)

| Damage | Repair Option |
|---|---|
| No Visible Deterioration | Coatings, Pile Wrap |
| <15% section loss | Pile Jacket |
| 15%-30% section loss | Pile Jacket with Reinforcement |
| >30% section loss | Partial Replacement |

**Seismic Retrofit**

Older foundations, which were not designed for the earthquake loading may need to be strengthened or repaired to account for possible seismic activity. Buckle et al. (2006) has proposed Seven basic approaches for seismic retrofitting of a bridge whose foundation is being reused:

i. Strengthening: increases capacity of overloaded elements to resist greater forces or moments.
ii. Improvement of Displacement Capacity: Provides additional displacement capacity
iii. Force Limitation: Provides deliberate yield points to prevent adjacent members from becoming overloaded.
iv. Response Modification: Fundamentally alters the manner that forces are transmitted through structure.
v. Site Remediation by Ground Improvement: Ground improvement techniques can be employed
vi. Acceptance of Control of Damage to Specific Components: Allow member to be damaged during design earthquake, so long as it does not impact the stability of the structure.
vii. Partial Replacement: Replace bridge components that are unsuitable for reuse.

**Micropiles**

Micropiles are generally small diameter (6 inches to 9 inches) piles, which are installed through jacking, driving or by drilling and casting the pile in place. Most common type of micropiles are the drilled, cast-in-place micropiles. The capacity of micropiles is obtained from both end bearing and side resistance, although end bearing contribution is neglected in the design. However, micropiles can attain high skin friction due to the availability of larger surface area. The advantages and limitations of micropiles are summarized in Table 4.

Table 4 Advantages and limitations for micropiles (after Aktan and Attanayake, 2015)

| Advantages | Limitations |
|---|---|
| The equipment is relatively small and can be mobilized in restrictive areas | Vertical micropiles are limited in lateral load capacity |
| Can be installed in all ground conditions | More expensive than other options. |
| Cause minimal disturbance to adjacent structures | - |
| Cause minimal noise and vibration | - |
| Can be used in low head room conditions (6 ft minimum) | - |
| Can be used for underpinning existing foundations | - |
| Can be installed as batter piles | - |

**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 was prepared with consultation with FIU team members and was disseminated with the help of AASHTO Committee on Bridge and Structures. A total of twenty responses were received while this report is being prepared.

**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. “Chapter 4: Existing Bridge Replacement” has been prepared based on the literature reviewed for this project. Also, the

survey was conducted with the help of AASHTO Committee on Bridge and Structures. The responses of the survey were presented in previous quarterly report.

**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:*

Issues with the selection, design and construction of bridge foundation by ABC methods are being documented from literature. This section will be completed as soon as more information is available.

**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:*

The University of Oklahoma (OU) is currently preparing the draft guideline for bridge foundation. The draft will be disseminated for review by experts as soon as possible.

**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:*

The University of Oklahoma (OU) is currently preparing the final report for this project. The draft will be disseminated for review by experts as soon as possible.

# 5. Expected Results and Specific Deliverables

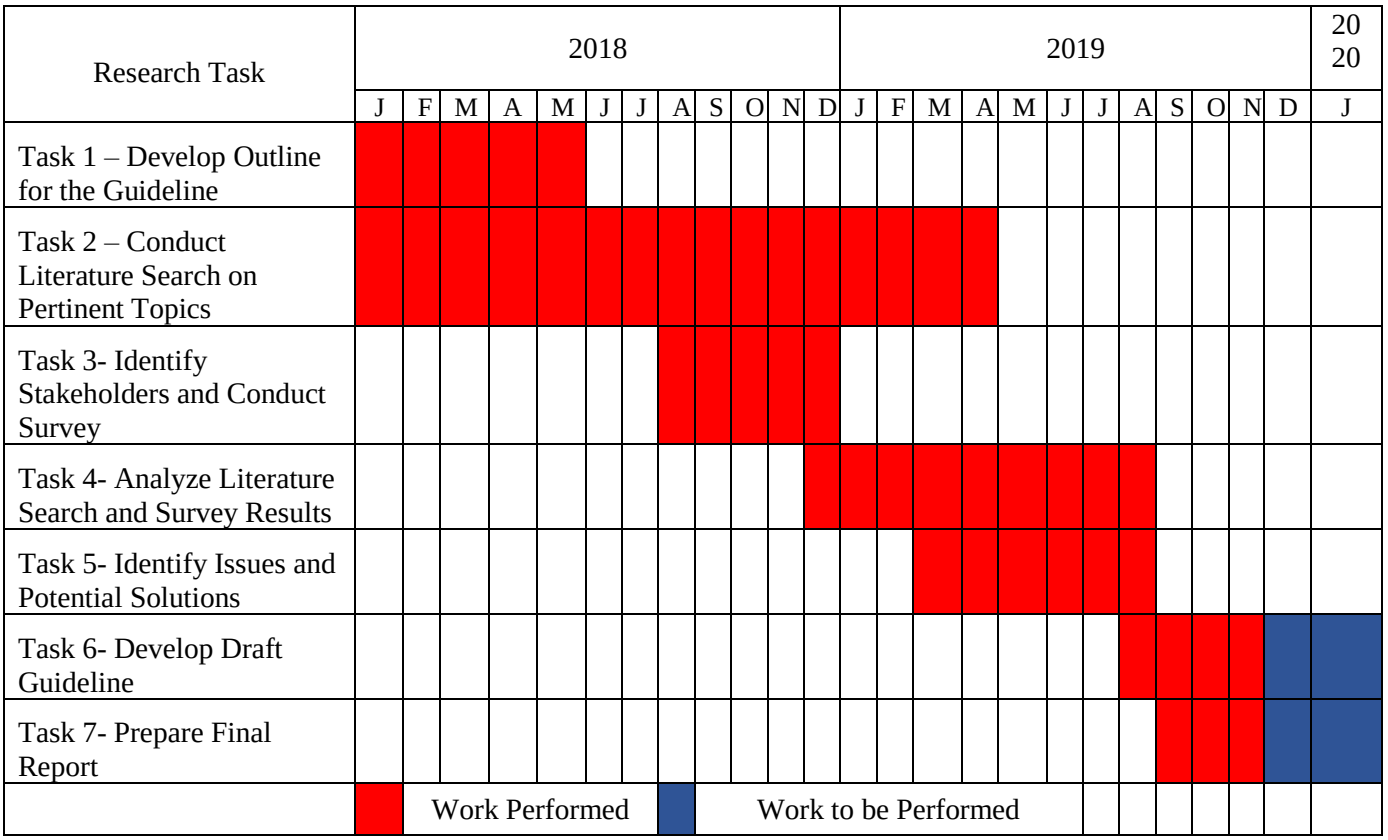
At the end of the project a user-friendly guideline on design and construction of bridge foundation and substructure by ABC techniques will be available for transportation authorities, engineers and other stakeholders. The specific deliverables from this project will be:

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.

| Item | % Completed |
|---|---|
| Percentage of Completion of this project to Date | 80% |




# 7. References


[1] Agrawal, A. K., Jalinoos, F., Davis, N., Hoomaan, E., & Sanayei, M. (2018), "Foundation Reuse for Highway Bridges." (No. FHWA-HIF-18-055).

[2] Aktan, H. and Attanayake U. (2015), "Research on Evaluation and Standardization of Accelerated Bridge Construction Techniques." Report: RC-1618A. Michigan Department of Transportation, Research Administration, Lansing, MI.

[3] Boeckmann, A.Z. and Loehr, J.E. (2017), "Current Practices and Guidelines for the Reuse of Bridge Foundations." NCHRP Synthesis 505, Transportation Research Board of the National Academies, Washington, D.C

[4] Brown, D.A., Turner, J.P., and Catelli, R.J. (2010), "Geotechnical Engineering Circular (GEC) No. 10 Drilled Shafts: Construction Procedures and LRFD Design Methods." NHI Course No. 132014, Report No. FHWA NHI-10-016, Federal Highway Administration (FHWA), Washington, D.C. 20590.

[5] Buckle, I., Friedland, I., Mander, J., Martin, G., Nutt, R., Power, M. (2006), "Seismic Retrofitting Manual for Highway Structures: Part 1 — Bridges.", FHWA-HRT-06-032,

Office of Infrastructure Research and Development, Federal Highway Administration (FHWA), McLean, VA 22101.

[6] Wan, B., Foley, C.M., Ainge, S.W., Nguyen, C. (2013), “Procedures, Cost and Effectiveness for Deteriorated Bridge Substructure Repair.” WHRP 0092-11-08 Wisconsin DOT, Milwaukee, WI, 53233.