ACCELERATED FOUNDATION REPAIR/RETROFITS FOR CAPACITY UPGRADATION AND STRENGTHENING

Quarterly Progress Report
For the period ending 2025, June

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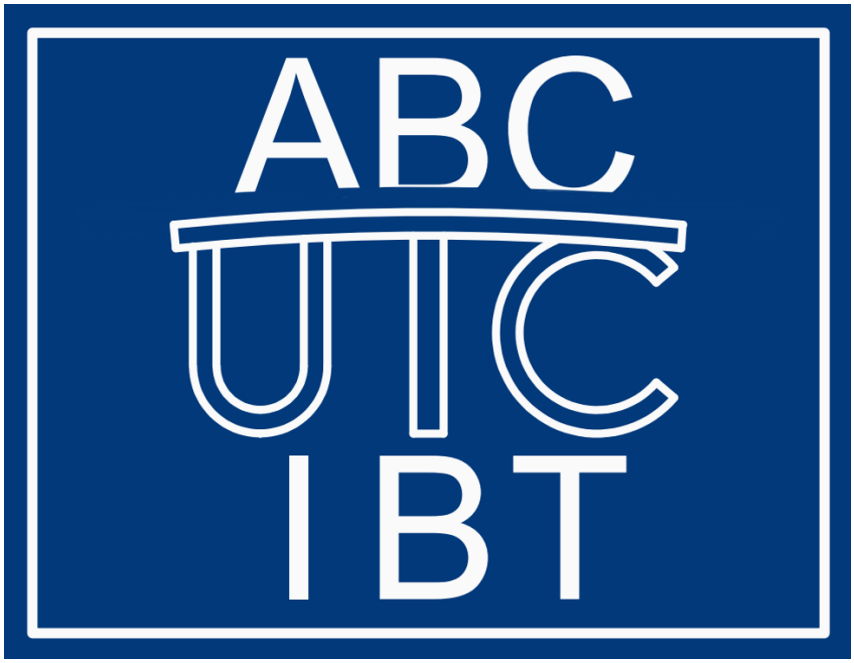

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1. Background and Introduction

The economic case for foundation reuse in bridge replacement/renewal projects is compelling. Foundation reuse can lead to significant cost savings as in bridge replacement project the typical cost of substructure can be in the range of 40 to 50 percent of the total bridge cost. In the current practice, the foundation reuse approaches are developed as one-off application using an ad hoc approach requiring rediscovery of many selection and design aspects. Such efforts entail high engineering cost in both the design phase as well as in the implementation phase as multiple pathways have to be analyzed and proof-of-concept demonstrated for each use case. It is notable that in many cases of foundation retrofits, mini-/micropiles emerge as the preferred choice. However, the use of micropiles typically presents a challenge related to the variation in their performance from site-to-site and installation-to-installation. Indeed, for every implementation of micropiles in foundation retrofit project, 2-10% of the micropiles have to be proof tested or tested to failure. Therefore, a systematic study is needed that utilizes the experience of various case histories that exist in the literature to develop future research questions that can lead to standardization of foundation reuse by capacity upgradation and strengthening utilizing mini-/micropiles.

2. Problem Statement

Despite the frequent use of mini- and micropiles for bridge foundation reuse, their application remains largely non-standardized and highly project-specific. Design and construction decisions are often based on limited precedent, requiring extensive proof testing and increasing both uncertainty and engineering effort. The absence of a unified framework that links design choices, construction practices, and observed performance prevents consistent and predictable capacity upgrading of existing foundations. This lack of standardization limits the broader, cost-effective adoption of foundation reuse in bridge replacement and renewal projects.

3. Objectives and Research Approach

The proposed project objectives include:

The project will explore potential of data science and soil-structure interaction mechanics guided AI (machine learning) approaches to reuse of foundation. Further, the type of analyses and standardization envisaged goes well beyond the current practice in design (currently based upon FHWA methods whose database could be enhanced and which need major refinement for harmonizing ultimate and service limit capacity estimation), technology evaluation and implementation in construction.

4. Description of Research Project Tasks

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

Task 1 – Literature Compilation.

Collection and collation of foundation reuse case studies based upon use of mini-/micropiles available in the literature or obtained through shareable data available with practitioners and DOTs. A thorough investigation of previous research and documented work in the analysis of

axial and lateral capacity enhancement of existing foundation retrofitted with micropiles and related areas will be conducted. These case studies data will be assembled, analyzed, and critiqued to determine relevancy to this project.

Progress: This task has been completed 100%

Task 1 remained complete. Literature information was used as needed to support interpretation and verification of the subsequent analyses.

Task 2 – Evaluation of Case Studies

- Critical evaluation of the case studies collected and collated in Task 1 will be performed to extract the data relevant to this project. The evaluation will consider all parameters related to 3 classes of micropile characteristics, namely, structural, geotechnical and construction. The parameters in these 3 classes will consist of: reinforcement type, casing-type/length and grout material; the subsurface conditions, and construction technique.
- Case studies will be categorized in terms of the completeness and of thoroughness of both quantitative data and descriptive information. Pertinent soil data will be obtained from soil data reports based upon in-situ investigations. In addition, the load testing data will consist both of the proof tests and the so-called "sacrificial" ultimate capacity field tests.

Progress: 95%

The critical evaluation of the case studies was substantially completed. Cause–effect relationships between construction characteristics and foundation response were examined, and the principal sources of uncertainty were grouped according to construction/installation, geotechnical/interface, and structural characteristics. Limitations of the available database were documented, including the absence of sufficiently consistent lateral-response data.

Task 3- Evaluation of Micropile Retrofit Design Methods

- All of the case studies documented in Task 2 will be evaluated against the predicted capacities based upon the widely recommended capacity estimation methods for both service and ultimate failure loadings. This evaluation will present the gap between the traditional design approaches recommended in the design manuals (and other similar documents) and actual capacities achieved in the field. Based upon the PI experience, the actual capacity achieved in the field by these foundation systems depend in a complex manner upon all the 3 classes of micropile characteristics identified in Task 2. Therefore, the capacities predicted by traditional method that do not account for a number of these characteristics cannot be systematically reliable.
- The key purpose of the task will be to establish this gap in knowledge along with the descriptive identification of the sensitivity of micropile capacity to all of the characteristics. We will aim to develop a sensitivity ranking for these parameters, which will then feed into the AI and data science algorithms that will be explored in task 4.

Progress: 80%

A sensitivity assessment of the principal parameters controlling retrofit performance was developed. Grouting parameters, interface stiffness, ultimate shaft resistance, and casing/bonded length emerged as high-priority variables. Installation method and soil conditions were also identified as important variables requiring foundation-type-specific calibration. Parameters for which insufficient information was available were explicitly classified as data gaps rather than being assigned unsupported sensitivity rankings.

Task 4- **Standardization of Foundation Reuse Specifications**

- Develop research question that need further exploration in collaboration with external partners including FL DOT, contractors and practitioners, in particular how data science and soil-structure interaction mechanics guided AI (machine learning) approaches can be incorporated to increase the efficiencies in adopting micropiles for reuse of foundations. This step is expected to be particularly innovative and challenging since the parameter set for the design of micropiles is likely to consist of both quantitative and descriptive elements. Therefore, this last task will be of exploratory nature.

Progress: 50%
The relationship between parameter sensitivity and future data-driven modeling was established. High-priority variables were identified as candidate features for future data-science and soil–structure-interaction-guided machine-learning approaches. Requirements for more systematic collection of construction and load-test metadata were developed.

5. Expected Results and Specific Deliverables

Output: Literature review, a roadmap for standardized foundation reuse approaches, quarterly and final reports, journal articles, and conference presentations.

Outcome: Development of targeted research questions to enable standardization of foundation reuse through capacity upgrading and strengthening using mini-/micropiles.

Impact: Advancement of cost-effective, cost-saving strategies for bridge replacement projects.

6. Schedule

The progress of tasks in this project is shown in the table below.

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

Project tasks	Year 1				Year 2			
1. Literature Compilation								
2. Evaluation of Case Studies.								
3. Evaluation of Micropile Retrofit Design Methods								
4. Standardization of Foundation Reuse Specifications								

7. References

- [1] Misra A, Roberts LA. Axial service limit state analysis of drilled shafts using probabilistic approach. Geotechnical & Geological Engineering. 2006 Dec;24(6):1561-80.
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