ACCELERATED CONSTRUCTION OF PILE FOUNDATIONS BY MEANS OF ELIMINATION

Quarterly Progress Report
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1. Background and Introduction

The advancement of Accelerated Bridge Construction has primarily been through focused effort on deck and superstructure design and construction methods. Further acceleration can be achieved through focused effort on bridge substructures. Ongoing efforts in the State of Iowa may provide benefit to ABC methods by identifying code conservatism. Reducing the total foundation requirements and effort required for substructure construction will result in a reduction of overall construction costs and time.

A project recently completed for the Iowa Department of Transportation investigated the contributions of concrete encasements of steel H-piles used for bridges which have historically not been considered in the design process. The initial reason for the project was to determine the remaining capacity of a pile when subjected to scour, leaving bare the uncased portion of a pile. A tool was developed to calculate capacity and a subsequent laboratory investigation was completed to validate the pile capacity assessment tool. The study concluded the pile capacity is greater than what has been otherwise calculated. As a secondary result, consideration has been given to revising the capacity calculations of new piles especially in fully-encased pile bents. This project aims to identify the unbraced height limits of steel H-piles when fully-encased and thus expedite foundation construction by taking advantage of the increased capacities and reducing the total number of required piles. By addressing design code conservatism, construction time may be decreased.

2. Problem Statement

A project recently completed for the Iowa Department of Transportation investigated the contributions of standard P10L concrete encasements of steel H-piles used for bridges, which have historically not been considered in the design process. The initial reason for the project was to determine the remaining capacity of a pile when subjected to scour, leaving bare the uncased portion of a pile. A tool was developed to calculate capacity and a subsequent laboratory investigation was completed to validate the pile capacity assessment tool. The study concluded the pile capacity is greater than what has been otherwise calculated. As a secondary result, consideration has been given to revising the capacity calculations of new piles especially in fully-encased pile bents.

Fully-encased pile bents are also used for bridges in the State of Iowa with regularity. It is believed that the unbraced height limits of these pile bents may be greater than the limits of individually encased piles when subject to the same axial load. An increased capacity would allow fully-encased pile bents to be used in locations susceptible to greater amounts of scour.

The current practice of designing the fully-encased pile bent in Iowa is to place the weak axis of the pile parallel to the bridge longitudinal direction with the exterior piles battered at a 1:12 slope. The standard orientation and need for battered piles should be reviewed as the possibility exists that there may be additional efficiencies realized by changing to pile orientation and/or removing the need for battered piles.

Current standard design of steel H-pile bents in Iowa does not include the capacity contribution of the concrete encasement that is used to protect against corrosion and other damaging effects.

This has become a notable issue when pile bents are subjected to scour events and a load rating engineering is left to determine the actual capacity of the piles. For this reason, a rapid assessment tool was developed to calculate the capacity of individual concrete-encased piles.

The assessment tool predicted a capacity greater than the calculated capacity of the uncased pile. To further validate the capabilities of the assessment tool, a laboratory investigation was completed which provided results for four different pile encasement variations.

The specimens were tested in a pin-fixed boundary condition without any eccentricity. The results from the experimental tests were compared with the predictions from the assessment tool. These were the key findings:

- The pile assessment tool provides a conservative estimation of the axial capacity of the piles. The prediction results were 8% to 24 % lower than those from the experimental results.
- Concrete encasement increases the initial axial stiffness of the piles.
- Consideration of the concrete encasement greatly increases the axial capacity of the piles.
- Ignoring the effect of the concrete encasement, as with the use of the equations suggested by the AISC, can result in a significantly conservative prediction.

As a result, consideration has been given to include the concrete encasement contribution to newly designed piles in addition to providing a tool to evaluate existing piles.

For new bridge designs it is has been found more cost effective to fully encase the grouping of pier piles in one monolithic pier rather than individually encasing each pile. Currently the decision to fully-encase rather than individually encase the piles is made when there are ice or debris issues associated with the waterway in which the pier stands. Determining that the unbraced height of the fully-encased piles meets or exceeds the unbraced height for the individually encased piles would allow for more fully-encased pile bents to be constructed resulting in a cost savings for bridge projects.

3. Research Approach and Methods

The objectives of this project will be achieved via these three tasks:

1. Literature Review and summary of Phase I findings
2. Expand pile capacity tool
3. Tool validation through laboratory investigation

4. Description of Research Project Tasks

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

Task 1 – Literature Review and Summary of Phase I Findings

A literature review of previously completed research will be added to the resources previously found and summarized in the already-completed project report. As before, the main objective of this task is to obtain an exhaustive understanding of concrete encased steel H-piles used for bridge projects. As part of this task, the design documents for previously constructed bridges in Iowa which monolithically encased pile bents will be gathered to be included in subsequent tasks.

Description of work performed to this period

A literature review has been completed including a study of bridge concrete-encased pile foundations, analytical solutions for the buckling load of partially encased steel H-piles, and the use of monolithic pile encasements.

Task 2 – Expand Pile Capacity Calculation Tool

The tool was first developed to rapidly assess existing piles subject to scour and it proved to be effective in calculating the capacity when including the concrete encasement into the evaluation. Further study expanded the application of the tool beyond assessment of existing piles and into the design of new piles. The concrete encasement used in the tool development is based on the P10L standard, which is the current Iowa design standard for pile bents with steel H-piles. The P10L standard specifies standard dimensions for specific piles sizes, either square or round in cross-section. Accordingly, the capacity of piles in non-standard encasement sizes or in monolithic pile bents is not directly calculated but, rather, inferred from the other calculations. The existing tool has been proven through analysis and laboratory validation and can now be further developed to directly calculate pile capacities beyond those in standard encasements.

As with the development of the first tool, the research team will investigate inelastic buckling, elastic buckling, and plastic yielding of the piles. Numerous finite element models will be created to ensure multiple combinations of encasements and pile exposure are considered. Upon completion of the analysis, the results will be incorporated into the existing tool for an easy user interface.

Description of work performed to this period

Finite element models were developed to investigate the performance of piles. Typical H-pile sizes used in the State of Iowa were used with varying lengths of encasement and soil embedment.

Task 3 – Tool Validation through Laboratory Investigation

The previously developed tool was validated through laboratory investigation. Similarly, the updated tool will also be validated in the laboratory.

In fully-encased pile bents, the cross-sectional dimensions of the concrete encasement is greater than the P10L standard dimensions and therefore the concrete contributes a greater stiffness to the encased portion. Additionally, adjacent piles are positively connected through the encasement.

The influence of additional encasement size and adjoining piles on the capacity of any single pile is unknown. Therefore, the laboratory testing will aim to directly compare the results of the previous study where the P10L standard was used in the test specimens.

The specimen details from the first test are shown in Table 1.

Table 1 – Specimen Details from Previous Pile Capacity Investigation

Specimen	Section	Pile length (ft)	Encasement length (ft)	Experimental (kips)
1	HP10×42	16	N/A	612

2	HP10×42	16	10	715
3	HP10×42	30	20	563
4	HP10×42	38	30	606

The test will directly compare to the results of Specimen 3 which consisted of a HP 10x42 pile with a total length of 30 ft. and an uncased length of 20 ft. In lieu of the P10L encasement, the pile will be encased with two other HP 10x42 piles with a spacing and concrete cross-section consistent with a monolithic encasement. The two additional piles will only be encased and not loaded. The extending pile will be individually loaded in a manner similar to that of the first laboratory study. In this way, the capacity results can be directly compared to the previous specimen and the influence of the encasement and additional piles can be determined.

Further, an additional test will be completed which specifically investigates the system behavior rather than the behavior of an individual pile. The investigation will be completed by constructing a specimen of the same size and dimension of the previous specimen, but instead of holding the adjacent piles short of the point of bearing, the three piles will be of equal length and will fully bear against a reaction block. The point of loading will be on the encasement instead of the pile bottom. This will allow the investigators to determine how loads are distributed between adjacent piles.

Description of work performed to this period

No work has been performed for this task in this period.

Task 4 – Final Report

The project findings from the previously described tasks will be prepared by means of a final report. A summary of activities and results of the finite element model analysis and corresponding laboratory study will be included. A discussion of the modified tool, its capabilities, and its limitations will be provided.

Description of work performed to this period

No work has been performed for this task in this period.

5. Expected Results and Specific Deliverables

An updated and revised design and assessment tool validated by selective laboratory tests will be provided. This tool will aid the design and assessment of driven steel pile foundations with the likely result of pile size or number reduction.

6. Schedule

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

Item	% Completed
Task 1: Literature Review and Phase I Summary	100%
Task 2: Expand Pile Capacity Calculation Tool	65%

Task 3: Tool Validation through Laboratory Investigation	0%
Task 4: Final Report	0%

	Month											
	1	2	3	4	5	6	7	8	9	10	11	12
Task 1: Literature Review												
Task 2: Expand Capacity Tool												
Task 3: Tool Validation												
Task 4: Final Report												