ACCELERATED BRIDGE CONSTRUCTION
UNIVERSITY TRANSPORTATION CENTER

ABC-UTC GUIDE FOR:

Accelerated Construction of Pile Foundations by Means of Elimination

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ABSTRACT

This document summarizes the results of a study to calculate the capacities for monolithic encased piles with different pile lengths and encasement lengths through finite element (FE) simulations. The results indicate that the capacities of H-piles in monolithic concrete encasement are greater than those of individually encased piles. Additionally, piles arranged such that the weak axis is restrained achieve greater capacities than piles arranged with the strong axis restrained. The results of this research can be used by design and load rating engineers to calculate the capacities of concrete-encased H-piles and can be one of many resources utilized in overall bridge design and assessment.

ACKNOWLEDGMENTS

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1. BACKGROUND AND INTRODUCTION

The current standard design of steel H-pile bents in Iowa does not include the capacity contribution of the concrete encasement used to protect piles from corrosion and other damaging effects. This omission is notable when pile bents are subjected to scour events and load rating engineers must determine the actual capacity of the piles.

A previous project (Deng et al. 2018) investigated the capacity contributions of standard P10L concrete encasements of steel H-piles used for bridges. The motivation was to determine the remaining capacity of piles subjected to scour, which leaves bare the unencased portion of a pile, and to develop a rapid assessment tool to calculate the capacity of individual concrete-encased piles. The assessment tool predicted capacities greater than those calculated for unencased piles.

To validate the predictions made by the assessment tool, a laboratory investigation (Liu et al. 2021) was completed involving four different pile encasement variations. The results indicated that concrete encasement increases the piles' initial axial stiffness, consideration of the concrete encasement greatly increases the piles' axial capacity, and ignoring the effect of the concrete encasement yields excessively conservative predictions.

An additional consideration is that for new bridge design, fully encasing a grouping of piles into one monolithic pier has been found to be more cost-effective than individually encasing each pile. Currently, the decision to fully encase rather than individually encase piles is made when ice or debris flows are predicted within the waterway in which the pier stands. However, it may also be the case that the unbraced height limits of fully encased pile bents are greater than the limits of individually encased piles subjected to the same axial loads.

Moreover, the current practice for designing a fully encased pile bent in Iowa is to place the weak axis of the piles parallel to the bridge's longitudinal direction. However, additional efficiencies may be realized by changing the pile orientation.

2. PROBLEM STATEMENT

The results from Deng et al. (2018) and Liu et al. (2021) suggest that the capacity calculations for newly designed piles should be revised, especially for fully encased pile bents.

As part of this work, the characteristics of fully encased piles and the orientation of piles along the weak or strong axis also needed to be explored. Doing so would allow recommendations to be developed regarding maximum unbraced height, pile size and length, and pile orientation and enable the tool developed in Deng et al. (2018) to be expanded to include not only the assessment of existing piles but also the design of new piles with monolithic concrete encasement.

3. FINITE ELEMENT SIMULATION

The capacities of fully encased piles with varying parameters were investigated through finite element (FE) simulations. For comparison, individually encased piles were also simulated. Hundreds of FE models with combinations of different pile section sizes, concrete encasements, pile exposure lengths, and pile orientations were created, and the piles' inelastic buckling, elastic buckling, and plastic yielding were investigated.

Two three-pile models were created (Figure 1), one with the piles' weak axes restrained by the concrete encasement (left) and one with the piles' strong axes restrained by the concrete encasement (right). Each model included three 30 ft long HP10×42 piles spaced 3 ft apart and a 20 ft long monolithic concrete encasement. The concrete encasement was based on the Iowa P10L standard for pile bents with steel H-piles. The width and thickness of the concrete encasement were 9 ft and 16 in., respectively.

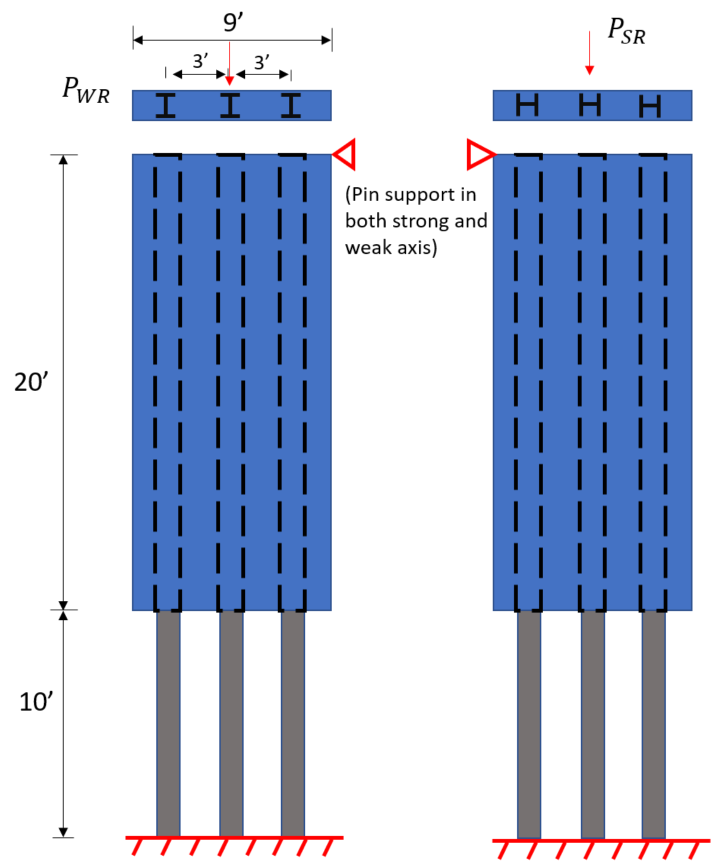

Figure 1. Three-pile models

Two types of loading were applied to each model: single-point loading and distributed loading. The models were loaded over the middle pile.

Because analysis of single piles is preferred for design and load rating, a simplified single-pile model (Figure 2) was developed using the results of the monolithically encased pile models. The single-pile model consisted of a single 30 ft long pile and a 20 ft long concrete encasement based on the Iowa P10L standard. To account for the lateral support from adjacent piles and the concrete, pin supports were assigned along the length of the concrete encasement. The concrete encasement in Figure 2 (left) is restrained in the pile's weak axis, while the concrete encasement in Figure 2 (right) is restrained in the pile's strong axis.

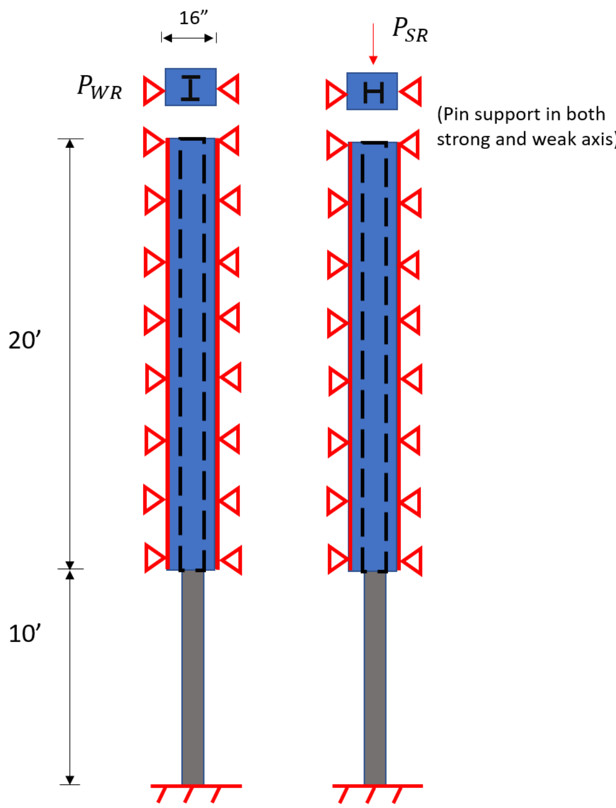

Figure 2. Single-pile models

The single-pile model was compared against the three-pile models with the same pile sections and encasement and pile exposure lengths.

4. KEY FINDINGS AND CONCLUSIONS FOR FULLY ENCASED PILES

The following key findings and conclusions were obtained regarding the design of fully encased piles in monolithic piers:

- For piles with the same length but different encasement lengths, a longer concrete encasement length provides higher ultimate capacities, and vice versa. This indicates that monolithic concrete encasement helps to increase the capacities of steel H-piles
- The ultimate capacities of piles with the weak axes restrained are higher than those with the strong axes restrained. This suggests that a pile design would be more effective with the piles arranged such that the weak axes are restrained.
- A comparison of the results from this work with the results from Deng et al. (2018) for individually encased piles indicated that when the strong axes are fully restrained in monolithic encasement, the models yield similar results. However, the capacities for fully encased piles where the weak axes are restrained are significantly higher than those for piles where the strong axes are fully restrained and for individually encased piles. The capacities increased by a significant percentage when the piles' weak axes were restrained.

5. REFERENCES

Deng, Y., B. M. Phares, and P. Lu. 2018. *Development of a Rapid Assessment Tool for Pile Capacity and Stability in Response to Scour Situations*. Bridge Engineering Center, Iowa State University, Ames, IA.

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