Development of a Rapid Assessment Tool for Pile Capacity and Stability in Response to Scour Situations

tech transfer summary

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RESEARCH PROJECT TITLE
Development of a Rapid Assessment Tool for Pile Capacity and Stability in Response to Scour Situations

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The Bridge Engineering Center (BEC) is part of the Institute for Transportation (InTrans) at Iowa State University. The mission of the BEC is to conduct research on bridge technologies to help bridge designers/owners design, build, and maintain long-lasting bridges.

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This pile assessment tool can be used to quickly calculate the capacity of steel H-piles with concrete encasements and to assist state rating engineers in making rapid decisions on pile capacity and stability.

Project Objective

The objective of this work was to develop a tool to quickly assess bridge pile capacity while taking into account the varying amounts of unbraced pile lengths and the stiffness contribution of concrete encasements.

Problem Statement

From time-to-time, the Iowa Department of Transportation (DOT) rating engineer is called on by field personnel during flood events to make rapid decisions regarding bridge closures and pile capacity and stability when significant scour around pile bents is identified. To quickly make decisions regarding pile capacity and stability based on manual calculations, the rating engineer has historically had to make multiple, on-the-fly assumptions.

Due to complexities in estimating remaining capacity in these atypical situations, the rating engineer must sometimes make conservative assumptions in the interest of providing timely responses. If practitioners are asked to provide timely, realistic estimations of pile capacity and stability, it is desirable to take into account both the increase in pile unbraced lengths and the influence of the stiffness of the concrete encasements.

Background

Scour is defined by the USDA Forest Service as “the erosion or removal of streambed or bank material from bridge foundations due to flowing water” (Kattell and Eriksson 1998) and is the most common cause of highway bridge failures in the US (AASHTO 2012). Scour removes material from around piles and influences the boundary conditions and unbraced lengths of the piles.

Fully encased bridge piles

Individually encased bridge piles

When scour removes soil from around the piles, the unbraced lengths of the piles increase. This increase of unbraced length has a negative impact on the actual capacity and stability of these piles. On the other hand, the concrete encasements around piles is ignored in the pile bent design and by the codified specifications and manuals while the stiffness of the concrete encasements has a positive contribution to pile capacity and stability.

Since experimental work to characterize the strength of columns is generally expensive, numerical simulation offers a more cost-effective approach to develop relationships for quickly estimating the strength and stability of piles.

Project Methodology

To develop a sound numerical evaluation program to evaluate pile conditions, finite element (FE) models were established using appropriate FE modeling techniques. To provide validation of the techniques, FE models were first established for the following:

- Linear elastic buckling analysis
- Non-linear elastic buckling analysis with initial consideration of steel H-piles without concrete encasements
- Steel H-piles with concrete encasements

The basic geometries for individually encased piles were used in the analytical investigation. So, as long as a fully encased pile bent has piles spaced no closer than those used in individual pile bents, the assumption of individual behavior remains conservative.

After validating the FE modeling techniques, the researchers performed parametric studies to understand the influence of concrete encasements on pile buckling strength. The individually encased pile bents used in the P10L standard (currently the Iowa design standard) were the focus of this research.

Five H-pile sections (HP10×42, HP10×57, HP12×53, HP14×73, and HP14×89) were used, taking into account different combinations of the unbraced pile lengths and concrete encasement lengths. The buckling strength of the steel H-piles with concrete encasements was evaluated under two different loading conditions—concentric and eccentric.

Based on the FE results and calibrated results, the buckling strength of steel H-piles with different concrete encasement lengths under concentric and eccentric loads were calculated.

Next, a tool was developed to quickly evaluate the buckling strength of steel H-piles with concrete encasements.

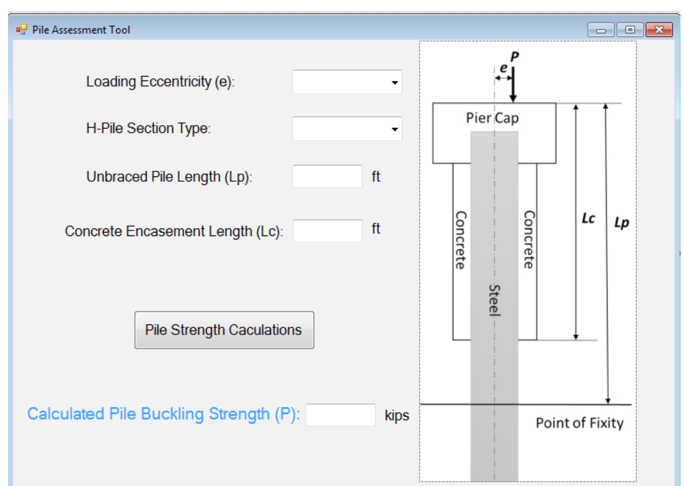
Key Findings

When rating engineers are asked to provide timely, realistic estimations of pile capacity and stability, they need to take into account both the increase in unbraced pile lengths and the influence of the stiffness of concrete encasements.

Because of the threat posed to bridge integrity by scour, the behavior of steel piles with partial-length concrete encasements (i.e., step columns) should be evaluated carefully.

Implementation Readiness and Benefits

In this project, a numerical evaluation program was designed and implemented. The pile assessment tool that was developed can be employed to quickly calculate pile capacity and to assist state rating engineers in making rapid decisions on pile capacity and stability.



Graphical user interface for the pile assessment tool

Users enter values for four parameters to calculate the pile buckling strength (*P*) using this tool:

- Loading eccentricity (*e*)
- H-pile section type (HP10×42, HP10×57, HP12×53, HP14×73, or HP14×89)
- Unbraced pile length (*L*p)
- Concrete encasement length (*L*c)

In fact, the rating engineer could establish the maximum permissible amount of scour for each pile bent prior to any flood event since the tool is relatively easy to use.

References

AASHTO. 2012. *Load and Resistance Factor Design (LRFD) Bridge Design Specifications*, Customary U.S. Units, 6th Edition. American Association of State Highway and Transportation Officials, Washington, DC.

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