Task 2 Report – Experimental Design

Project Title: Concrete-Filled Steel Tube to Concrete Pile Cap Connections-Further Evaluation/Improvement of Analysis/Design Methodologies

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Submitted To: MDT

Date Submitted: January 2021

1 Introduction

The Montana Department of Transportation has found concrete-filled steel tube (CFT) piles connected at the top by a concrete pile cap to be a very cost-effective support system for short and medium span bridges. This type of system offers low initial cost, short construction time, low maintenance requirements, and a long service life. While the gravity load performance of these systems is well understood, their strength and ductility under extreme lateral loads (e.g., seismic events) is more difficult to reliably predict using conventional design procedures. This project aims to further develop newly established design and analysis methodologies to ultimately ensure bridge performance is fully consistent with design intent.

The specific tasks associated with this research are as follows:

Task 1 – Literature Review

Task 2 – Experimental Design

Task 3 – Testing

Task 4 – Analysis of Results

Task 5 – Reporting

This report documents the work completed as part of Task 2 – Experimental Design.

2 Overview

The MDT CFST connection design/analysis methodologies rely heavily on empiricism and may not be valid for all cap configurations/dimensions. In this task, the current methodologies and the research that led to them were thoroughly analyzed to identify potential shortcomings that can be addressed with further testing. An experimental program (to be executed in Task 3) was developed to address the shortcomings identified in this analysis. Specifically, the proposed experimental design will vary load setup, specimen scale, and reinforcement details relative to the original experiments, and provide requisite test results to fully establish the efficacy of the design/analysis methodologies.

This research will begin with the testing of a half-size specimen to provide continuity between this and the previous test series. This specimen will be lightly reinforced, and represent a typical MDT connection design for use in situations where the lateral demand is not expected to control the design. Depending on the outcome of this test, the research may then progress to a 2/3rd-scale specimen with similar reinforcement to isolate any potential effects associated with specimen scale. Upon completion of these initial tests, in consultation with MDT, the additional tests will be designed in response to the results obtained. The nature of the failures and the behavior of the caps as testing proceeds could affect the parameters that should be focused on in subsequent tests. Preliminary analysis of the results from each test will be shared with MDT to obtain input and approval concerning any possible changes to the test matrix. These additional specimens will be designed to further exercise the design/analysis methodology, and will most likely involve specimens designed to fully develop the full plastic-hinge capacity of the CFT, and will possibly involve varying the shear-to-moment ratio.

This document provides details on the loading and instrumentation plans, and provides the specimen dimensions and reinforcing details for the first two tests.

3 Test Setup, Instrumentation, and Loading Scheme

The test specimens will consist of a single connection from an overall bridge bent, as illustrated in Figure 1. In the specimens, the caps will be terminated at the inflection points halfway between CFTs, and the CFT will be terminated at an assumed inflection point along its length. The specimens will be supported and loaded in such a way as to generate the deflected shape expected in this subsection of the full-size bent (as illustrated by the dashed line in the subsection of Figure 1).

In this phase of research, the test specimens will be inverted and tested vertically, as indicted in Figure 2. The concrete pile caps will be post-tensioned to the strong floor, and a hydraulic actuator (reacting against the anchored load frame) will apply a lateral load to the tip of the CFT, as indicated. This loading scheme varies from the scheme used in the previous phases of research where the specimens were tested horizontally on their sides. This variation was made to investigate any potential affects that may have been attributed to the previous test setup.

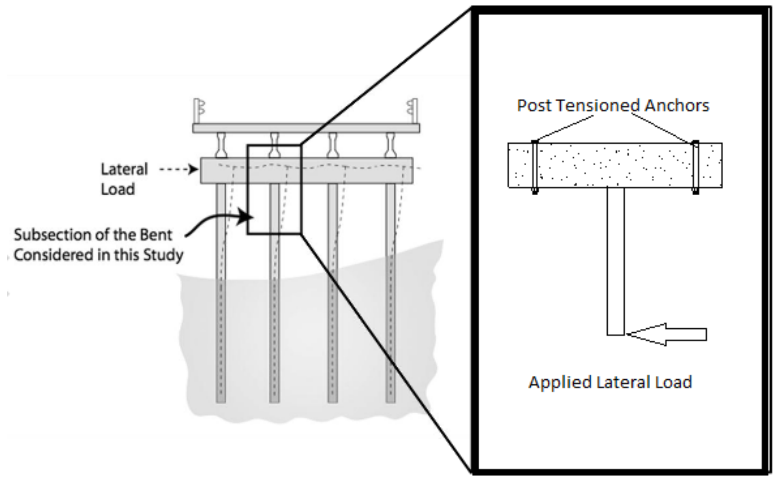

Figure 1: Subsection of bent

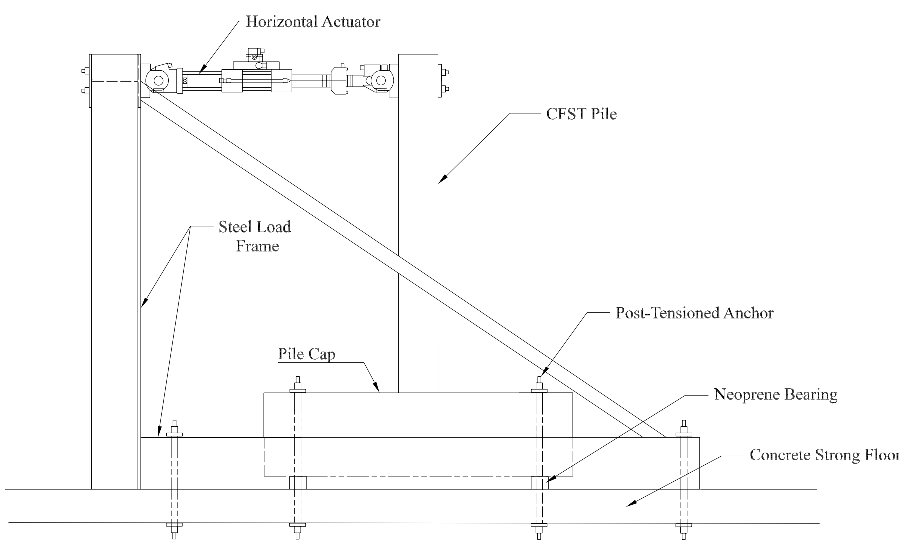

Figure 2: Test Setup

The specimens will be loaded cyclically until failure with the displacement history shown in Figure 3. In this loading scheme, the tip of the CFT will be cycled at 0.5% drift intervals (with three cycles of fully reversed displacement at each interval) until a drift of 4% is reached. At this point, the increase in drift will be at 1% intervals until 7% drift is reached (again with three cycles of fully reversed displacement at each interval). At this point, the drift cycles will be increased at 2% intervals until failure.

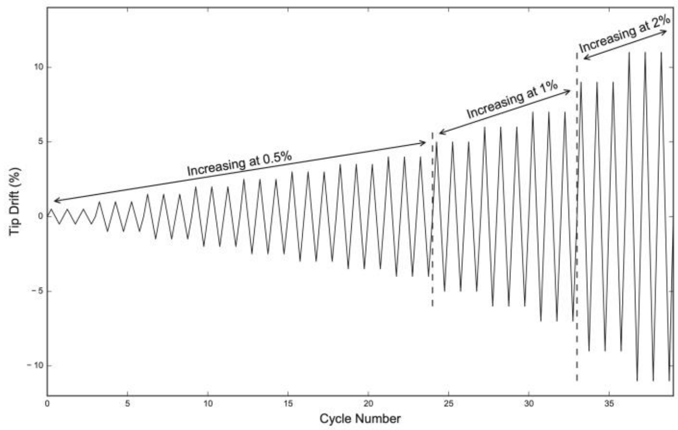

Figure 3: Cyclic loading history (Kappes, 2013)

4 Initial Specimen Design

As stated previously, this phase of research will begin with the testing of a half-size specimen to provide continuity between this and the previous test series. Depending on the outcome of this first test, testing may progress to a 2/3rd-size specimen with similar reinforcement to isolate any potential effects associated with specimen scale. After completion of these first two tests, the testing may progress to specimens designed to fully establish the plastic-moment capacity of the CFT, and specimens designed to vary the applied moment to shear ratio. The preliminary designs for the potential first two tests are presented below.

The proposed test specimens will be scaled from the MDT Standard Minimum design, which is lightly reinforced and is used in situations where the lateral demands are not expected to control the design of the connection. The structural drawings of this Standard Minimum connection are provided in Figure 4. A full-size test specimen based on this Standard Minimum Design is shown in Figure 5. Note that this full-size specimen will not be tested in this research, but is provided here to assist in demonstrating the scaling process. The half- and 2/3rd-size specimen designs are provided in Figure 6 and Figure 7, respectively. In these specimens, the model geometries were scaled from the full-size system, as were the general locations and approximate amount (as a percent of the concrete volume) of reinforcing steel. The minimum spacing between rebar was also considered during the scaling process. It should be noted that, due to testing configuration limits (governed by the location of strong-floor holes), both specimen caps will be 8-ft long, and have a clear span between post-tensioned tie downs of 6 ft.

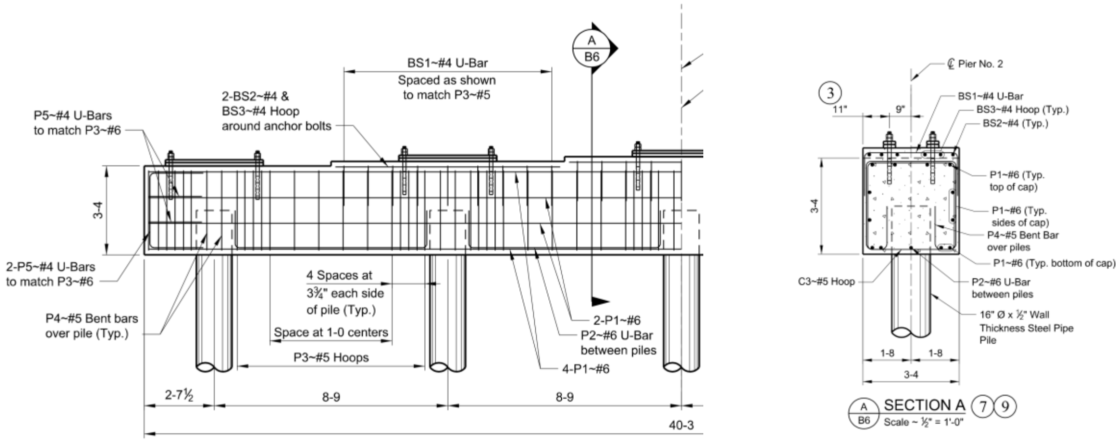

Figure 4: MDT Standard Minimum cap design

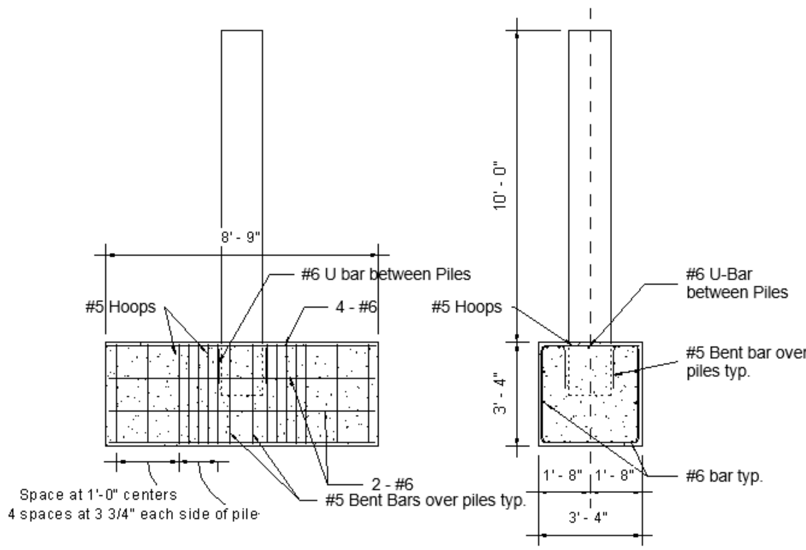

Figure 5: Full-size test configuration

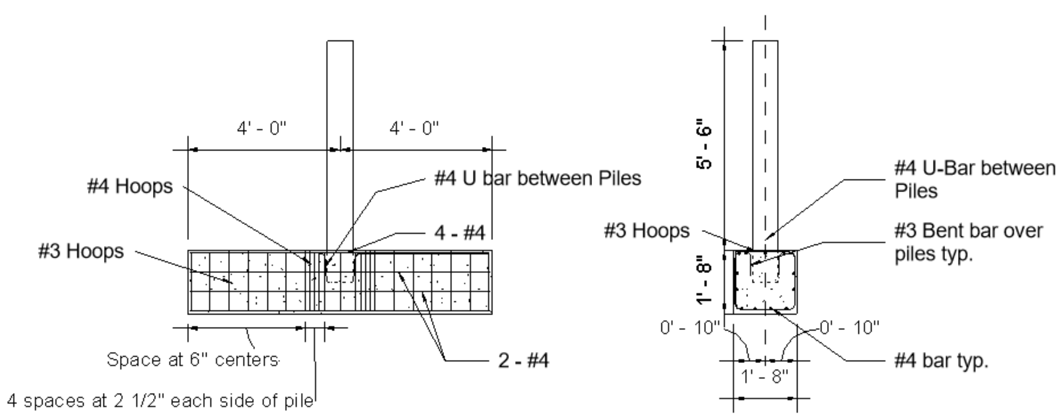

Figure 6: Half-size configuration

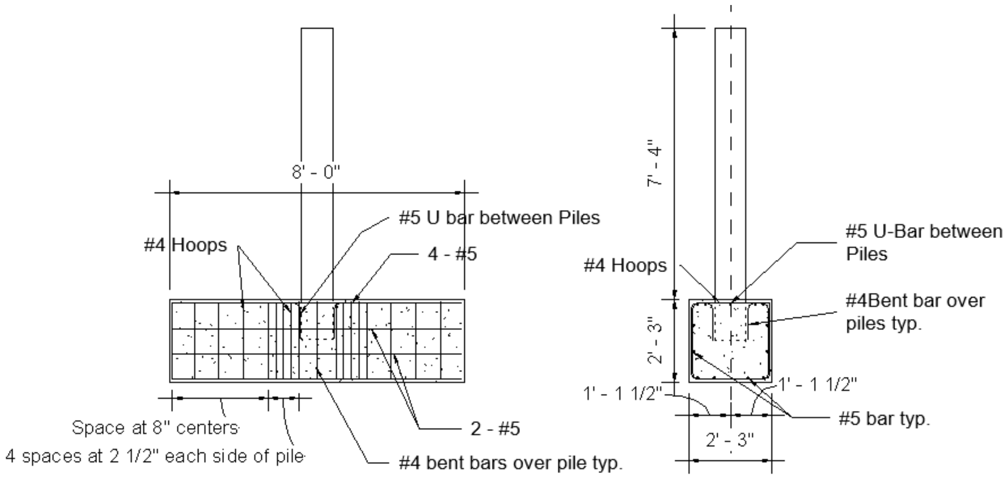

Figure 7: 2/3rd-size configuration

A preliminary design of the load frame has been completed, and will most likely be constructed and installed in early Spring 2021. The instrumentation is currently being calibrated and readied for testing. Construction of the first specimen will begin upon MDT-approval of preliminary design, with testing following shortly thereafter.

5 References

Kappes, L. M. (2013). Performance of Steel Pipe Pile-to-Concrete Cap Connections Subject to Seismic or High Transverse Loading: Phase III Confirmation of Connection Performance.