NEW SESIMIC-RESISTING CONNECTIONS FOR CONCRETE-FILLED TUBE COMPONENTS IN HIGH-SPEED RAIL SYSTEMS

Quarterly Progress Report
For the period ending May 30, 2018

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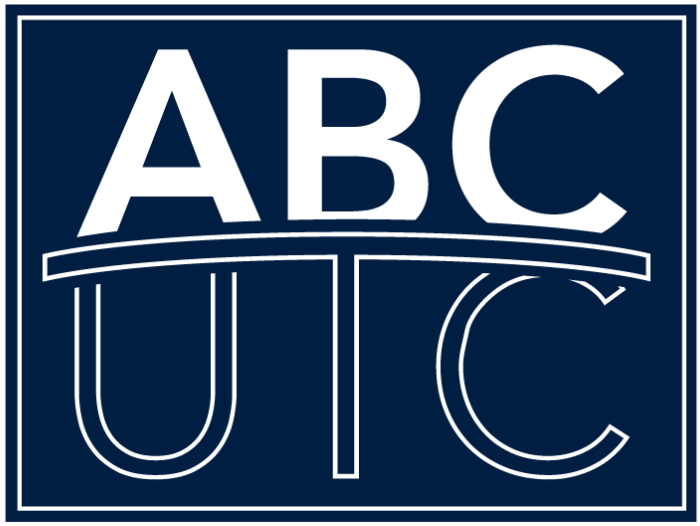

ACCELERATED BRIDGE CONSTRUCTION
UNIVERSITY TRANSPORTATION CENTER

Submitted to:
ABC-UTC
Florida International University
Miami, FL

1. Background and Introduction

In seismic design of transportation structures there are several competing demands that must be met: high strength and stiffness, large ductility, damage resistance and efficient construction. Prior research at the UW demonstrates that concrete-filled tubes (CFTs) can meet these competing demands. For a given diameter, CFTs have larger strength and stiffness than an RC component. Testing of CFT connections demonstrates their ductility, with drift capacities larger than 8%. When used with precast components, CFTs facilitates ABC.

This research builds on the prior CFT research to develop connections specific for use in structural systems for high-speed rail (HSR). While the FIU study focuses on the column-to-cap connection, this study will investigate a new, untested direct column-to-pile connection. This connection is critical to the structural performance and cost of the system, but few studies have focused on it, in particular for ABC. This study will advance design and construction of pile connections for HSR.

2. Problem Statement

The research will investigate the connection and HSR system response using advanced, nonlinear analysis methods. A thorough literature review will identify types of connections and document their structural response; the UW team will work with the HSR team to identify one or more connections for further study. Using high-resolution finite element modeling, salient parameters of selected connections, including materials, geometry, and soil-structure interaction, will be studied. Those results will be used to develop spring and line-element nonlinear models of the components and connections as a function of the important connection parameters. The final research task will investigate the seismic response of a prototype HSR CFT system using these nonlinear models. Connection design details, seismic performance objectives, seismic hazard levels, and soils will be varied to study their impact. The results will provide important initial guidelines for the connection design and seismic performance which will found a future experimental research study to validate the work.

3. Research Approach and Methods

The overall goals of the proposed research are to:

- Investigate CFT connections and other column-to-pile connections through a literature review.
- Select column-to-pile connections for study in consultation with the CA HSR technical team.
- Investigate the seismic response and resilience, including damage, of selected CFT connections using high-resolution finite element analyses.
- Identify a HSR system for study, in collaboration with the CA HSR technical team.
- Using the identified system, conduct a limited structural analysis simulation using line-element nonlinear modeling methods to investigate the impact of salient parameters on the response including (1) connection type, (2) soil structure interaction and (3) seismic hazard level.

- Report findings to the CA HSR with a proposed experimental testing program to investigate and validate the connections.

4. Description of Research Project Tasks

The following is a description of tasks. To date, none of these objecties have been achieved because the funding is not here and a graduate student has not been hired.

Task 1 – Literature Review and Agency Discussions.
A comprehensive review of past experimental research will be completed. Experimental results evaluating resistance, stiffness, and force-deflection of direct column-to-pile connections will be studied. It is anticipated that Task 1 will be completed within the first two months of the research study.

Task 2 –Collaboration and meeting(s) with CAHSR.
The UW research team will meet with the CAHSR technical team with the objectives of (1) understanding the design objectives for the column-to-pile connection, (2) investigating what agencies in other parts of the world have done in developing High Speed Rail, and (3) identifying a possible system for further investigation though nonlinear analyses. It is expected that this meeting will take place 3 months after the initiation of the project. The team will not proceed with the other tasks until approved by the CAHSR.

Task 3 – Investigation of Connection Design Parameters though FEA
A parametric study of the connection will be conducted the modeling approach developed by Moon, Lehman and Roeder in 2013. The analytical program will (1) simulate the bond condition of a straight-seam tube and (2) investigate spacing and geometry of the interior rings proposed to provide mechanical bond (Fig. 3). Bond stress is viewed as a critical parameter in the analysis. The CFST composed of a straight-seam tube and concrete without a low-shrinkage admixture (No LSA), had very little bond capacity in comparison with the other CFST specimens.

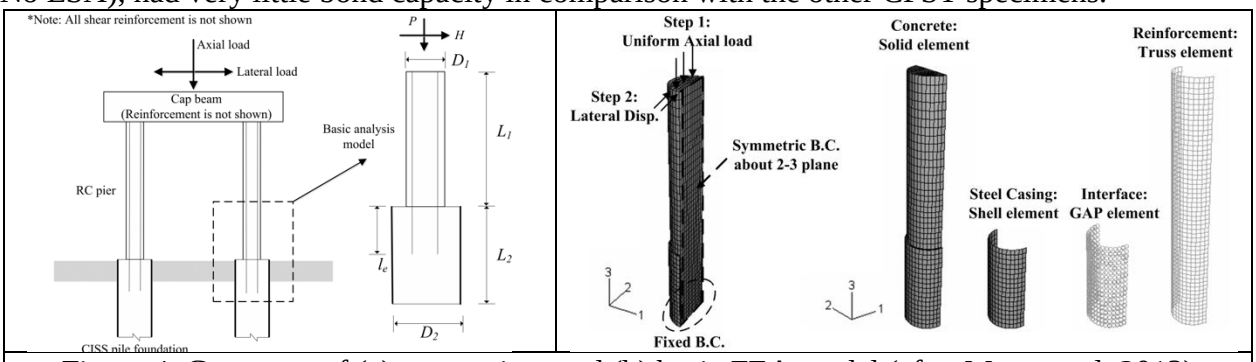

Figure 4: Geometry of (a) connection; and (b) basic FEA model (after Moon et al. 2013)

Task 4 – Performance Evaluation of System Presently Under Consideration.
Working with the CAHSR team, the UW team will identify an HSR system for structural investigation using nonlinear analysis methods. It is expected that a zero-length, fiber-section element will be used to simulate the connection(s), while distributed plasticity elements will be used to model the columns and piles; this approach will be calibrated using the results from Task

3. However, it is not possible to fully develop design guidelines for the connection without experimental results (this experimental program is proposed as a future task). Horizontal and vertical springs will be used to model soil-structure interaction. Both gravity and seismic demands will be studied. The UW team has developed both connection and column models as part of a prior study (Stephens 2016) and these modeling approaches will be used here. With the time limits, it is expected that a limited study will be conducted with the primary variable soil-structure interaction.

Task 5 – Final Report.
A Final Report will be written that summarizes the methods used and the findings reached during the project. Detailed information about and results from the analyses conducted in Tasks 3 and 4 will be summarized in the analyses. The report will also present future research studies to further investigate the connections experimentally; the experimental results are required to fully develop design expressions for the connections.

5. Expected Results and Specific Deliverables

Tentative ABC-UTC Guidelines for Design and Behavior of Column-to-Pile Connections.
Initial guidelines will be developed for the connection designs. These designs are conceptual and expected to be followed by experimental testing; this testing is critical to investigate the salient design methods and parameters as well as to validate the modeling approaches. To the extent possible will take into account the conditions in which the HSR is to be built (e.g. seismic vs. non-seismic, soil-structure interaction for different soil conditions, etc.) Seismic conditions will be a primary design constraint given the focus on the California HSR route.

A five-minute Video Summarizing the Project
A five-minute video will be produced that summarizes the project in collaboration with FIU.

Conceptual designs for a representative CA-HSR bridge.
Conceptual designs, based on the prototype system, will be prepared. Descriptions, calculations and drawings prepared for those systems will enable CAHSR to evaluate both the structural performance and the likely construction time and cost

6. Schedule

Quarter 1 is going to be in Fall 2018 after a student is hired and a visiting student joins the project team.

Task Number and Description		Y1 Q1	Y1 Q2	Y1 Q3	Y1 Q4
Task 1	Literature Review	Deliverable: Summary and Excel Database			
Task 2	CAHSR Collaboration	Deliverable: Interim Report			
Task 3	FEA Analyses	Deliverable: Connection Behavior and Initial Designs			
Task 4	NLA of Prototype System	Deliverable: NLA recommendations and results			
Task 5	Reporting	Deliverable: Final Report			
Coordination: Virtual and in-person meetings with CAHSR		Virtual	In Person	Virtual	in Person