MPC-638
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Project Title

Analysis of ABC Bridge Column-to-Footing Joints with Recessed Splice Sleeve Connectors

University

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Research Needs

Accelerated Bridge Construction (ABC) has been implemented in bridge construction since it provides significant advantages for commuters in urban areas. Recently, ABC has gained attention within regions of high seismicity. Prefabrication of bridge structural components is a highly effective method and is one of the ABC methods of Prefabricated Bridge Elements and Systems (PBES) proposed by the Federal Highway Administration. Connections between such precast components play an important part in the overall seismic performance of bridges. There is a need to develop ABC column-to-footing joints for bridges located in high-seismic regions and robust analytical models are an important component of this effort. Grouted splice sleeve connectors are assumed for assembling the column-to-footing joints and in particular these are joints where the bars are grouted at both ends (GGSS). Current designs of PBES incorporating ABC often use GGSS at the interface of the elements being connected. This research aims to understand the effect of placing the GGSS inside the footing and recessing them below the column-to-footing interface. The gap between the end of the GGSS and the column-to-footing interface is assumed to be grouted inside corrugated steel ducts. The main goal of the study is to show that such joints constructed with precast elements perform in a satisfactory manner similar to monolithic cast-in-place (CIP) joints. A second goal of the research is to develop guidelines for the seismic design of these joints. This is an important step in the implementation of ABC in seismic regions.

Research Objectives

The objectives of this project are:

(1) develop analytical models to implement the use of alternate designs for column-to-footing joints with recessed splice sleeve connectors.

(2) examine the use of alternate designs of column-to-footing joints as components of an actual bridge and develop design guidelines for ABC bridges in seismic regions.

(3) perform static pushover analysis, quasi-static cyclic analysis, and nonlinear dynamic analysis under scaled earthquakes.

(4) present the results at national conferences and journal publications.

Research Methods

The proposed research will evaluate the performance of alternate bridge column-to-footing joints constructed with ABC methods under cyclic and earthquake loads. The research will be performed by comparing the analytical results to experiments of prototype bridge columns constructed using ABC methods for column-to-footing joints (Tazarv and Saiidi 2015; Ameli et al. 2016, Barton 2020). Analytical models will be developed for implementing these systems using OpenSees (McKenna et al. 2000). The methods of analysis will include static pushover analysis, quasi-static cyclic analysis, and nonlinear dynamic analysis under scaled earthquakes. The alternate design of column-to-footing joints will be implemented in actual bridge simulations. Design guidelines will be develop for implementation of such details in ABC bridges in seismic regions.

Expected Outcomes

The research will provide an effective approach for constructing new bridge column-to-footing joints using ABC in high seismic zones. Analytical models will be developed in OpenSees (McKenna et al. 2000) with design recommendations for implementing the results of the research. One of the expected outcomes of the study is bridge columns with low damage after large earthquake events. A second outcome of the study is column-to-footing joints that perform similar to monolithic cast-in-place joints in high seismic regions.

Relevance to Strategic Goals

State of Good Repair

The column-to-footing joints to be analyzed in this proposal are important for developing bridges using precast columns for high seismic regions. Under current design specifications, bridge collapse under severe earthquakes is prevented but damage is allowed. New ABC techniques are emerging for connecting precast columns to footings or cap beams in high seismic regions. A new concept consisting of recessed mechanical connectors, in this case grouted splice sleeves, will enable the development of precast bridge column-to-footing joints that would perform similar to monolithic cast-in place bridges under strong earthquakes. The analytical methods developed will be compared to experimental results and design guidelines will be produced.

Educational Benefits

One PhD student will be involved in the analytical and design work. The technology transfer activity will involve high school students through an Annual Exploring Engineering Camp, during which small-scale models will be built to show details of the bridge columns. In addition, small-scale models will be constructed by students during a mini-engineering day. The P.I. will make a presentation at the annual UDOT Engineering Conference and at other national conferences.

Technology Transfer

The main objective of this research is to create an alternate detail of column-to-footing joints for accelerated construction of bridges in seismic regions. There is a need for developing such innovative technology and the proposal addresses that need. The resulting technology will create bridges that are seismically resilient and emulate the performance of cast-in-place bridges. The work will be presented at conferences such as the Transportation Research Board Meeting and leading journals such as the Journal of Bridge Engineering, ASCE. In addition, a webinar will be presented through the Transportation Learning Network. A presentation will be made at the Utah Department of Transportation Annual Conference. In addition, technology transfer will occur through workshops, web pages, social media, and seminars, including the Annual AASHTO Subcommittee on Bridges and Structures Meeting.

Work Plan

The proposed study will consist of the following tasks:

Task 1. Build analytical model of column-to-footing joint – 3 months

An analytical model for a cast-in-place and a precast column-to-footing joint will be built. Force-based beam-column elements with fiber sections will be used to construct the computational model based on plastic hinge weighted integration, as shown in Figure 1. The model will include the effects of low-cycle fatigue and bond-slip (Ameli and Pantelides 2016). The proposed model will be validated with experiments through both local and global response comparisons.

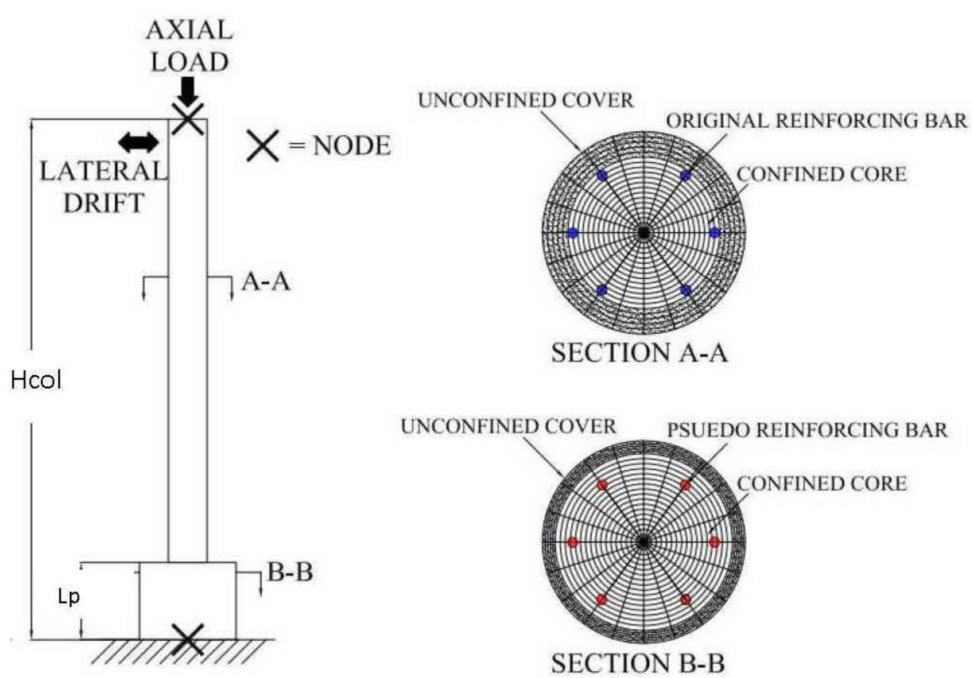

Figure 1. Schematic of numerical model using fiber elements.

Task 2. Perform analysis of bridge column-to-footing joints with recessed splice sleeve connectors - 6 months

The objective of this part of the computational study is to develop a predictive modeling strategy for simulation of precast concrete bridge columns with recessed grouted splice sleeve connectors. Recently, two columns were constructed using recessed grouted splice sleeve connectors for 6 in. into the footing, as shown in Figures 2 and 3 (Barton 2020). The experiments showed excellent hysteretic performance and this performance will be simulated in this research.

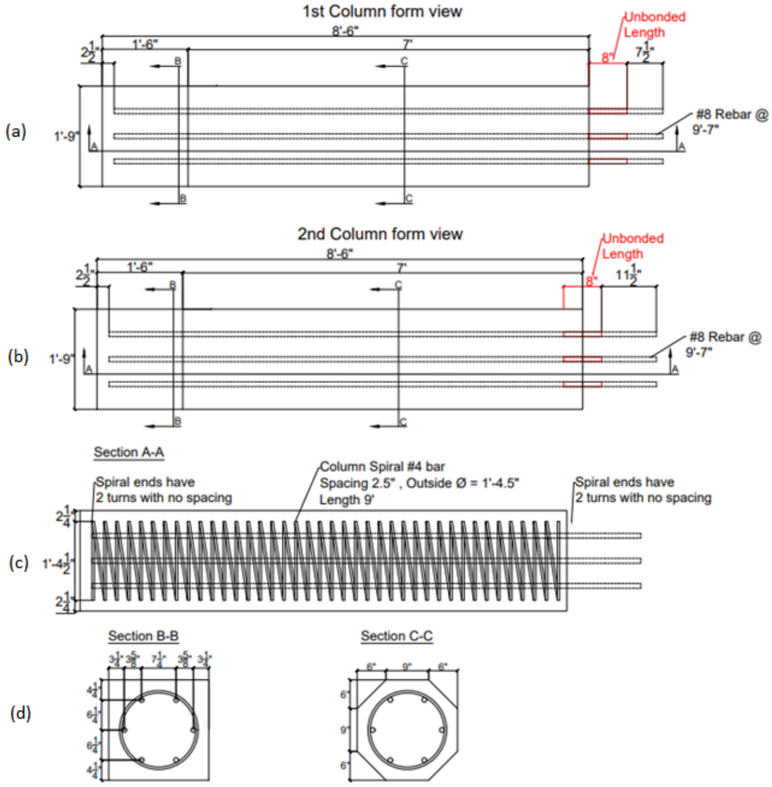

Figure 2. Column details: (a) Test 1 column; (b) Test 2 column; (c) Column reinforcing details; (d) Column cross-section.

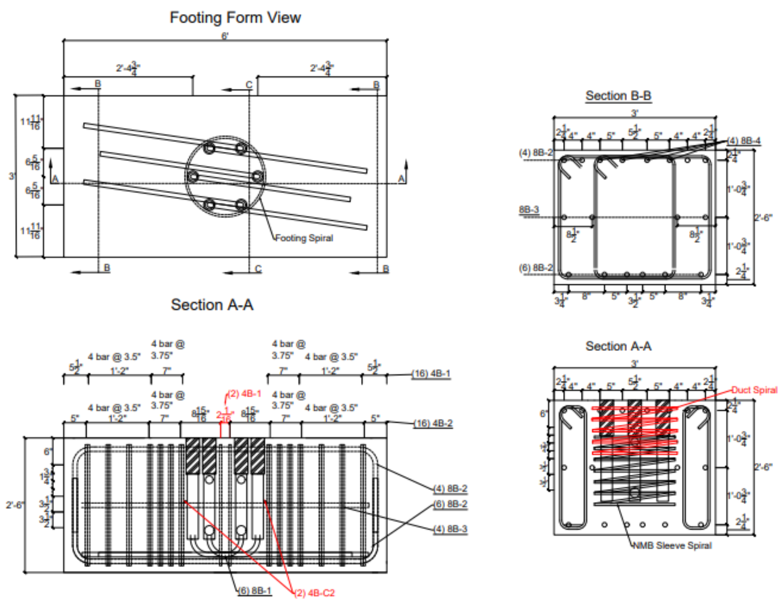

Figure 3. Footing details.

Special emphasis will be placed on the reduced displacement capacity of such bridge columns compared to conventional cast-in-place bridge columns. Several options will be developed and examined and will be compared to existing experimental results (Ameli et al. 2016). The computational models will be based on beam-column elements with distributed plasticity. In the distributed plasticity models or fiber models, nonlinear material behavior can occur at any element cross-section, as shown in Figure 1. These cross-sections are discretized into a finite number of fibers and pertinent uniaxial material stress-strain relationships are assigned to each type of fiber. Numerical integration is evaluated along the element to obtain the global response. The models will involve the development of static pushover analysis, quasi-static cyclic analysis, and nonlinear dynamic analysis under scaled earthquakes.

Task 3. Analysis and seismic design of bridge bent – 3 months

In this task, a numerical model will be created to assist in the development of a design method for implementing the proposed bridge column-to-footing joints. The model will be calibrated with the results of Task 2. Two types of analysis will be performed: (1) static cyclic analysis to find the capacity of the column-to-footing joints, and (2) nonlinear time-history dynamic analysis to find the level of demand on the bridge bent. This will provide information on capacity-demand relationships for the column-to-footing joint alternatives, and will reveal more insight into the overall behavior of the bridge under various input ground motions. Four parameters will be used to determine their influence on the design and seismic response of the prototype bridge bent, which are: design displacement ductility, column axial load, column aspect ratio, and column longitudinal bar steel ratio. The bridge bent with ABC details will be analyzed using models with a capability to perform static pushover analysis, quasi-static cyclic analysis, and nonlinear dynamic analysis under scaled earthquakes.

Project Cost

Total Project Costs:	$117,857
MPC Funds Requested:	$ 59,857
Matching Funds:	$ 58,000
Source of Matching Funds:	University of Utah, $46,200
	Reaveley Engineers, $11,800

References

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