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# LESSONS FROM BIAXIAL SHAKE TABLE STUDIES OF A TWO-SPAN ABC BRIDGE SYSTEM WITH SOCKET CONNECTIONS

M. Saiidi [1], J. Jones [2]

[1] *Professor Emeritus, University of Nevada, Reno, Distinguished Researcher, UCLA, saiidi@unr.edu*
[2] *Bridge Engineer, Alaska Department of Transportation, jaredjones181@gmail.com*

***Extended Abstract***

Accelerated bridge construction (ABC) of concrete bridges utilizes prefabricated components that include concrete deck elements, girders, diaphragms, cap beams, columns, and footings. Connections among these components are critical to ensure reliable load path, structural integrity, resistance against vertical and lateral loads, and ductile structural fuses. This consideration is particularly important for bridges in high seismic zones because some bridge elements typically undergo large plastic deformations and the connections must remain intact to accommodate these deformations and enable the bridge to dissipate the earthquake energy.

Bridge components may be placed in two categories: capacity protected and ductile. Those in the first group are designed to remain essentially elastic with no yielding, whereas the bridge elements in the second category are designed to yield, undergo large inelastic deformations, and still maintain their strength. As a result, the performance criteria for these ABC connections are not uniform. For example, whereas the connections among prefabricated deck panels should ensure capacity protected behavior of both the connection and adjoining elements, the connection between the cap beams and columns should guarantee capacity protected behavior in the cap beams and connection themselves but ductile nonlinear behavior in the columns to dissipate energy.

The presentation in this keynote speech is about one of the three 0.35 scale, two-span concrete bridge models that were tested on shake tables under simulated earthquake runs with successively increasing amplitudes until failure. The study was funded by the California Department of Transportation. Figure 1 shows the details of the bridge model that will be the focus of this presentation. Each of the three bridge models incorporated six connection types (referred to as ABC connections in this abstract) joining different prefabricated elements. Ultra-high performance concrete (UHPC) was used in some of the connections. The superstructure was continuous, supported by seat-type abutments and a two-column pier with circular columns at the center. Plastic hinging in the bridge model shown in Fig. 1 was expected at the top and bottom of the columns that utilized pocket connections at the top and socket connections at the bottom. The columns were fully prefabricated and inserted into openings in the cap beam at the top that was subsequently filled with high-strength grout. However, the bottom ends of the columns were prefabricated only to the level of the footing top with steel reinforcement cages extended and were placed inside openings

in the footing. The openings were filled with grout subsequently. The column connections at the top modeled integral bent cap joints with full moment transfer but at the bottom the connections were two-way rebar hinges with reduced moment transfer to the footings. This detail is used at the base of many piers with two columns or more to reduce the size of the footings.

What is particularly unique about this study is that, unlike many of previous shake table tests, the connections were subjected to biaxial seismic excitations, both in the in-plane and out-of-plane directions. Past research of two-column bridge piers focused only on the in-plane behavior. The combined loading in the in-plane and out-of-plane directions could increase critical stresses that would alter the damage mode in the connections.

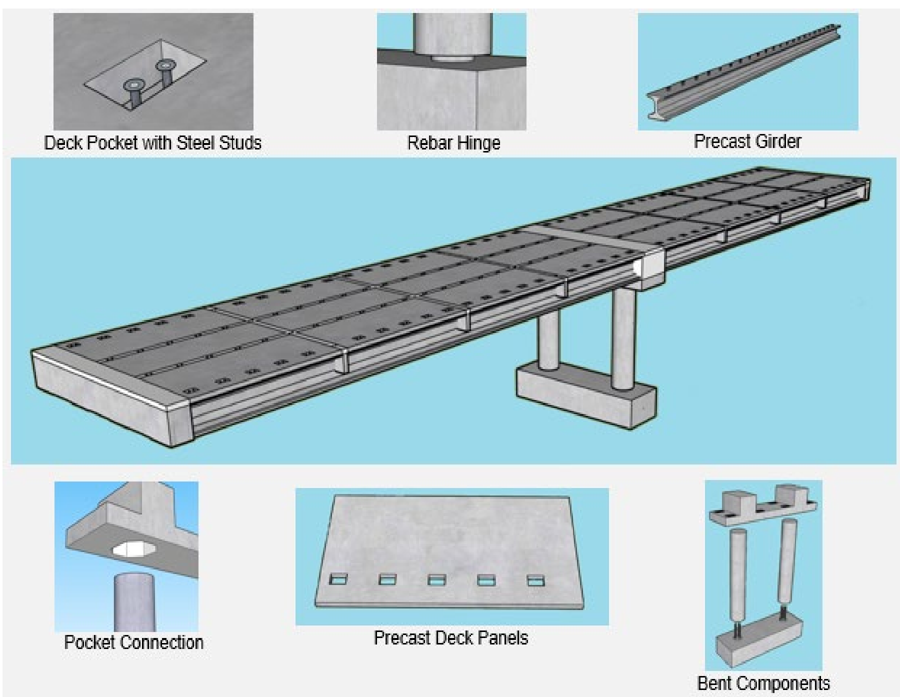


Figure 1- Details of bridge model.

The shake table tests showed that the design of all the components and connections met or exceeded the target performance even under earthquake amplitudes that were approximately twice the design level earthquake. Plastic hinges were formed at column ends and no damage was observed in the capacity protected elements and connections. The highlights of the design, construction, testing protocol, instrumentation, measured behavior of the bridge under excitations of different intensities, post-testing analytical studies, and lessons learned from the study will be presented.

***Keywords***: *Seismic; socket connections; accelerated bridge construction; shake table testing; prefabricated.*