Development of Prefabricated Concrete Bridge Railings

QUARTERLY PROGRESS REPORT

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Submitted by

Sri Sritharan, Terry Wipf, Ashley Ecklund

Department of Civil and Environmental Engineering

Iowa State University

Ames, Iowa

Submitted to

Atorod Azizinamini

Director, ABC-UTC

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A. DESCRIPTION OF RESEARCH PROJECT

Many organizations are promoting and utilizing Accelerated Bridge Construction (ABC) practices to reduce traffic impacts and to reduce societal costs. One of the most common means to achieve ABC is to utilize prefabricated elements which are brought together, on-site, to construct the in-place bridge. The purpose of this research is to begin the process of developing crash-tested prefabricated concrete bridge railings that have durable anchorage details.

The developed prefabricated bridge railings must be attached to a bridge superstructure with durable connections that satisfy the MASH 2009 Specification. Needed anchorage systems include details that connect the prefabricated bridge railing to the bridge deck and details that connect one prefabricated bridge railing to an adjacent prefabricated bridge railing. The end products of this research will be crash-tested prefabricated bridge railings with recommended durable anchorage systems and details that meet design test level TL-4 in accordance with MASH and LRFD Bridge Design Specifications.

A.1. PROBLEM STATEMENT

With the significant interest in ABC there has been valuable research in many important and varied areas. However, one area that has not yet received notable research is in the area of prefabricated, crash-tested barrier rails. As a result, ABC projects to date have tended to rely upon systems that utilized crash-tested systems integrated into other, larger prefabricated elements. Although this has proved sufficient while ABC has been in its relative infancy, there is a critical need to develop prefabricated bridge railings that have been crash-tested.

A.2. RESEARCH APPROACH AND METHODS

To achieve the complete objective of developing crash-tested prefabricated bridge railings, a two-step process will be required. In brief, the two steps will be: (1) development and laboratory testing of prototype concepts and (2) crash-testing of promising concepts. The work completed here will be restricted to item (1). It should be pointed out that a plan for implementing (2) has already been put into motion.
A.3. DESCRIPTION OF TASKS TO BE COMPLETED IN RESEARCH PROJECT

Following are description of tasks as described in the proposal and their current status.

**Task 1:** Conduct a national literature search to review all bridge railing (cast-in-place and prefabricated railings) designs and details including anchorage systems that have been crash tested for use on the national highway system by state DOTs and private agencies. Survey state DOTs to determine their needs related to prefabricated bridge railing. Information from research projects through the NCHRP, SHRP2, FHWA, and other national, state, and pooled-fund sponsored research will be reviewed as part of this task. Railing shapes that meet the current MASH requirements will be considered in this task and subsequent tasks. As part of this search, consideration will also be given to the different types of elements used in prefabricated bridges.

There are a few different permanent precast concrete barriers that have been developed with different anchoring methods. Precast barriers are generally categorized by the shape of their profile. The New Jersey shape, the F-shape and the single slope are the three most commonly used precast concrete barrier profiles in the United States.

Common methods for anchoring precast concrete barriers to bridge decks include through-deck bolts and adhesive anchors. With the through-deck anchoring method, a hole is drilled through the entire bridge deck and a bolt is inserted through both the barrier and the deck. It is secured with heavy washers and nuts on both ends of the steel bolt. One issue with this design is getting access to the underside of the bridge to secure the nut. Another issue is weathering of the exposed connection. Figure 1 shows a typical anchoring detail for the through-deck configuration.
A different way of connecting a barrier with the through-deck method is by pretensioned rods that are inserted all the way through the wall and the deck slab. They are then anchored to the bridge deck by end plates, washer, and nuts. An example of this can be seen in Figure 2.

Another precast concrete barrier anchoring technique that is used is an adhesive-bonded anchor. This method is completed by drilling a hole into the bridge deck and then inserted the threaded bolt through the barrier and into the deck. The bolt is then secured with an adhesive. This method can be seen in Figure 3. One issue with this anchoring method is the strength of the adhesive used.
A precast barrier wall system similar to the adhesive anchored connection is engineering and patented by Clampcrete. It has been crash tested and approved for use. It is connected to the bridge deck by polyester resin anchors that are drilled into the bridge deck. This system is shown in Figure 4.

**Task 2:** Based upon the results of the literature search, the research team will develop conceptual prefabricated railings with associated anchorage systems and details. Although the ultimate goal is to develop a system that can be adopted for multiple railing shapes, only one shape will be utilized in the experimental program to be conducted in Task 3. At a minimum, the concepts will consist of details for connecting the rails to the deck and for connecting adjacent rails. It is
anticipated that a minimum of three different rail-to-deck and three different rail-to-rail systems will be conceptualized.

For this project, based on a nationally conducted survey, an F-shape profile was chosen. When connecting the precast concrete barrier to the bridge deck, two connection concepts were designed. The first design concept includes a u-shaped stainless steel bar that is inserted through the bottom of the bridge deck and into the barrier segment. The u-shaped rebar will then be secured with 10 ksi, non-shrink, fiber grout. This concept can be seen in Figure 5.

![PRECAST CONCRETE BARRIER DETAILS OF CONNECTION USING U-BAR](image)

*Figure 5 Details of Connection Using U-Bar*

Another concept consists of an inclined stainless steel bar and bar splicer. The bar splicer will be precast into the bridge deck. Then the stainless steel bar will be inserted into the barrier segment and threaded into the bar splicer. This connection will also be sealed with grout and is shown in Figure 6. Figure 7 shows a photo of the bar splicer that will be used.
The barrier-to-barrier connection detail includes four headed rods precast into the end of the barrier segment. The headed rods are inserted into a pocket in the adjacent barrier. Figure 8 shows this detail. Also, more detailed drawings of the barrier test concepts are included at the end of this report.
The test level 4 design load of 54 kips was used to design the connections. To limit the damage to the barrier and bridge deck, the connections were designed to allow the connections to fail instead of the barrier and bridge deck.

**Task 3:** The two barrier connection systems shown above have been tested in the laboratory with quasi-static testing. The loads were applied cyclically using a hydraulic actuator. The systems will be evaluated based upon how they impact their individual strengths and how they impacted the performance of the deck overhangs used to support the railing. The actuator that will be used in shown in Figure 9.
The barrier segments were tested individually to test the barrier to deck connection. Then they were connected and tested again. The force was applied at the joint to measure the force distribution. A ponding test will also be conducted on the connections to test for durability. A schematic drawing of the lab test set-up can be seen in Figures 10 and 11.
Three concrete beams support the deck slab. The deck slab will have an overhang of 3.5 feet. The hydraulic actuator was mounted onto the concrete block to apply load along the precast barrier segments. The concrete blocks are anchored into the lab floor. The concrete beams and the formwork for the suspended deck slab are shown in Figure 12.
The construction of the barrier rails was fabricated by a precast plant in Omaha. They were delivered to the Iowa State Lab February of 2016. Images of the precast construction are shown in Figure 13.

![Figure 13 Precast Barrier Fabrication](image)

The construction of the deck slab and the loading block were done in the Iowa State University Structures Lab. The following images (Figures 14-16) display the progress in the lab.
Figure 14 Inclined Bar Connection in Bridge Deck

Figure 15 Pockets for U-bar Connection in Bridge Deck
Laboratory testing began March of 2016. The first laboratory test was conducted on the precast barrier with the inclined rod connection, PBI. The loading block and actuator were set up to apply loads to the center of PBI. The test setup is shown in Figure 17. The push load was applied incrementally up to 54 kips. It was applied in six kip increments.
The barrier performed as expected. Cracks developed along the deck around 18 kips. It wasn’t until the loading reached 48 kips that diagonal, hairline cracks began to form on the barrier near the barrier to barrier interface. The maximum deflection of the barrier was measured at 0.807 inches. Photos of the barrier performance can be seen in Figures 18 and 19.

![Figure 18 Test 1 (PBI Middle) Deck Cracks](image1)

![Figure 19 Test 1 (PBI Middle) Barrier Cracks](image2)
Test 2 will include the testing of the barrier with u-shaped connections and will begin April 2016.

**Task 4:** A final report will be developed that documents the entire project with a special emphasis on the results of Task 3. More importantly, recommendations for rails on which full-scale crash testing should be conducted will be made. If appropriate, the research team will make recommendations for potential modifications to the details.

The final report is anticipated to be submitted May of 2016.

**A.4. EXPECTED RESULTS AND SPECIFIC DELIVERABLES**

The primary deliverable resulting from this work will be barrier rail recommended to undergo full-scale crash testing.
References:


APPENDIX A

Detailed Prefabricated Concrete Barrier Drawings
STAINLESS STEEL BAR WITH THREADED END AND BAR SPACER CONNECTION