

JOINT TRANSPORTATION RESEARCH PROGRAM

Principal Investigators: Robert J. Frosch, Purdue University, frosch@purdue.edu, 765.494.5904

Michael E. Kreger, The University of Alabama, mekreger@eng.ua.edu, 205.348.3213

Program Office: jtrp@purdue.edu, 765.494.6508, www.purdue.edu/jtrp

Sponsor: Indiana Department of Transportation, 765.463.1521

SPR-3714

2016

Guardrails for Use on Historic Bridges

Introduction

Bridges that are designated historic present a special challenge to bridge engineers whenever rehabilitation work or improvements are made to the bridges. Federal and state laws protect historically significant bridges, and railings on these bridges can be subject to protection because of the role they play in aesthetics. Unfortunately, original railings on historic bridges do not typically meet current crash-test requirements and typically do not meet current standards for railing height and size of permitted openings. The primary objective of this study is to develop strategies that can be used to address existing railings on historic bridges and to develop solutions that meet current design requirements. In addition to the modification, selection, and design of the bridge railing, the bridge deck is also impacted by changes made to the railing. Due to increased force levels recently required by AASHTO, deck overhangs must have significantly more reinforcement than in past practice. These increases are being realized on all bridge decks and may pose particular challenges for the attachment of railing to historic bridges. Therefore, a secondary objective of this project is to investigate the design of the deck overhang and determine whether reduced amounts of reinforcement are possible.

For Volume 1 (Replacement Strategies), three phases of research were conducted. First, an overview of current practice for addressing historic bridge railings was performed. Second, an investigation was conducted to document historic bridge railings in Indiana. Finally, rehabilitation solutions were developed to address the specific bridge railings found in Indiana. Based on this research, three retrofit strategies were developed: inboard railing, curb railing, and simulated historic railing. These rehabilitation solutions can be used to address historic bridge railings not only in Indiana, but also across the country.

For Volume 2 (Bridge Deck Overhang Design), experimental testing of half-scale and full-scale overhang specimens was conducted, and the results were analyzed. Failures of in-service bridge railings were also evaluated. Based on this research, recommendations are provided for the more efficient and economic design of bridge

deck overhangs which are applicable not only for historic bridges, but for all concrete bridge decks.

Findings

Volume 1: Replacement Strategies

Indiana's historic bridge inventory was investigated to determine how many historic bridges remain in service as well as to document the types and variety of historic railings in existence. As of January 2014, 658 historic bridges remain in service in Indiana, on which 61 different historic railings were identified. Of these, 7 railing types, along with bridges with no railing, constitute two-thirds of the entire inventory. It is interesting that of the other railings, 25 occur on only one bridge and 11 occur on only two bridges. Therefore, 59% of the different railing types are unique. Based on this analysis, research focused on addressing the most common railings identified. However, an attempt was also made to address as many of the unique railings as possible.

Three different options utilizing modern, previously crash tested railings were identified to upgrade the railings on Indiana's historic bridges. The first option is to install a modern railing inside the original railing. When this option is exercised, the original railing may remain on a bridge. The second option is to install a special inboard railing on the curb. This special railing, which can be used if the bridge has a sidewalk, protects pedestrians on the sidewalk and allows the original railing to be retained. The third option is railing replacement. A collection of approved, crash-tested railings developed by a number of states was used as a baseline to design simulated railings to approximate the appearance of historic railings.

Simulated railings were developed to cover a variety of historic concrete and steel railings. These railings maintained the overall structure and crash-resistant geometry of the base railing while integrating geometric features of the historic railing. In all, it was possible to simulate 42 of the historic railings existing in Indiana. These railings cover 66.3% of all historic bridges in the state. Three timber railing types, which were not considered in the scope

of this research, accounted for 8.4% of all historic bridges in the state. Sixteen railing types did not possess a historic look, did not possess acceptable geometry, or did not exemplify historic craftsmanship. These railings accounted for 25% of all historic bridges in the state.

Volume 2: Bridge Deck Overhang Design

Based on the experimental testing program, along with analysis of the results, the following findings were made:

1. A diagonal tension failure in the deck overhang/barrier joint is a potential failure mode. However, this failure mode is only possible for very short bridge lengths (<30 ft) and will not control the capacity of the overhang/barrier system of a typical bridge deck.
2. The strength of the overhang/barrier wall system is controlled by punching shear rather than the yield-line mechanism. This finding is significant in that design of the overhang according to AASHTO requirements is based on the yield line strength. Reviews of in-service barrier impacts support the finding that punching shear controls the capacity of the system, with field failures producing the same failure surfaces as observed in the laboratory.
3. Barrier impact loads are transferred to the bridge system through the deck overhang over a large distribution length. Load was found to be distributed to the overhang at least 10 times the horizontal loading dimension (L_i), significantly larger than considered by current design provisions. Because of this very effective distribution, there are significantly lower demands on the overhang reinforcement from the barrier impact force than considered using current design provisions. Consequently, a significant reduction in transverse reinforcement relative to that currently required by the AASHTO design specification can be achieved.

Implementation

There are two primary targets for implementation of the results of this research: recommendations regarding upgrading historic bridge railings and recommendations regarding design of bridge deck overhangs. The recom-

mendations regarding bridge deck overhang are generally applicable for both new and rehabilitation projects.

Upgrading Railings

Through the use of the strategies developed in this research program, it is possible to retain historic railing appearance for the majority of historic bridges in Indiana. In many cases, it is also possible to improve aesthetics. Most importantly, however, these strategies allow for improvement in the safety of the traveling public.

Bridge Deck Overhangs

It is recommended that the bridge deck overhang be designed based on vertical forces. Considering the very effective lateral force transfer to the overhang and the maximum applied lateral force as limited through the punching shear capacity of the barrier, design of the overhang to resist the lateral impact force is not required. If the lateral impact force is to be considered, two modifications from current design requirements as specified by AASHTO are recommended:

1. Applied lateral force should be based on the lesser of the punching shear strength of the barrier and the yield line strength.
2. The deck overhang distribution length should be considered as $10L_i$, where L_i is the longitudinal length of distribution of impact force.

By implementing these recommendations, significant cost savings can be realized through the reduction of reinforcement required in the bridge deck overhang.

Recommended Citation for Report Vol. 2

Frosch, R. J., & Morel, A. J. (2016). *Guardrails for use on historic bridges: Volume 2—Bridge deck overhang design* (Joint Transportation Research Program Publication No. FHWA/IN/JTRP-2016/34). West Lafayette, IN: Purdue University. <https://doi.org/10.5703/1288284316361>

View the full text of this publication here: <http://dx.doi.org/10.5703/1288284316361>

Published reports of the Joint Transportation Research Program are available at <http://docs.lib.purdue.edu/jtrp/>.

