Performance Evaluation of Recent Improvements of Bridge Abutments and Approach Backfill

Tech Transfer Summary

November 2018

TR-736
Performance Evaluation of Recent Improvements of Bridge Abutments and Approach Backfill

Sponsor
Iowa Highway Research Board (IHRB)

Principal Investigator
Mohamed K. ElBatanouny, PhD, SE, PE
http://orcid.org/0000-0001-9029-2104

Project Team
Kathleen A. Hawkins
http://orcid.org/0000-0001-8447-987X
Nathaniel S. Rende, SE, PE
http://orcid.org/0000-0002-6428-9670

Project Advisor
Paul D. Krauss, PE
http://orcid.org/0000-0002-0107-6256

Wiss, Janney, Elstner Associates, Inc.
330 Pfingsten Rd
Northbrook, Illinois 60062
www.wje.com

Founded more than half a century ago, Wiss, Janney, Elstner Associates, Inc. (WJE), is an interdisciplinary engineering, architecture, and materials science firm specializing in delivering practical, innovative, and technically sound solutions across all areas of new and existing construction. WJE combines state-of-the-art laboratory and testing facilities, nationwide offices, and knowledge sharing systems to provide solutions for the built world.

This research project evaluated the effectiveness of the current approach slab design standards used by the Iowa Department of Transportation (Iowa DOT) in mitigating deterioration and settlement of bridge approaches.

Objective

The main objective of this study was to determine whether or not the revisions made since 2005 to the approach slab design standards used by Iowa DOT have improved the resistance of bridge approaches to bump formation. The performance of eight bridges was assessed and issues not addressed by current design standards were identified. This research provides recommendations for improving bridge approach design and construction to prevent the commonly-observed deterioration mechanisms.

Background & Problem Statement

Approach slabs are designed to transfer traffic from the roadway to the deck of a bridge smoothly. At the joint with the roadway, the approach slab will often rest on a sleeper slab or the subbase. At the joint with the bridge deck, the approach slab will rest on the abutment. Two types of abutments are common: integral, where the abutment moves with the girder supporting the superstructure due to length changes, and stub, where the girder may move freely relative to the abutment due to the presence of a bearing. An expansion joint between the approach and both abutment types is required to facilitate movement and backfill is placed behind the abutment during construction.

A bump at either end of the bridge deck often forms due to differential settlement between the approach slab and the bridge abutment. These bumps hinder ride quality, cause damage to the vehicles and bridge decks, and are costly to repair and maintain. Differential settlement is typically caused by the presence of voids beneath the approach slab. Voids may be initiated by the longitudinal displacement of an integral abutment, which crushes the backfill material behind it, or by poor compaction of the original backfill material. They grow due to erosion and poor drainage.

To address the bump, Iowa DOT completed a detailed research study in 2005. The standards were revised based on the conclusions. Currently, Iowa DOT specifies that the expansion joint lay between the approach slab and the bridge deck. Granular backfill and subdrains are used under the approach slab to prevent erosion.

Research Description

The study includes review of the design and construction documents of selected bridges built after the 2005 field trials and selection of specific bridges for field evaluation. All the inspected bridges were subjected to visual condition assessment of the approach slabs and abutments, including the pavement surfaces, joints, abutment wings, berm slope, and subdrain outlets, for cracking, erosion, and related distress. Each component was assigned a rating from poor (at the end of its service life) to good (insignificant distress).

The settlement of the approach slabs of four of the bridges was investigated using nondestructive evaluation techniques including ground-penetrating radar (GPR) assessment, borescope inspection, and surveying. GPR was used to detect the location and extent of voids beneath the approach slabs while the borescope camera was inserted through access ports in the wingwalls and cores in the approach surface to confirm the existence of voids, where possible. The elevation profile of the approach slab was determined through surveying and elevations of the approach slab and the bridge deck on either side of the expansion joint were measured. The elevations were used to calculate a bridge approach index (BI), which indicates the severity of any bumps.

The data was synthesized to identify trends in the type, location, and severity of distress. Future work and potential designs were recommended to address this systematic deterioration.

List of selected bridges for field inspection.
Key bridge features and inspection techniques included.

Bridge	County	Year Built	Abutment Type	Roadway Type	Inspection Type
5111.5O034	Jefferson	2006	Stub	PCC Pavement	Visual and NDE
5126.5S078	Jefferson	2009	Integral	PCC Pavement	Visual and NDE
5622.5O061	Lee	2011	Integral	PCC Pavement	Visual and NDE
5624.2O061	Lee	2011	Integral	PCC Pavement	Visual and NDE
9245.6S001	Washington	2015	Stub	HMA Pavement	Visual
5617.7L061	Lee	2011	Integral	PCC Pavement	Visual
5657.4O002	Lee	2011	Integral	PCC Pavement	Visual
5627.1O061	Lee	2011	Integral	PCC Pavement	Visual

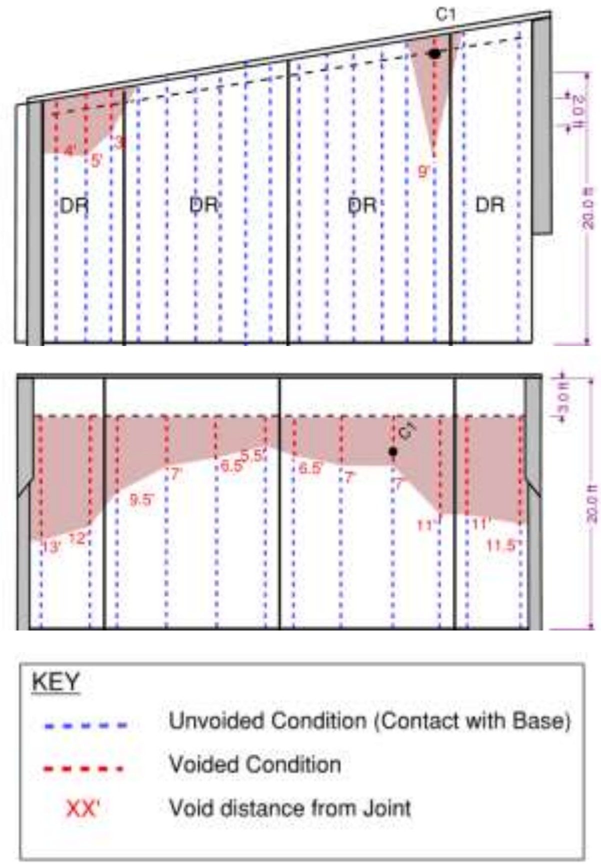
Key Findings

The findings of this study can be summarized as:

1. The inspected bridge approaches were generally in good condition. No excessive settlement or cracking of the approaches was observed. The approach slab and abutment elements rated between moderate and good condition. Abutment and abutment wings were in good condition and subdrains were generally in good condition although some were partially blocked. Joints and barriers had the greatest amount of deterioration. Several were in moderate or poor condition, primarily due to missing or failed sealant.
2. Failed joints between the barrier walls and the approach slabs of the integral abutment bridges were typically observed. The resulting gaps were large, measuring more than 1 inch in some cases, and would allow large volumes of water to drain from the deck under the approach slab.
3. Measured expansion joint widths were significantly different from designed widths; in one case the joint width exceeded the design width by 3 inches.

Gap between north barrier and approach slab at west approach of bridge 5627.1O061.

4. GPR testing indicated presence of voids under the approach slabs adjacent to the abutments at the three integral bridges inspected in detail, and limited voiding under the approach slabs at the stub abutment inspected in detail. Void extents varied. The voids extended approximately 4 feet into the approach slab from the expansion joint near the centerline of the pavement to a maximum void length of 13 feet at the barriers.
5. Cores collected at all four bridges confirmed the presence of voids detected by GPR. The core drop was only 0.25 inches at the stub abutment bridge while core drops varied up to 6.25 inches across the integral abutment bridges. The maximum drop was observed at bridge 5624.2O061.
6. In some locations, the access ports were blocked with debris or soil/backfill which prevented borescope inspection. In the inspected locations, the borescope confirmed the voids detected by GPR and indicated voids under two bridge approaches where GPR data was not collected.
7. The survey data showed that the inspected bridge approaches are generally performing adequately. Although some settlement was observed, the maximum settlement measured was approximately 1.0 inch. The maximum settlement typically occurred in the first span of the approach slab from the bridge towards the midspan of the slab. The maximum differential elevation was 0.4 inches at bridge 5624.2O061.

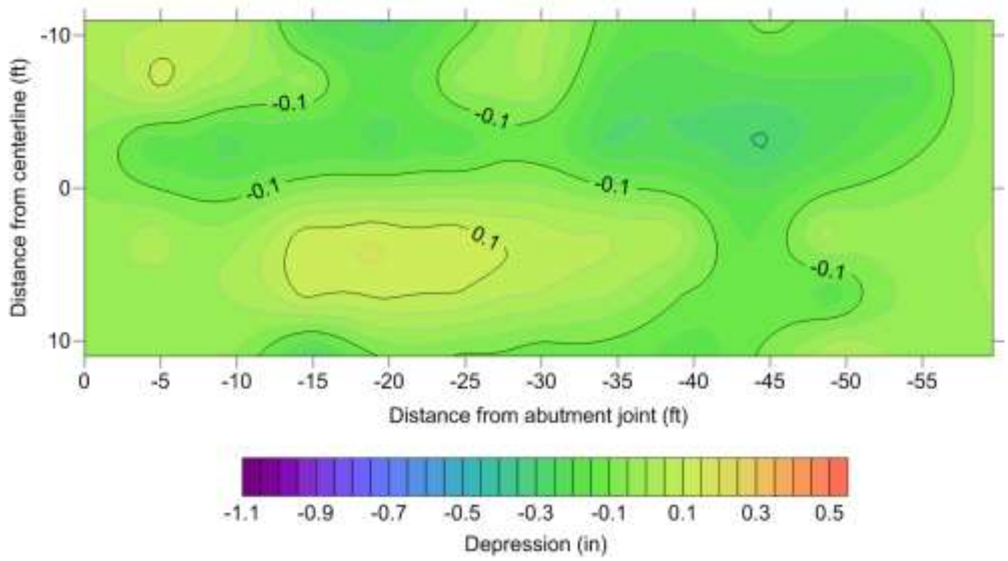


Void conditions at east approach of bridges 5111.5O034 (top, stub abutment) and 5126.5S078 (bottom, integral abutment) according to GPR.

View of core drop (3.5 inches) at Bridge 5126.5S078.

The results show that integral abutment bridges had larger voids, which leads to two discussion points. First, the larger voids are partially attributable to the cyclic longitudinal movement of the abutment; however, the voids are exacerbated by the gap between the bridge barriers and approach slabs. Failure of the sealant is likely caused by large differential movements between the approach slab and the barrier. This gap allows deck runoff water to saturate the backfill below, causing the backfill to compact and erode. While none of the bridge approaches had experienced enough settlement to be a concern, extensive erosion may eventually lead to deterioration and failure of the bridge approach slab due to loss of support.

Second, integral abutments are generally preferred to stub abutments because they require relatively little maintenance. The steel bearings used in stub abutments are susceptible to corrosion, difficult to reach, and expensive to construct and maintain. However, integral abutments require more maintenance than previously thought due to their tendency to develop voids. A life-cycle cost analysis including maintenance costs of the two types of abutments need to be conducted to determine which is truly more cost-effective.

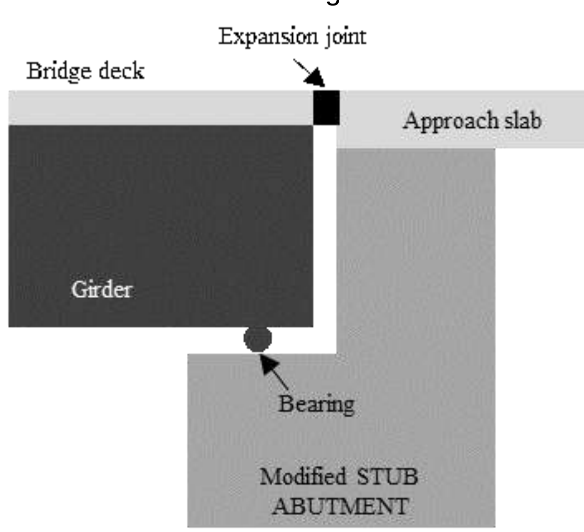


Contour map of the depression experienced by the east approach of bridge 5624.2O061 according to surveying data. On the horizontal axis, 0 ft refers to the location of the abutment joint and -60 ft refers to the location of the roadway joint.

Recommendations and Implementation Benefits

Recommendations from this research study are as follows:

1. A new maintenance plan incorporating more frequent inspection and/or maintenance should be implemented to improve the condition of the joints.
2. A joint sealant capable of tolerating the large differential movements between the barriers and the approach slabs should be applied in existing bridges. For new bridges, methods eliminating this differential movement should be applied, such as casting the barriers as part of the approach slab system.
3. More stringent procedures for sealing access ports and a reliable cleaning method are required for access ports to be reliable sources of information in future inspections.
4. GPR surveys should be included in future inspections if voiding under slabs is a primary concern due to the technique's effectiveness and reliability.
5. A comparative study of the advantages and disadvantages of the different types of abutments across their life cycle should be conducted.
6. A possible new design detail for a modified stub abutment is shown below. This will eliminate the joint between the approach slab and abutment and will eliminate the paving notch. New designs addressing the failure of the joint between the barrier and the approach slab, the differences between measured and designed expansion joint widths, and other challenges should be considered.



Schematic of a proposed detail for 'modified stub abutment'.

The contents of this research study may be used by Iowa DOT to update or revise their inspection protocol for detecting voids under the approach slabs. Revisions to maintenance intervals for the joints may also be considered.

The findings of this report indicate that some revisions to the design of stub and integral abutments may be beneficial. Modifications to the barrier and approach slab connection is recommended to seal or eliminate the gap that develops between the two elements and leads to water intrusion and erosion of backfill material. The contents and references provided in this report could be used to revise the Standard Road Plans for design of Bridge Approach Pavement (BR).