A Literature Review of Approach Slab and its Settlement for Roads and Bridges in Wyoming

WYDOT Sponsor:
Mr. Michael E. Menghini, P.E.
Assistant State Bridge Engineer-Design
WYDOT Bridge Program
5300 Bishop Blvd, Bldg 6100
Cheyenne, WY 82009-3340
307-777-4427; michael.menghini@wyo.gov

Principal Investigator:
Dr. Kam Ng
Assistant Professor
University of Wyoming, Laramie, Wyoming, 82071
307-766-4388; kng1@uwyo.edu

Co-Principal Investigator:
Dr. Thomas Edgar
Associate Professor
University of Wyoming, Laramie, Wyoming, 82071
307-766-6220; tvedgar@uwyo.edu

Submitted To:
Wyoming Department of Transportation
Programming Research Unit
5300 Bishop Blvd.
Cheyenne, WY 82009

January, 2013

Table of Contents

Problem Statement

An approach slab serves as a transitional system between an approach road and a bridge. The primary function of the approach slab is to diminish the amount of differential settlement between a filled embankment and a bridge abutment. If the approach slab properly functions, a bump will not be felt by a driver while driving across bridge abutments.

The Wyoming Department of Transportation (WYDOT) has been using a geotextile reinforced backfill for the concrete approach slab for about 20 years. Figure 1 shows a sectional view of the concrete approach slab with a geotextile reinforced backfill system. This detail is documented in the WYDOT (2008) Bridge Applications Manual Chapter 4, Section 4.14−Approach Slabs. This approach slab system was originally developed based on a research project completed by Edgar et al. (1989) with the objectives of 1) reducing long-term maintenance costs as a result of excessive embankment settlement; and 2) alleviating the lateral load acting on the bridge abutment walls and lateral deformation causing expansion device closure.

For many years, settlements of the concrete approach slab and backfill have been observed by WYDOT engineers and site personnel at new bridges that were just opened to traffic as well as older existing bridges. These settlements create typical voids ranging from 6 to 12-inches between the base of the approach slab and the backfill. WYDOT engineers have observed that settlements occurred at the approach roadway end as well as at the bridge end. These voids reduce the bearing support from the backfill material to the approach slab, and in several cases, cause damage to abutment corbels. On the entrance ends, the road bump due to the settlement creates a greater impact load to the bridge, resulting in increase damage to joints and decks.

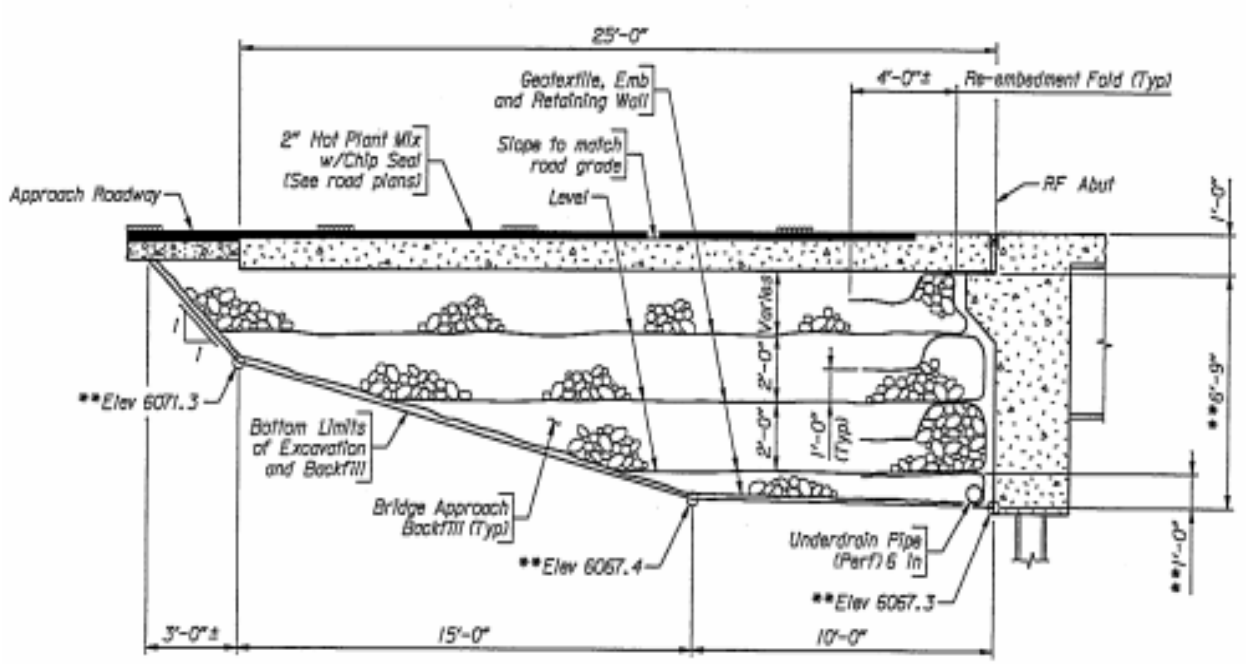

Figure 1: Sectional view of the concrete approach slab with a geotextile reinforced backfill system (Adapted after WYDOT Bridge Applications Manual)

According to current WYDOT bridge inspection reports, approximately 16% of the bridges have settlement issues, and many have yet to be discovered. Among the many bridge locations with this settlement problem throughout the State of Wyoming, four locations summarized in Table 1 have been selected to illustrate this problem. The first location is a new Interstate-25 bridge over Randall Avenue in Laramie County, Cheyenne. After opening the bridge to traffic, voids created by the settlement of backfill materials were observed at the approach slab. The second location is at the Interstate-25 bridge, North of Casper in Natrona County. Crushed base was used as the backfill material. Backfill settlement was observed at the approach slab, and it was suspected that the crushed backfill material may have caused the settlement. The third location is at the Interstate-80 bridge over the Union Pacific railroad (Ozone bridge) between Laramie and Cheyenne in Laramie County. This third location was the original, heavily instrumented bridge site used in the research project that led to the development of the approach slab system. Similar backfill settlement was observed at the rear face (RF) abutment of the College Drive and Interstate-25 Interchange in Laramie County, Cheyenne. Since the interchange will be converted into a Diverging Diamond Interchange, the problematic approach slab will be replaced with a new approach slab.

Table 1: A summary of four selected bridge locations with an observed approach slab settlement problem

Bridge Location	**Observations and Repairs**
Randall Avenue and I-25, MP 11.24, Laramie County, Cheyenne	Voids were observed between the base of the approach slab and the backfill surface immediately after the bridge was opened to traffic. Plan of repair has not been developed.
I-25, MP 227.99 (Structure Nos. DFL and DFK), Natrona County, North of Casper	Crushed base was used as the backfill material. Similar voids were observed. The approach slabs and reinforced backfills were replaced.
I-80 over Union Pacific Railroad (Ozone), MP 340.65 (Structure Nos. AYD and AYE), Laramie County	This location was the original, heavily instrumented bridge site used in the research project to develop the approach slab system. Only the approach slabs were replaced.
College Drive Interchange, I-25, MP 7.85 (Structure No. KEF), Laramie County, Cheyenne	Voids were observed at the RF abutment. Since the existing interchange will be converted into a Diverging Diamond Interchange, the approach slab will be rebuilt in compliance with the current approach slab specifications.

Much fieldwork for retrofitting approach slabs has been performed recently by WYDOT maintenance crews. The retrofit methods include

1) replacing damaged approach slabs with new slabs;
2) filling voids with flowable materials;
3) jacking up settled slabs; and
4) repairing bumps by patching asphalt pavement at a typical length ranging from 300 to 500 ft depending on the amount of settlement.

These rehabilitation works are typically tied to highway related projects or bridge rehabilitation projects involving multiple structural deficiencies. It is believed that these retrofit methods will not be cost effective and beneficial in long run, because the problem cannot be completely resolved and settlement may persist after the repair. Therefore, it is important to identify and investigate the fundamental causes of the problem and to develop comprehensive, pragmatic and cost-efficient solutions to rectify the problem once and for all.

These problematic approach slabs have imposed a risk on the safety of the public using these infrastructures, continuously created challenges for maintenance crews to retrofit the approach slab and to minimize any detrimental effects on traffic, and increased WYDOT road maintenance expenses. Should this problem be unresolved, the resulting impact will be exacerbated when additional bridges using this approach slab system are built in the future, backfill settlements continue in existing bridges, and settled slabs are retrofitted with untested approaches.

Problem Background

Geotextiles have been used by the Wyoming Highway Department (WHD), now the WYDOT, since the 80s to reduce settlement of the approach slabs and lower maintenance costs (Price and Sherman, 1986). It was estimated at that time that the WHD typically spends $1,600 annually per bridge in maintenance cost repairing this problem (Sherman 1988). Undeniably, a much higher cost is expected to repair this problem today.

Beginning in the Fall 1984, a research project was sponsored by WHD to improve the performance of the approach slab with a geotextile reinforced backfill system. A series of laboratory tests were conducted to examine several backfilling methods for the approach slab behind the bridge abutment. A field test program was subsequently conducted at the I-80 bridge over the Union Pacific railroad (Ozone Bridge Project) to validate the proposed methods concluded from the laboratory test program. The field test results concluded that the approach slab with a geotextile reinforced backfill and a 2 to 4-in cardboard to form a gap between the backfill and the abutment:

1) showed significantly less settlement; and
2) reduced lateral load acting on the abutment.

After monitoring for about a year, a maximum vertical settlement of 1.06 inches and lateral settlement of 0.5 inches were measured near the mid-width and behind the East Bound Lane-West bridge abutment. An extended research to evaluate the long-term performance of the approach slab was suggested but not implemented.

Several issues have been encountered by WYDOT over these years, and they are briefly described as follows:

1) Difficult to ensure the woven geotextiles are tight or in tension during installation;
2) The polypropylene woven geotextile fabric may not effectively drain water;
3) Difficult to construct a 1.5 to 1 side slope of a filled embankment;

4) Difficult to compact the previous backfill material although it complies with the graduation requirements specified in the WYDOT Standard Specifications for Road and Bridge Construction (2010), Subsection 803.14;
5) Difficult to ensure the cardboard is saturated and eventually forms a gap between the backfill and the bridge abutment;
6) Challenges with detecting voids beneath approach slabs, and in consequence many problematic approach slabs are yet to be discovered; and
7) No guidelines for retrofitting works.

Congruent to this problem, two main questions were asked and need answers: *What causes this problem and how do we fix it*? Having no research investigation and scientific data to support for this problem, several factors causing this issue are speculated, notably:

1) the suitability of current material specifications for backfill material and geotextile;
2) deficiency of the construction processes, such as compaction requirements and excavation preparation; and
3) inadequate design of the reinforced approach slab system.

Many research projects dealing with approach slabs have been conducted by other state DOTs and government agencies since the completion of the WYDOT research project in 1989. The relevant research activities are briefly summarized in the Appendix. We believe that many new technologies have been developed to improve the approach slab system. These accumulated research outcomes will enhance our understanding of the problem, possibly provide solutions to the approach slab settlement encountered in Wyoming, and determine whether further research investigations in the future are warranted.

Study Objectives

Recognizing the urgent need to solve the settlement problem in the approach slabs and the continuous increase in the overall WYDOT maintenance cost, a research program to conduct a literature review of the approach slab and the associated settlement problem as well as to provide potential solutions is proposed. The objectives of this study are:

1) identify and narrow the focus on parameters causing the settlement problem;
2) develop rational approaches to retrofit the approach slab system;
3) revise and improve the approach slab system design and construction; and
4) propose changes in current WYDOT design and construction manuals for the approach slab system.

Study Benefits

Research outcomes obtained from the proposed work plan described in the next section will be presented in a manner that will be suitable for application and adaptation in the State of Wyoming. The anticipated benefits are summarized as follows:

1) reduce excessive settlement in the approach slab, eliminate road bumps at the approach slab, and improve the road and bridge rideability;
2) provide a more cost-effective and improved approach slab system;

3) provide more rational and cost-effective procedures for remediation of existing problematic approach slabs;
4) lower the overall maintenance cost and time; and
5) increase the safety of the public using the roads and bridges throughout Wyoming.

Work Plan/Scope

The work plan was established based on the aforementioned problem and study objectives. It is envisioned that the research objectives will be achieved by completing five major tasks which are described below. A time schedule to complete these tasks within the projected 18-month period is also provided in this proposal.

Task A: Literature Review

This task will focus on conducting a comprehensive literature review pertinent to the reinforced approach slab. The review will include the following:

1) document and review current state of knowledge and the current state of practice, including personal experiences, relating to the bridge approach slab system;
2) examine existing problems with the approach slab system experienced by WYDOT and other state DOTs as well as their methods of remediation;
3) study current specifications and guidelines pertinent to the approach slab system prepared by state and national agencies, such as AASHTO and FHWA;
4) identify potential application and adaptation through literature review; and
5) identify gaps in the body of knowledge necessary to develop a nationwide survey in Task B.

With the various research activities that have been conducted on the approach slab system as summarized in the Appendix, this task will able to effectively achieve the research objectives and provide a direction for any future works.

Task B: Nationwide Survey

Upon completing Task A, gaps in the body knowledge will be identified and formulated in a series of questions for the development of a nationwide survey conducted in this task. The survey will be sent to the relevant state and local agencies (e.g., state DOTs), American Association of State Highway and Transportation Officials (AASHTO) members and prominent national committees (e.g., Transportation Research Board's (TRB) Subsurface Soil-Structure Interaction Committee and Geosynthetics Committee). The Principal Investigator (PI) has assisted in conducting a nationwide survey of more than 30 DOTs for bridge deep foundation practices. Survey data will be collected, analyzed and reported to fill in missing knowledge, in order that comprehensive recommendations can be developed in Task C. To improve data collection and enhance security, the survey will be developed using commercial online survey software, such as SurveyMonkey®.

Task C: Conclusions and Recommendations

Based on the outcomes obtained from Tasks A and B, conclusions will be made. The conclusions will identify the paramount factors causing the settlement problem in the

approach slab system, highlight the limitations of existing approach slab systems, and address the aforementioned issues encountered by the WYDOT. Recommendations will be established to 1) provide rational methods to retrofit problematic approach slabs on existing roads and bridges; and 2) suggest improvement in regards to the design and construction of the approach slab system.

Task D: Products and Technology Transfer

To update the progress of the research project, short quarterly reports will be submitted to WYDOT. Integrating all the outcomes obtained from previous tasks as well as comments given by WYDOT representatives, a draft final report will be prepared. A final report, containing all aspects of the proposed research, an executive summary and a plan for any future works, will be prepared and submitted. A technical presentation on the completed project will be given to the WYDOT Research Advisory Committee (RAC). The research findings of the project will be distributed to designers and practitioners in the fields of structural, geotechnical and construction engineering through technical presentations at local, regional and/or national conferences. To further publish the significance and major outcomes of the project, at least one journal/conference paper and a technology transfer sheet will be created.

Task E: Implementation

Integrating the result outcomes obtained from previous tasks, this task will propose changes in the current WYDOT design and construction specifications for the approach slab system. This implementation process will be performed in close coordination with the WYDOT representatives in the Bridge, Geology, Materials, and Field Operations Programs.

Work Schedule

The projected duration for the research presented in this proposal is 18 months, tentatively beginning July, 2013 through December, 2014. A detailed schedule per task is shown in Table 2.

Table 2: Detailed schedule proposed for the research tasks

Task		2013				2014											
		Q3			Q4		Q1			Q2			Q3			Q4	
A	Literature Review																
B	Nationwide Survey																
C	Conclusions and Recommendations																
D	Products and Technology Transfer																
E	Implementation																

Cost Estimate

The detailed budget estimate is presented in Table 3. Funds are requested to support wages covering 1¼ months for Kam Ng, ½ month for Thomas Edgar, and 18 months for a graduate student. The fringe benefits for each employee are as specified and are charged individually as direct costs in accordance with the current rates: 1) 45.56% for

PI and Co-PI; and 2) 0.7% for a graduate student. The cost estimate includes for a final report and presentation, a technical presentation at a conference within the United States, publications, and a technology transfer sheet. The indirect cost with a rate of 20% is charged on all direct costs except student's tuition, fees and health insurance. The total cost estimate for this research project is $69,466.

Table 3: Detailed budget estimate for the research of University of Wyoming

A Literature Review of Approach Slab and its Settlement for Roads and Bridges in Wyoming

Budget Estimate

	YEAR 2013		YEAR 2014			
	Q3	*Q4*	*Q1*	*Q2*	*Q3*	*Q4*
Salary						
Principal Investigator (1.25 month)	$ 2,500	$ 2,500	$ 2,000	$ 1,500	$ 1,000	$ 875
Co-Principal Investigator (1/2 month)	$ 765	$ 765	$ 765	$ 765	$ 765	$ 765
Graduate Student (18 months)	$ 3,783	$ 3,783	$ 3,783	$ 3,783	$ 3,783	$ 3,783
Fringe						
Principal Investigator (1.25 month)	$ 1,139	$ 1,139	$ 911	$ 683	$ 456	$ 399
Co-Principal Investigator (1/2 month)	$ 349	$ 349	$ 349	$ 349	$ 349	$ 349
Graduate Student (18 months)	$ 26	$ 26	$ 26	$ 26	$ 26	$ 26
Travel-Domestic	$ 300	$ 300	$ 300	$ 300	$ 300	$ 1,300
Student Tuition and Health Insurace	$ 1,489	$ 1,489	$ 1,489	$ 1,489	$ 1,489	$ 1,489
Other Direct Costs						
Computer Support	$ 1,800	$ -	$ -	$ -	$ -	$ -
Software (Survey)	$ -	$ -	$ 200	$ -	$ -	$ -
Editing/Printing/Copying	$ 50	$ 50	$ 50	$ 50	$ 500	$ 300
Total Direct Cost:	$ 12,202	$ 10,402	$ 9,874	$ 8,946	$ 8,668	$ 9,286
UW Indirect Costs (20%)	$ 2,142	$ 1,782	$ 1,677	$ 1,491	$ 1,436	$ 1,559
Total Costs	$ 14,344	$ 12,184	$ 11,551	$ 10,437	$ 10,104	$ 10,846
TOTAL ALL COSTS	$ 69,466					

Implementation Process

The research outcomes obtained from the work plan and the final report through technology transfer will serve as a foundation for implementation performed in Task E. It is envisioned that the recommendations described in Task C and presented in Task D will be adapted by the respective WYDOT Programs described as follows:

1) Bridge Program – Improved approach slab design and details may be incorporated into the WYDOT Applications Manual Chapter 4, Section 14.4-Approach Slabs.
2) Geology and Materials Program – Revisions may be applied to the WYDOT Standard Specifications for Road and Bridge Construction (2010). Particularly, revisions on Subsection 803 for pervious backfill materials and Subsection 805 for geotextiles, that are applicable to the approach slab system.
3) Field Operations Programs – Improved construction sequences and methods for reinforced backfills and reinforced concrete approach slabs may be incorporated into the WYDOT Standard Specifications for Road and Bridge Construction

(2010), Subsection 507. Guidelines for retrofitting works may be adopted and incorporated into the relevant maintenance manuals.

The implementation process will be accomplished in close coordination with respective WYDOT program representatives. Meetings in-person with the WYDOT representative will be expected to facilitate the implementation process.

Technology Transfer

Staffing

The project team will be comprised of faculties, staff and a graduate student from the University of Wyoming (UW) who specialize in geotechnical engineering. Kam Ng, assistant professor of geotechnical engineering, will serve as the Principal Investigator (PI). Kam Ng has 10 years of industry experience in design and construction of buildings and bridges. He has completed several research projects relating to bridges for the Iowa DOT. His research outcomes have led to the design recommendations and subsequent revision of the Iowa DOT Bridge Design Manual Section 6.

Thomas Edgar, associate professor in the geotechnical engineering and also the PI for the original research project on the approach slab, will serve as the Co-Principal Investigator (Co-PI). His past experience and knowledge on the approach slab system will provide valuable contributions to the research.

Facilities

The Department of Civil and Architectural Engineering at UW has computer, structural and geotechnical/material laboratories that are adequate for this research project. The UW high-speed computing network supports services for instruction and research. The UW libraries offer facilities and services that aid in research, teaching and studying. The UW libraries have extensive interlibrary loan capabilities that further enhance research activities.

Deliverables

To update the research progress, accomplishments and any problems encountered, short quarterly progress reports will be prepared. All of these documents with appropriate changes based on the review comments received from WYDOT representatives will be integrated to form a draft final project report documenting the entire project effort. The research work will conclude with a final report and a technology transfer sheet. The final report will include results of each task presented and an executive summary. The research team will review the report for accuracy and consistency prior to submission to WYDOT.

Responsibilities

The Wyoming Department of Transportation shall,

1) provide funding for the research project;
2) provide WYDOT representative(s) to provide technical support and advise;
3) review survey questions; and
4) provide reviews and comments on short quarterly reports and a draft final report.

The research team representing the University of Wyoming shall,

1) provide administration of research, oversight of the research development and budget;
2) execute the proposed work plan accordingly;
3) facilitate meeting(s) with the RAC, WYDOT and other agencies to accomplish the proposed tasks; and
4) present and report research progress and outcomes to WYDOT.

References

Edgar, V. T., Puckett, A. J., and D'Spain, B. R. (1989). Effects of Geotextiles on Lateral Pressure and Deformation in Highway Embankments. Final Report Submitted to the Wyoming Highway Department. 252 p.

Price, J. T. and Sherman, W. F. (1986). Geotextiles Eliminate Approach Slab Settlement. Public Works, 117(1), pp. 58-60.

Sherman, W. F. (1988). Fabric Reinforced Soil Approach Fills. Earth Modification Using Geosynthetics Seminar, WACES, Cody, WY.

Wyoming Department of Transportation (WYDOT) (2008). WYDOT Bridge Applications Manual.(http://www.dot.state.wy.us/wydot/engineering_technical_programs/bridge/bridge_applications_manual)

Wyoming Department of Transportation (WYDOT) (2010). Standard Specifications for Road and Bridge Construction. (http://www.dot.state.wy.us/wydot/engineering_technical_programs/manuals_publications/2010_Standard_Specifications)

Appendix

A summary of research activities relating to the approach slab

Sponsoring Agencies	Report Date/Status	Project Title
CDOT	1995	Eps, Flowfill, and Structural Fill for Bridge Abutment Highway Backfill
	June 2000	Performance of Geosynthetic-Reinforced Walls Supporting the Founders/Meadows Bridge and Approaching Roadway Structures
DELDOT	May 2007	Instrumented Geogrid Reinforced Mechanically Stabilized Earth Wall Undergoing Large Settlement
FHWA/NDDOT	2002	Fabric Reinforced Backfill Under Approach Slabs
IADOT	January 2005	Identification of the Best Practices for Design, Construction, and Repair of Bridge Approaches
KSUCTR	2011/Active	Finite Element Analysis of Concrete Approach Slab on Soil Embankment
LaDOT	2004	Finite Element Analysis of Concrete Approach Slab on Soil Embankment
	July 2005	Determination of Interaction between Bridge Concrete Approach Slabs and Embankment Settlement
	November 2009	The Rideability of a Deflected Bridge Approach Slab
LTRC	March 2005	Evaluation of DOTD Semi-Integral Bridge and Abutment System
	2011	Integral Abutment Bridge for Louisiana's Soft and Stiff Soils
	Active	Field Demonstration of New Bridge Approach Slab Designs and Performance
MoDOT	January 2003	Determination and Prioritization of MoDOT Geotechnical Related Problems with Emphasis on Effectiveness of Design for Bridge Approach Slabs and Pavement Edge Drains
	April 2004	Evaluation of Bridge Approach Slabs, Performance and Design
	December 2010	Bridge Approach Slabs for Missouri DOT Looking at Alternative and Cost Efficient Approaches
	Active	Field Evaluation of Alternative and Cost-Efficient Bridge Approach Slabs
NHDOT	2007	Alternate Approach Slab Reinforcement
NJDOT	September 2002	Finite Element Modeling of Bridge Approach and Transition Slabs
ODOT	January 2011	Identification and Evaluation of Pavement-Bridge Interface Ride Quality Improvement and Corrective Strategies
OkDOT	October 2011/ Active	Applied Approach Slab Settlement Research, Design/Construction

A summary of research activities relating to the approach slab (continue)

Sponsoring Agencies	Report Date/Status	Project Title
TRB-NCHRP	2008	Development of a Recommended Practice for Use of Controlled Low-Strength Material in Highway Construction
	Active	Guidelines for Geofoam Applications in Slope Stability Projects
TxDOT	September 2011/Active	Recommendations for Design, Construction, and Maintenance of Bridge Approach Slabs
	December 2003	Investigation of Settlement at Bridge Approach Slab Expansion Joint: Bump at the End of Bridge
SCDOT	February 2001	Investigation into Improvement of Bridge Approaches in South Carolina
USDOT	October 2010	Alternative and Cost-Effective Bridge Approach Slabs
USDOT/WisDOT	September 2011	Toward Improving the Performance of Highway Bridge Approach Slabs
VDOT	November 1999	Guidelines for the Use, Design, and Construction of Bridge Approach Slabs
WisDOT	August 2008	Preventing Settlement-and Bumps-at Bridge Approaches
WYDOT	July 1989	Effects of Geotextiles on Lateral Pressure and Deformation in Highway Embankments
YSUCTME	December 2010	On Reducing Bumps at Pavement-Bridge Interface

CDOT−Colorado Department of Transportation; DELDOT−Delaware Department of Transportation; FHWA−Federal Highway Administration; KSUCTR−Kansas State University's Center for Transportation Research; LaDOT−Louisiana Department of Transportation and Development; LTRC−Louisiana Transportation Research Center; MoDOT−Missouri Department of Transportation; NCHRP−National Cooperative Highway Research Program; NDDOT−North Dakota Department of Transportation; ODOT−Ohio Department of Transportation; OkDOT−Oklahoma Department of Transportation; SCDOT−South Carolina Department of Transportation; TRB−Transportation Research Board; TxDOT−Texas Department of Transportation; USDOT−United States Department of Transportation; VDOT− Virginia Department of Transportation; WisDOT− Wisconsin Department of Transportation; WYDOT− Wyoming Department of Transportation; and YSUCTME−Youngstown State University Center for Transportation and Materials Engineering.