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Project Title

Mitigation of Differential Settlement at Highway Bridge Approaches

University

University of Utah

Principal Investigators

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Research Needs

Differential settlement in the transition zone between the bridge structure and the approach embankment often creates a "bump" which is a potential safety hazard and comfort issue for drivers. "Studies conducted by DOTs around the country suggest that about 25 percent of the 600,000 bridges in the US are affected by bridge approach settlement, or the "bump at the end of the bridge." The difference in elevation between the approach pavement and the bridge deck results from a complex interaction between the bridge structure, backfill soils and foundation soils; poor drainage is one contributing factor. The settlements can result in unsafe driving conditions, rider discomfort, structural deterioration of bridges and long-term maintenance costs (http://wisconsindot.gov/documents2/research/00-13bridgesettlement-b.pdf).

Foundation soil type and subsurface conditions are a major contributor to differential settlement at bridges. Cohesive soils contribute more to bridge approach settlement than do granular soils because the former are frost-susceptible, absorb water, settle over time and may become weaker when wet. For example, investigators in Wisconsin measured significantly less movement of the approach fills for bridge abutments seated on granular foundation soils (http://wisconsindot.gov/documents2/research/00-13bridgesettlement-b.pdf). In addition, there are other factors that can lead to settlement of the approach area: (1) compression or movement of the embankment fill, (2) settlement or movement of foundation soils beneath the embankment, (3) design or construction problems (e.g., compaction, joint problems, movements due to temperature, etc.) and (4) poor drainage.

Even though preloading or surcharging of the foundation soils is a primary method employed by many DOTs to prevent a "bump at the bridge," unacceptable amounts of bridge approach settlement still occur. It is not clear whether this poorer performance is due to: (1) insufficient construction time allotted to preload the foundation soils and achieve adequate primary consolidation settlement and aging of the soil under preloading, (2) improper estimates of the

amount of primary and secondary consolidation by geotechnical practitioners, (3) unexpected subsurface soil variations, (4) or higher than usual secondary consolidation settlement. Nonetheless, the methods and procedures currently used by the various DOTs are not always enough to ensure safe and good performance.

Research Objectives

1. Develop potential methods or best practices to mitigate bridge end differential settlement (i.e., bump at the bridge) that can be implemented in addition to or in lieu of preloading of foundation soils at the time of bridge construction, or during subsequent bridge maintenance operations. Indicate whether the proposed methods are intended to address primary consolidation or secondary consolidation settlement, or both.

2. Provide practical information, data, detailed analysis, evaluations, documentation and recommendations regarding the various methods with respect to design details, construction practices and post-construction.

3. Assist the Utah Department of Transportation (UDOT) and its agents in selecting and deploying the recommended methods in new construction, or maintenance operations, as applicable.

4. Recommend to UDOT emerging methods and technologies for future research and potential implementation by the Department.

Research Methods

The research will use observational, case history, numerical and laboratory methods to achieve the following: (1) Reconnaissance of Existing Bridges to determine the root cause and contributing factors that produce a bump at the bridge, (2) Review of best practices of State DOTs to develop a framework for further development and evaluations (3) Development of Screening / Ranking System to assist DOTs in selection of possible technologies to be used for a particular site. This ranking will have both qualitative and quantitative criteria to assist in the selection, (4) Laboratory testing evaluations of possible new materials, especially LCC. This testing will focus on the material property behavior and its resistance to applied and cyclic loadings, (5) Numerical and analytical evaluations of the proposed remedial solutions, including evaluations of the approach slab and its support.

Expected Outcomes

General Outcomes: Identifying additional geotechnical or structural means to mitigate the bump at the bridge will be of benefit to the DOTs. These benefits might be achieved by providing the project team with advantages and detriments of supplemental options in terms of their efficacy, cost, schedule and ease-of-construction. Furthermore, identifying innovative means to mitigate this issue during design and construction, whether through initial cost savings or by providing superior long-term performance, will provide additional safety and value. This will be gained either through savings from initial capital investment or through life-cycle cost reductions, hence assisting in the preservation of key infrastructure.

Specific Outcomes: (1) Implementation of a screening process to select best-practices for mitigation of bump at bridge for specific project needs, (2) Design recommendations regarding the use of LCC as a limited embankment replacement for areas near the sleeper slab (i.e., shallow foundation supporting the approach slab, (3) Design recommendations regarding the possible use of other alternative foundation treatments in the approach slab area, (4) Design information and recommendations regarding the possible length and type of approach slab that may be needed to reduce angular distortion in the bridge approach area.

Relevance to Strategic Goals

USDOT Strategic Goal: State of Good Repair

By preventing the formation of the bump at the bridge, the Nation's roads will be safer and keep U.S. citizens moving with fewer maintenance closures. This research is also consistent with the Mountain-Plains Consortium focus of providing "cost-effective preservation and maintenance practices for highways…" and "inspecting, evaluating, and designing bridges to promote longevity and cost-effective maintenance…".

Educational Benefits

One graduate student from the Department of Civil & Environmental Engineering at the University of Utah will be funded to work on this project. In addition, it is expected that one or more undergraduate students will work on this project. The results from this project will be incorporated into graduate level classes in the areas of geotechnical and structural engineering.

Technology Transfer

The results from this research will be presented at the annual UDOT Engineering Conference, the Annual Transportation Research Board Meeting, and a special seminar to be sponsored by UDOT in which UDOT engineers and engineers from other governmental agencies and commercial companies will be invited. Papers will also be published in relevant journals such as Transportation Research Record, Journal of Materials Engineering, and Transportation Geotechnics. Furthermore, a webinar will be arranged through the Mountain-Plains Consortium.

Work Plan

Additional details on the major tasks and methods that will be used in this research project to achieve the stated objectives are provided below. The expected month of completion for each task is provided in parentheses at the end of the description.

1. *Reconnaissance of Existing Bridges (0 months)* – UDOT has identified select bridge locations that have manifested some type of approach / bridge distress in relation to differential settlement (Table 1). These locations will be visited by Research Team and UDOT personnel to assess the type and scope of the problems at these locations. The findings of this reconnaissance will be documented as a field summary report.

Table 1 – Bridge Locations for Reconnaissance Visit

DE F-581	SR-108 over UPRR, Clearfield
C-812	3900S over I-15
F-131	700W over I-215
DE F-582	SR-108 over Santa Fe Trail, Clearfield
DE F-681	SR-75 over I-15, Springville
F-718	SR-67 over Legacy Pkwy, Woods Cross
F-755	US-89 over UPRR, Pleasant Grove
DE F-769	SR-77 over UPRR, Springville
1F-804	MVC-NB over creek north of Bingam Creek
2C-979	SR-85 over Jordan River, Lehi
3C-793	Univ Ave to I-15 South Ramp, Provo
4C-898	US-40 WB to I-80 WB Ramp, Kimball Jct.
4C-899	US-40 WB to I-80 WB Ramp, Kimball Jct.
DE 3F-649	I-15 SB over 12300 S
DE 1F-784	I-15 NB over 11400 S
DE C-802	SR-26 over Weber River, Riverdale

2. *Literature Review (3 months)* – The Research Team will identify, compile and summarize methods, best-practices and other promising emerging technologies used by other state DOTs, agencies, contractors, etc. to address bump at the bridge issues. This compilation will include methods and technologies associated with the structural and foundation systems of the bridge, bridge approach slabs and its supporting foundation (i.e., sleeper slab), ground improvement of the foundation soils and other embankment, slope reinforcement and retaining wall technologies deployed in the bridge approach area.

3. *Development and Implementation of Technology Screening / Selection Process (3 months)* – This Research Team will make recommendations to UDOT regarding methods, practices and technologies holding the most promise for immediate implementation (i.e., technologies that are shovel ready).

4. *Development and Evaluation of Emerging Technologies (10 months)* – The Research Team will identify any knowledge gaps for promising technologies and how these gaps might be addressed by additional research and evaluations to make these technologies "shovel ready." These evaluations will consider the proposed research approach, level-of-effort, associated costs and implementation strategy to enable the deployment of emerging technologies. Initially, the Research Team has identified the following general methods or technologies as potential candidates for future evaluation and potential implementation: (1) design and construction of lightweight cellular concrete (LCC) as complete or limited embankment replacement in the approach slab area for both sloped and vertical embankments, including the reinforcement requirements for the LCC embankment / wall , (2) other alternative foundation treatments in the approach slab area, and (3) lengthening of the approach slab to limit the amount of angular distortion and the effects of the bump.

5. *Report Preparation and Project Reporting and Dissemination (2 months)*

Project Cost

Total Project Costs:	$144,368
MPC Funds Requested:	$40,000
Matching Funds:	$104,368
Source of Matching Funds:	Utah Department of Transportation