Long-Term Bridge Performance Program

TECHBRIEF

FHWA LTBP Workshop to Identify Bridge Substructure Performance Issues

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About LTBP

This research was conducted as part of the Federal Highway Administration's Long-Term Bridge Performance (LTBP) Program. The LTBP Program is a minimum 20-year research effort to collect scientific performance field data, from a representative sample of bridges nationwide, that will help the bridge community better understand bridge deterioration and performance. The products from this program will be a collection of data-driven tools including predictive and forecasting models that will enhance the abilities of bridge owners to optimize their management of bridges.

Objective

This TechBrief provides an overview of the proceedings and findings of the "FHWA Workshop to Identify Bridge Substructure Performance Issues" held in Orlando, FL, from March 4 to 6, 2010. The purpose of the workshop was to consider overall bridge performance and identify geotechnical performance metrics that may correspond to good and poor performance. The issues identified and the recommendations made at the workshop are being used in the design and implementation of the Long-Term Bridge Performance (LTBP) program.

Introduction

FHWA launched the LTBP program to improve understanding of bridge performance. The program's mission is to foster improved bridge performance, health, stewardship, and management through the analysis of data collected over a 20-year period on representative samples of highway bridges in the United States. To achieve this mission, the program is designed to produce or support improved deterioration models, reliable life-cycle cost and forecasting models, design procedures, and decisionmaking tools. One of the earliest steps in the implementation of the LTBP program was determining which aspects of bridge performance to study.

After the LTBP program was initiated in April 2008, FHWA conducted a series of focus group meetings with bridge experts from State transportation departments in different regions of the country. The conclusions from those meetings are the subject of future TechBriefs. Among the general bridge performance issues identified, the following issues related to structural foundation elements or geotechnical factors were documented:

- Methods to measure scour that are direct, reliable, and timely.
- Performance of scour countermeasures.
- Performance of structure foundation types.
- Identification and performance of unknown foundation types.
- Performance of integral and semi-integral abutment bridges.

In order to further evaluate, prioritize, and refine these geotechnical issues, FHWA sponsored a workshop in Orlando, FL, from March 4 to 6, 2010. FHWA invited participants with different backgrounds and perspectives to ensure diversity of input. The 43 workshop attendees included bridge/geotechnical experts from State transportation departments, FHWA, academia, and industry groups.

The workshop served as an opportunity to define how geotechnical issues could be incorporated in the LTBP program, what geotechnical data should be collected under the LTBP program, and what tools and technologies would be needed for collection of that data. The workshop consisted of a plenary session followed by three breakout sessions with the following objectives:

- **Breakout session I:** Identify key performance issues related to substructures and foundations.
- **Breakout session II:** Identify data needs and gaps related to the key geotechnical performance issues.
- **Breakout session III:** Identify tools, technologies, and monitoring necessary to collect critical geotechnical performance data.

The Plenary Session

The workshop began with a plenary session at which a series of speakers provided an overview of the LTBP program, summarized the findings from the focus group meetings, described the general LTBP research approach, discussed the pilot bridge phase, and gave an overview of geotechnical factors related to bridge performance. This session was intended to provide context for the subsequent breakout session discussions.

Several examples of geotechnical issues affecting bridge performance were described, including mechanically stabilized earth (MSE) walls, foundations on rock, abutment issues (in particular, settlement at the bridge-abutment interface and its effects on the superstructure), and scour.

The Breakout Sessions

The purpose of the breakout sessions was to consider overall bridge performance and identify geotechnical performance indicators that may correspond to good and poor performance. The information generated was to be provided to the LTBP program as recommendations to accommodate collection of additional data as well as to identify methods to collect and evaluate the data.

The focus group meetings held by the LTBP program had identified a few general topics related to substructures and foundations. The participant groups were asked to consider these and other geotechnical issues related to bridges that could merit consideration and to identify and define the key bridge performance issues related to substructures and foundations, data needs and gaps related to these key issues, and tools, technology development, and monitoring necessary to collect critical geotechnical performance data for the LTBP program.

Breakout Session I: Bridge Performance Issues

The first breakout session focused on identifying the most important bridge performance issues related to foundations, substructures, and geotechnical features. This breakout session developed and prioritized the key geotechnical issues that affect critical aspects of bridge performance as well as performance of the bridge as a whole.

Following brainstorming on bridge performance issues in the three breakout groups, the lists and priorities from each group were collected and presented. Despite different approaches to identifying and rating the importance of the issues, the groups generally identified the same issues and priorities. A summary of the priorities identified by each group is presented in table 1. Common issues identified by multiple groups were the bump at end of the bridge, integral abutments, settlement of abutments and piers, material corrosion, and scour.

Breakout Session II: Data Needs and Gaps Related to Geotechnical Performance Issues for Bridges

The second breakout session focused on discussing the data needs and gaps related to the key performance issues identified in the first breakout session. Each breakout group developed a list of data that can currently be collected, data that need to be collected during the course of the 20-year research program, and data that cannot currently be collected but would be important to the objectives of the program.

Following brainstorming on data needs and gaps in the three breakout groups, the lists and priorities from each group were presented to the larger group. The complete list of data needs and gaps identified by the three groups is available in the full report, *FHWA LTBP Workshop to Identify Bridge Substructure Performance Issues: March 4–6, 2010, in Orlando, FL.* Table 2 provides some of

Table 1. Breakout session I: Summary of priority geotechnical performance issues identified by each group.

Group 1	Group 2	Group 3
• Abutments: Bump at end of bridge, integral abutments, piles • Foundations: Measured loads, widening, unknown foundations, tolerable movements • Hydraulics: Scour, drainage • Materials: Corrosion • Construction: Quality control	• Approaches: Settlement, global stability • Piers: Scour, total differential settlement, horizontal movement • Abutments: Vertical and horizontal joint movement, differential settlement, scour, pile performance • Abutment walls: Corrosion, drainage failure, scour, soil restraint	• Corrosion/deterioration (MSE walls, steel in piles, embankment material) • Bump at end of bridge (significant) • Fatigue/integral abutment/lateral stress • Drainage, runoff, erosion • Remaining service life—long-term performance

Table 2. Breakout session II: Data needs and gaps related to priority geotechnical performance issues for bridges.

Performance Issue	Data Needs			
	Construction Records	Inspection and Maintenance History	Characterization of Service Environment	Post-Construction Monitoring
Approach-bridge interface	• As-built plans • Foundation report	• Inspection reports • Photos • Voids under slabs • Winter maintenance practices	• Climate data • Traffic • Loads	• Settlement • Rideability • Deformations • Vibrations
Material degradation	• As-built plans	• Inspection reports • Winter maintenance practices	• Climate data • Groundwater info • Soil characteristics	• Corrosion detection • Condition of foundation elements
MSE walls	• As-built plans	• Visual indications of corrosion	• Climate data • Indications of salt intrusion from poor surface drainage	• Soil pH • Water pH
Hydraulics	• As-built plans • Abutment/pier type • Channel capacity • Type of scour countermeasures employed • Predicted scour	• Historical flow data • Channel stability and migration	• Flood data/records • Climate data • Ice data • Stream velocity	• Scour depth • Actual scour versus predicted scour

the data needs identified by the groups for the performance issues identified at the workshop. It was recommended that a follow-up task group formulate research needs related to data needs and gaps for the LTBP program.

Breakout Session III: Tools, Technology Development, and Monitoring Needed for Geotechnical Performance Data

The third breakout session focused on how geotechnical performance data can be collected. The breakout groups identified tools and technologies that are currently available and should be used in the LTBP program as well as technology development and monitoring that are needed to address identified data gaps.

Following brainstorming on tools, technology development, and monitoring in the three breakout groups, the lists and assessments from each group were presented to the larger group. The benefit of this session was that the breakout groups identified a comprehensive list of tools and technologies for data collection and, in some measure, mapped the tools/technologies to specific data needs as well as future and long-term needs. Table 3 provides some of the ideas developed on tools, technology development, and monitoring; the complete list is provided in the full report, *FHWA LTBP Workshop to Identify Bridge Substructure Performance Issues: March 4–6, 2010, in Orlando, FL*. It was recommended that a follow-up task group better define the tools, technology development, and monitoring of geotechnical-related bridge assets for the LTBP program.

Table 3. Breakout Session III: Needed tools, technology development, and monitoring.

Geotechnical Performance Issue	Tools Currently Available	Short-Term Technology Development	Long-Term Technology Development and Monitoring
Bump at the end of the bridge	• Ground-penetrating radar • Survey • Inclinometer • TDR moisture sensors • Settlement points at depth • Road profiler • Airborne LIDAR • User feedback (phone calls) • Accident data • Maintenance records • Peak particle vibration monitoring • Quality geotechnical data • In situ geotechnical testing • Tiltmeters	• High-speed pavement profilers • Smart pavement to capture loading	• Earth pressure cells • Smart soils with MEMS embedded
Foundations	• Strain gauges • Load cells • Survey • Inclinometer • Settlement points at depth • Laser scanning • Maintenance records • Quality geotechnical data • In situ geotechnical testing • Tiltmeters • Bridge response WIM • Crack meters • TDR cables embedded in foundation • Settlement of foundation • Load test data • Embedded GPS reference points in foundations	• Smart foundation elements • Technique to measure existing load on foundation • Laser/radar interferometry monitoring of deflection	• Earth pressure cells • Energy piles/geothermal heating for heating of decks

See notes at end of table.

Table 3. Breakout session III: Needed tools, technology development, and monitoring—Continued.

Geotechnical Performance Issue	Tools Currently Available	Short-Term Technology Development	Long-Term Technology Development and Monitoring
Deterioration	• Half cell potential • Resistivity • Sacrificial steel and inspection • Concrete coring • Concentrations of chloride and sulfate in concrete • Concrete cover measurements • Ultrasonics	• Optical TDR • Laser/radar interfereometry monitoring of deflection	• Shear/p-wave velocity (for elemental stiffness) • Smart paint/coating (to measure stress, corrosion) • Self-healing steel • Self-healing concrete • Maintaining compatibility of strains in repair materials • Embedded biosensors (i.e., effervescent bacteria)
Earth-retaining structures	• Strain gauges • Load cells • Survey • Inclinometer • TDR moisture sensors • Settlement points at depth • Laser scanning • Airborne LIDAR • Maintenance records • Quality geotechnical data • In situ geotechnical testing • Tiltmeters • Crack meters • Piezometers • Inspect drains • TDR cables	• Smart concrete/structure members to capture loading • Electro-conductivity of wall	• Earth pressure cells • New technique to measure water height behind wall face • Smart soils • Harnessing movement on bridge to capture energy to power sensors
Hydraulics (scour)	• Sonar • Plumb bobs • Float out device • TDR vertical and horizontal • Sub-bottom profiler • Ground-penetrating radar • Flow monitoring • Visual inspection/diver • Embedded GPS reference points in countermeasures	• In-place sonar • Float out device attached to structure • Vibrations of pier structure	• Smart particles • Satellite/airborne imagery to detect scour holes

GPS = Global Positioning System.
LIDAR = Light detection and ranging.
MEMS = Microelectromechanical systems.
TDR = Time domain reflectometry.
WIM = Weigh in motion.

Conclusions

A number of short-term geotechnical bridge performance priorities emerged from the workshop. These priorities can be summarized in four categories. For each of the performance issues, assessments of the cause and effect of the issue, the quality control and quality assurance aspects, the detection and monitoring aspects, and the remedial actions to overcome the issues need to be completed.

Approach/bridge interface issues included the following:

- Settlement, including foundation and fill settlements, erosion of toe fills, poor material quality, and substandard construction practices.
- Integral abutments, temperature loads, and ratcheting effects.

Material degradation/corrosion/long-term deterioration issues included the following:

- Effects of salt water on both concrete and steel piles.
- Metallic inclusions (e.g., soil nails, anchors).
- Aggressive soils.

MSE wall issues (material degradation and assessment of wall integrity) included the following:

- Condition of reinforcement, including possible corrosion, deterioration, and creep.
- Deformation of MSE walls.
- Quality of backfill.
- Leakage of backfill.

Hydraulic issues included the following:

- Direct, reliable, and timely methods to measure scour.
- Performance of scour countermeasures.
- Drainage, joint infiltration, weep holes, and underdrains.
- Erosion of approach embankments and of soil supporting and behind cast-in-place concrete walls.

From the results of this workshop and other available information, these issues can be considered for inclusion on the LTBP list of study topics. Each issue will have to be further studied for the state of practice, related research, and identification of key questions that might be addressed under the LTBP program.

A number of data needs were identified for the short-term bridge performance issues identified. Some data needs, such as as-built plans and climate data, cut across all the performance issues.

The workshop participants did an outstanding job of identifying the data needs. The identification of needed tools, technology development, and monitoring was helpful to FHWA.

Researchers—This study was performed by Rutgers, the State University of New Jersey, Highway R&D Services; the Virginia Center for Transportation Innovation and Research; Iowa State University; and Parsons Brinckerhoff. For additional information, contact Dr. Hamid Ghasemi in the FHWA Office of Infrastructure Research and Development, located at 6300 Georgetown Pike, McLean, VA 22101-2296.

Distribution—This TechBrief is being distributed according to a standard distribution. Direct distribution is being made to the Divisions and Resource Center.

Availability—Report No. FHWA-HRT-11-037, *FHWA LTBP Workshop to Identify Bridge Substructure Performance Issues: March 4–6, 2010, in Orlando, FL*, is available. It can be obtained from the National Technical Information Service, www.ntis.gov.

Key Words—LTBP program, Bridge performance, Bridge substructure, Substructure performance, Long-term bridge performance.

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