THE FHWA LONG-TERM BRIDGE PERFORMANCE PROGRAM

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Abstract

The Federal Highway Administration is initiating a major program in early 2006 with the objective of improving knowledge regarding bridge performance over a long period of time. The FHWA Long-Term Bridge Performance (LTBP) program will instrument, monitor, and evaluate a large number of bridges throughout the United States in order to capture performance over a 20-year period of time and, on the basis of the information collected from these structures, provide significantly improved life-cycle cost, performance, and predictive models that can be used for bridge and asset-management decision-making. The LTBP program will also conduct forensic investigations on decommissioned bridges, as the opportunity arises.

Introduction

Many transportation agencies in the United States and Japan, and throughout the world for that matter, have adopted systems, procedures, and tools that attempt to provide formal bridge and asset management. But, how many of these agencies actually manage their bridges and other highway assets in a fully rational and optimal manner?

The key components of rational and functional bridge or asset management systems include one or more databases that contain information on the characteristics of the assets being managed; databases and information on how structures and components deteriorate or result in reduced functionality or performance as a result of climatic conditions, traffic, and other "exposures"; information and routines that quantify the effectiveness of various maintenance, repair, and rehabilitation strategies; information regarding the costs of various maintenance or repair strategies, and "user" costs related to the functionality of the asset; and decision-making models and algorithms that attempt to optimize the allocation of resources (e.g., funds, material, and labor) in order to achieve some performance goal for the network of assets and its individual components.

Although many transportation agencies have adopted and employed bridge management tools like the AASHTOWare™ PONTIS program, there are still gaps in knowledge regarding how structures and materials perform and deteriorate over time (commonly referred to as life-cycle or life-cycle cost models), and how effective (and for how long) various maintenance, repair, or rehabilitation strategies really are for a given component or system. In addition, the materials being used for bridge construction today are changing rapidly and may be significantly different than conventional bridge materials (e.g., high performance steel, high performance

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concrete and self-consolidating concrete, fiber-reinforced polymer composites, and new alloys for rebar), and our long-term experience with the performance of these materials is quite limited. As a result, although many transportation agencies practice bridge management, there is still significant room for improvement in the information and data upon which the bridge management systems are based, and on the results and decision-making that occurs based on the output of these systems.

In order to address some of these gaps in knowledge, the Federal Highway Administration (FHWA) of the U.S. Department of Transportation will be initiating a Long-Term Bridge Performance (LTBP) program in 2006. This paper will discuss the initial vision and goals of the LTBP program, but it is likely that this will change somewhat over the planned 20-year lifetime of the LTBP program.

Vision for the FHWA Long-Term Bridge Performance Program

The FHWA's National Bridge Inspection Standards (NBIS) and associated National Bridge Inventory (NBI) database have facilitated the creation of one of the most comprehensive sources of bridge information in the world. However, the NBI is limited in the type of structural and performance data that it contains, and essentially provides no information on the individual elements or components of the bridges contained in it. Instead, the FHWA has developed a Bridge Management Information Systems (BMIS) Laboratory which supplements the standard NBI data with information regarding environmental exposure and, in some cases, element level data provided by selected State transportation agencies, in order to help facilitate data mining.

Both the NBI and element level data are typically collected using visual inspection techniques – hidden or inaccessible deterioration or damage, for example to prestressing strands or rebar within a concrete girder, is therefore not usually noted or collected as part of the regular biennial inspection that is required by the FHWA of all highway bridges open to the pubic. The qualitative, subjective, and possibly highly variable nature of this data is therefore inadequate for comprehensive long-term life-cycle decision-making. In addition, the operational performance of highway bridges (i.e., traffic congestion, accident data, freight movement across the structure) is not typically collected or reported on a State-wide or national basis for highway bridges. An essential need, therefore, for support of effective bridge management is long-term bridge performance information.

In order to address this need, the FHWA is embarking on an ambitious multi-year research program known as the Long-Term Bridge Performance (LTBP) program. This program, which was authorized by the U.S. Congress in mid-summer 2005, is being modeled somewhat after the Long Term Pavement Performance (LTPP) Program, which has been conducted within the United States since 1989.

The LTBP program will include detailed inspections and periodic evaluations and testing on a representative sample of bridges throughout the United States in order to monitor and measure their performance over an extended period of time. At the current time, it is envisioned that as many as 2000 bridges will be included in the program, representing many structural types and materials, in a variety of conditions, exposures, and locations. As authorized by Congress, the program will run for 20 years. It is anticipated that the resulting LTBP database will provide high quality, quantitative performance data for highway bridges that will support improved designs, improved predictive models, and better bridge management systems.

A second component of the LTBP program will be a set of instrumented bridges that can provide continuous, long-term, structural bridge performance data. A third component of the program will include detailed forensic autopsies of a number of bridges each year, using some of the structures that are decommissioned by State transportation agencies each year. The intent is to collect actual performance data on deterioration, corrosion, or other types of degradation; structural impacts from overloads; and the effectiveness of various maintenance and improvement strategies typically used to repair or rehabilitate bridges.

A preliminary description of the extent and intent of each of these components of the LTBP program is shown in Table 1.

Table 1. Preliminary Plans for LTBP Program Components

Program Component	Sample Size	Purpose	Information Anticipated
Long-Term Performance (LTP) Sample Bridges	1,000s	Long-term periodic inspection and evaluation	High-quality, quantitative performance data to support improved designs, improved predictive models, and better bridge management systems
Instrumented Smart Bridges	100s	Continuous monitoring of operational performance	Data about behavior under routine traffic conditions as well as rare, possibly extreme, events
Decommissioned Bridges	As available	Forensic autopsies	Information about capacity, reliability, and failure modes of bridges that have deteriorated from corrosion, overloads, alkali-silicate reaction, fatigue, fracture, etc.

The LTBP program is being designed to accommodate and develop both general trend information, and information specific to a variety of bridge types, locations, and environmental exposures.

Why is the LTBP Important to the United States?

The FHWA NBI contains information on more than 590,000 bridges, tunnels, and culverts – essentially, every highway structure which is open for public access, and is at least 20 feet (6.1 meters) in length. The average age of these structures is approximately 42 years. The number of structurally deficient and functionally obsolete bridges, as indicated in Figure 1, are approximately 83,000 and 133,000, respectively. This obviously creates a very difficult but important reason why effective bridge management tools are required in the United States, and why quality information on the actual condition, and effectiveness of maintenance and repair strategies, is critical.

In addition, there are about 10,000 bridges being constructed, replaced, or rehabilitated annually in the United States at a cost of over $7 billion, while total annual bridge costs, including maintenance and routine operation, are significantly higher. Although it may appear that we are keeping ahead of the current bridge deterioration rate of about 3,000 newly deficient bridges per year, most of the bridges being built today are using the same technologies, materials, and methods that were used to construct bridges 20 or more years ago.

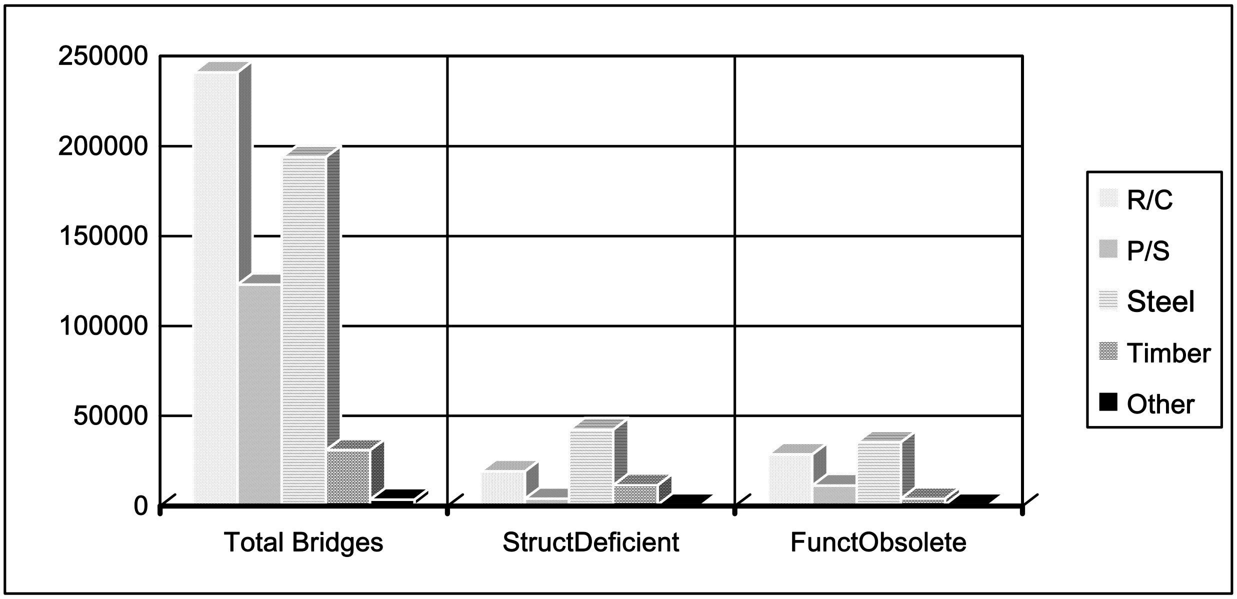

Figure 1. U.S. Bridge Distribution by Material and Deficiency

LTBP Scoping Study

In order to initiate the LTBP program, specifics regarding many aspects of LTBP criteria and program goals will need to be created and publicized throughout the United States. To assist in the development of this, the FHWA has employed the University of Delaware through its Center for Innovative Bridge Engineering (CIBrE) to prepare an overall proposed framework for the program. The specific objectives of the CIBrE scoping study include addressing issues and questions such as:

- What types of bridges and bridge components should be monitored?
- How should specific bridges be selected?
- What types of monitoring systems should be used?
- How should instrumentation plans be designed?
- What types of data should be collected?
- How will the data be used in the future?

- Based on how the data will be used, how should it be stored, organized, and made accessible to the bridge engineering user community?

To address these issues and questions, the CIBrE scoping study includes tasks that will cover:

- A detailed identification of issues;
- The type of and process for selection of bridges;
- Development of performance monitoring plans;
- Selection of monitoring hardware and software;
- Identification of appropriate analytical tools and practical experimental testing protocols;
- Management of data, meta-data, and data mining;
- Translating the results of data mining to practice (for both improved new design and construction, and overall bridge management); and
- Strategies for effective partnering with industry.

As one would imagine, there are many issues and parameters that will need to be addressed in the program. A short-list based on preliminary thinking associated with each of the tasks above includes those listed in Table 2.

Expected Outcomes of the LTBP Program

The LTBP program will require and result in the investment of a significant amount of money, labor, and physical resources (hardware, software) over the life-time of the program. In order to justify these investments, there are major outcomes that we anticipate will be achieved. Among these are:

- Data/information and technology for effective management, renewal, and protection of the existing highway infrastructure
- Advances in deterioration science and control to better understand:
  - deterioration mechanisms that offer reliable scenario analyses at project, network and system levels; and
  - deterioration models that can simulate interactions between pavement, bridges and traffic
- Reliable inspection/condition information thru non-destructive evaluation (NDE) tools and sensor data
- Optimum life-cycle cost models
- Maintenance and preservation/rehabilitation strategies
- Performance measures for operational, serviceability/durability, structural safety and rare extreme-event limit-states; and
- Rapid strengthening, repair, and retrofit schemes for emergency response following extreme events

Table 2. Preliminary List of Parameters to be Considered

<table>
<tr>
<td>Identification of Issues
• Deterioration mechanisms
corrosion, spalling, cracking, fracture, fatigue, overloads, scour, settlement (soil conditions), explosion, chemical attack, collision, natural disasters (e.g., floods, earthquake), fire
• Bridge elements
piers/columns, deck, girders/beams, abutments, expansion joints, construction joints, wearing surface, cables, piles, footings, pylon/ tower, pier caps, bearings, backwall, embankments, pin and hangers, traffic barriers, handrails, connection hardware (welds, rivets, bolts), drainage system
• System for ranking and selecting
most common deterioration mechanisms; most detrimental deterioration mechanisms (capacity, serviceability, cost for repair, aesthetics), ability to inspect and monitor</td>
<td>Bridge Selection
• Types of bridges/structures
girder, truss, rigid frame, arch, cable stayed, suspension, slab, moveable, orthotropic, tunnels and other transportation systems, geotechnical structures, integral abutments
• Construction materials of bridges
steel, reinforced concrete, prestressed concrete, timber, advanced composites, high performance materials, specialty alloys, coatings
• Other criteria
geometric data (length, width, clearances), geographic location (climate and environmental conditions), traffic volume, what bridge crosses, maintenance practice
• Number of bridges/structures
LTBP sample bridges (periodic inspection), instrumented smart bridges, decommissioned bridges (autopsies)</td>
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<td colspan="2">Performance Monitoring Plan
• Evaluation methods
visual, instrumented
• Data collected
short-term monitoring, long-term monitoring, intermittent and continuous (structural health) monitoring, ambient data, controlled load test data, destructive test data
• Minimize costs but maximize value</td>
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In addition, it is likely that the LTBP will help foster the development and improvement of technologies related to effective bridge and asset management, including:

- New NDE tools for assessment of critical but typically inaccessible bridge elements and components such as pre-stressing tendons, suspension and cable stay bridge cables, bearings and dampers, component repairs (e.g., via fiber-wraps and shells), and seismic response control devices;
- Wireless, multi-modal, wide-area sensing, imaging, networking, data acquisition, communication and computing technologies;

- Data quality assessment measures, real-time data and image processing, wide area data warehousing and archival, data mining, data-based modeling, data visualization, data management, data optimization and control; and
- Technologies that may contribute to effective measures for homeland security, global warming, sound and vibration control.

Conclusions

The FHWA Long-Term Bridge Performance program is an exciting opportunity that will provide significant advances in our knowledge of how highway structures perform over the long term. It will markedly improve our capabilities to design better, long-lasting structures and to more effectively manage the large number of structures already in service. Based on the information which will be collected and analyzed over the anticipated 20-year life of the program, we anticipate that the program will result in: (a) major improvements in materials and structures life-cycle models and cost analyses, (b) development of performance-based specifications; and (c) development of appropriate and quantifiable performance standards and measures.

The LTBP program is a highly ambitious program that will require creativity in field-based research, while ensuring far more stringent quality standards than that of a typical transportation research program. It will require a holistic systems-based approach and considerable synergy between bridge owners, the bridge engineering community, academia, and industry, as well as the international community. It is a challenge which the FHWA believes can and will be met.