A STRATEGIC ROADMAP FOR BRIDGE PRESERVATION RESEARCH

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Abstract

Transportation agencies are aware that it is no longer possible to just "build their way" out of ever increasing needs for roads and bridges. Different approaches are therefore required for our aging pavement and bridge infrastructure, especially when combined with limited resources and rapidly growing traffic volumes. Effective preservation practices can extend service life and can be of help in providing better, safer, and more reliable service to users at less overall or lifetime cost.

To address this need, the Federal Highway Administration (FHWA) sponsored a workshop to develop a "roadmap" of bridge preservation research and development (R&D) needs. The workshop brought together practitioners and researchers from Federal, State, and local governmental agencies, consultants and industry, and academia, in an effort to develop a broad array of bridge preservation research needs statements. This paper documents the efforts of that workshop, and lays out a plan for the future.

Introduction

The Nation's Transportation System as a Public Asset – The U.S. highway infrastructure represents a vital component in sustaining the health and growth of the U.S. economy. Indeed, the nation's roadway network makes possible the transport of trillions of dollars in goods and services each year, providing the physical interconnectivity needed to accommodate an increasingly mobile workforce, and "just in time" inventory management. Moreover, as a key component of the nation's roadway network, these roadways play a critical role in national defense, homeland security, emergency preparedness and response, and overall quality of life.

In 2006, approximately 237 million vehicles traversed U.S. highways, accounting for nearly 3 trillion vehicle miles traveled. These substantial volumes highlight the need to keep our highway infrastructure in good condition. One concern is that these growing traffic volumes have not been met with corresponding growth in roadway miles. Delays and congestion caused by roadway deterioration and long-term reconstruction and rehabilitation projects have become a major problem for transportation agencies and the motoring public.

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The Need for Transportation System Preservation – It is now evident that increasing traffic volumes are far outstripping new roadway mileage. At the same time, the traveling public is demanding a public highway system that is safe, efficient and economical to operate, yet experiences minimal disruption and safety hazards associated with highway and bridge work zones. Transportation agencies face a common problem of limited budgets for improving the highway system to meet current and future needs. For example, one State transportation agency estimated that road use taxes, their primary source of state transportation construction money, have grown at an average annual rate of only 1.5% for the last 6 fiscal years; meanwhile, the amount of Federal funding available for core highway programs has actually leveled off. And, compared to estimated public highway system needs over the next 10 to 20 years, there will be a significant shortfall in funding for its most critical construction and maintenance needs.

Facing these challenges, transportation agencies must get the most out of the transportation infrastructure they already have, and the investment they have made in it. Delaying maintenance and repairs until major rehabilitation or replacement is necessary requires extensive and disruptive work that increases the potential for accidents, injuries, and fatalities among motorists and road workers. A promising alternative is effective preservation of sound roadway pavements and bridges to assure physical/structural integrity and extend their service life before they need major rehabilitation or replacement.

Effective preservation practices can extend service life and can provide better, safer, and more reliable service to users at less cost. These points reflect common sense and intuitive conclusions, but many aspects of preservation actions or their effect on service have not been demonstrated quantitatively. As a result, transportation agencies face quandaries about how to apply the right preservation action at the right time to the right pavement or bridge. The tools for pavement and bridge preservation exist, but guidelines for their application are often limited. Research, development and implementation have historically focused on construction and rehabilitation activities and not on preservation and maintenance.

While there have been sporadic attempts in recent years to identify critical research needs in bridge preservation, there has been no widespread systematic effort to reach out to a broad spectrum of bridge preservation professionals to devise and develop a comprehensive plan for identifying and conducting critically needed research and development activities for the entire transportation system.

Background on Bridge Preservation

Prior to the late 1960s, the nation's bridge infrastructure could not be defined by any consistent measure such as numbers, types, construction materials, ages, conditions, or by total value as a public asset. Systematic programs of maintenance and preservation were generally not in place. The collapse of the Silver Bridge at Point Pleasant, West

Virginia in December 1967 was the seminal event in the development of bridge inspection programs, bridge data collection, formal bridge maintenance and improvement programs and ultimately modern bridge management systems in the United States.

The Federal Highway Administration (FHWA) now maintains an inventory of all bridges – structures with a total span greater than 20 linear feet (6.1 linear meters) – on all public highways. Data to support and continually update this inventory is submitted annually by all the State departments of transportation (DOTs) and federal agencies.

Figure 1 shows that, even by the late 1960's, the bridge population in the United States was large and aging. This was just prior to the development of the National Bridge Inspection Standards and the National Bridge Inventory (NBI). NBI data from 2005 indicates that there are 472,769 bridges (traffic bridges with total span length of 20 feet or more) on the nation's public highways. Of these, 399,727 (84.5%) highway bridges are in fair to very good condition. A critical need exists within the community of transportation departments to develop the wherewithal to preserve these bridges in their current good condition with effective preservation treatments that extend the service life of the bridge, increase user service and safety, and ultimately save public transportation dollars.

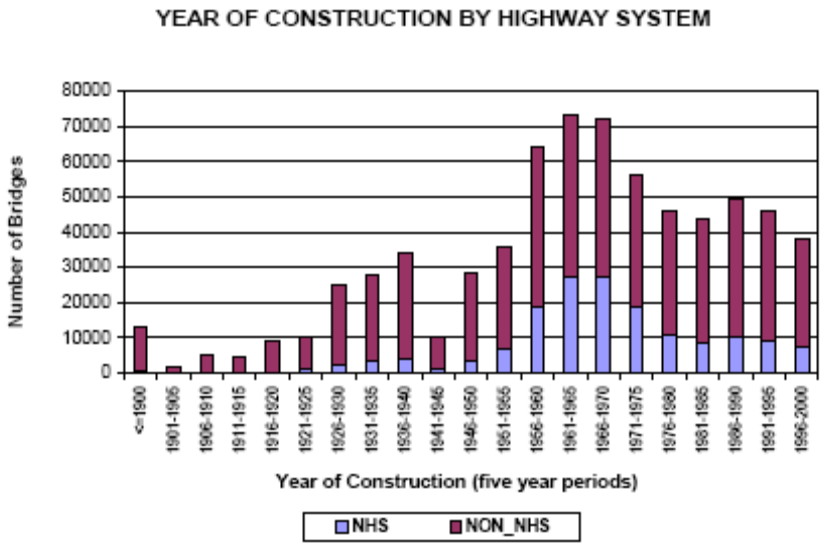

Figure 1 – Age Distribution of All Bridges in the United States - 2001

Identifying Critical Bridge System Preservation R&D Needs

The value and importance of the transportation infrastructure is unquestioned and the challenges to preserving that infrastructure are daunting. What is needed now is a way to help transportation practitioners make better choices for allocation of precious

transportation resources. Practitioners need to know what works, what doesn't work, and why. They need to know how to select preservation actions and when to apply them to get the most benefit for the least cost. They also need to know the factors that affect extensions of service life and the sensitivity each factor has for affecting the outcome of preservation actions.

To close this knowledge gap, the FHWA, along with AASHTO, sought a practitioner-driven analysis of fundamental and applied research needs in transportation system preservation. The FHWA worked with its partners in transportation agencies, industry, and academia to develop this roadmap for research, development and the implementation of preservation tools for asset management practitioners. This roadmap addresses both fundamental and applied bridge research, along with development and implementation needs, and is comprised of specific research needs statements (that include a description of the problem, objectives, general tasks, estimated research funding, implementation costs, and time required). The completed roadmap enables FHWA and its partners to seek funding and plan out activities which will enable preservation practitioners to address the knowledge gaps that impede program implementation and success.

The effort to develop this roadmap was designed to incorporate the knowledge and recommendations of a broad spectrum of bridge engineering experts and asset management practitioners. Input from state and local transportation agencies was sought along with input from TRB, academia, industry contractors and suppliers, and consultants. The study was conducted in a series of steps that:

- Identified broad areas of concern;
- Focused the thinking of these experts;
- Drew out expert recommendations in the form of clearly written, high priority needs statements for research, development and implementation; and
- Assembled these needs statements into a prioritized R&D roadmap.

This roadmap and the conclusions and recommendations herein are based on the results of the workshop and these needs statements.

Based on preparatory work conducted prior to the workshop, the following broad topics in bridge preservation were identified:

- Asset management and preservation
- Bridge decks
- Bridge joints
- Concrete superstructures and substructures
- Steel superstructures and substructures
- Selection of preservation actions
- Performance of preservation actions

The bridge preservation R&D needs workshop was conducted May 22- 23, 2007 in Dallas, Texas, and was scheduled in order to follow and build upon the FHWA-sponsored National Bridge Preservation Workshop (NBPW) in St. Louis, Missouri, held in April 2007. The discussions at the NBPW and the resulting conclusions were deemed highly useful to the bridge preservation R&D needs workshop.

Recommended Bridge Preservation R&D Needs Statements

Following the workshop, 28 bridge preservation needs statements developed during it were refined for completeness, technical content, feasibility and estimated cost and duration. Some statements that were similar in focus or were complimentary in nature were merged. The result was a collection of 25 distinct, important needs statements that could be packaged as a comprehensive program of research, development, and implementation, as indicated in the following table.

Bridge Preservation R&D Needs Statements Generated at the Workshops

Statement #	ASSET MANAGEMENT	ESTIMATED COST X 100 K	DURATION (Years)
Asset 01	Development of a bridge preservation process framework ensuring a standardized repeatable process for bridge preservation	$300	2
Asset 02	Establishment of Uniform Terminology and Definitions for Transportation System Preservation	$20	6 Months
Asset 03	Development Of A Process For Estimating The Remaining Service Life (RSL) Of Bridge Components And The Overall Bridge System Based On Observable Data.	$200	2
Asset 04	Evaluation of the AASHTO Commonly Recognized Elements (CoRe), Ten Years of Data	$300	1.5
Asset 05	Better Direct and Indirect Cost Models for Bridge Management Systems	$400	2
Asset 06	Modeling Early Bridge Deterioration and Prevention	$400	2
Asset 07	Evaluation, Analysis, and Documentation of Successful Bridge Preservation Practices	$1,100	6

Statement #	DECKS & JOINTS	ESTIMATED COST X 100 K	DURATION (Years)
Decks & Joints 01	Best practices for preserving bridge decks	$300	1
Decks & Joints 02	Determine the recommended practice and the life-cycle cost savings for using thin overlays to preserve concrete bridge decks	$900	3
Decks & Joints 03	Determine the recommended practice and the life-cycle cost savings for using sealers to preserve concrete bridge decks	$500	3
Decks & Joints 04	Determine the recommended practice and the life-cycle cost savings for preserving superstructure and substructure elements through the use and maintenance of watertight joints	$500	2
Statement #	**SUPERSTRUCTURES**	**ESTIMATED COST X 100 K**	**DURATION (Years)**
Superstructures 01	Development of a test for assessment of performance of weathering steel	$350	2
Superstructures 02	Development of Procedures for Preservation of Weathering Steel Bridges	$300	2
Superstructures 03	Performance Assessment of Existing Concrete Structure Corrosion Prevention/Mitigation Technologies	$1,000	4
Superstructures 04	Improved Inspection Techniques for Steel Prestressing Strand, Cables, and Ropes	$2,000	3.5
Superstructures 05	High-Durability Coatings and Sealer Materials for Structural Concrete	$350	2
Statement #	**SUBSTRUCTURES**	**ESTIMATED COST X 100 K**	**DURATION (Years)**
Substructures 01	Preservation of concrete highway bridge substructure units by preventing or delaying the initiation of active corrosion of the steel reinforcement	$400	2
Substructures 02	Preservation of concrete highway bridge substructure units by controlling the corrosion rate of the steel reinforcement once corrosion has initiated	$300	1.5
Substructures 03	Development of a high performance galvanic anode	$600	3
Substructures 04	Substructure preservation decision matrix to address corrosion issues of the steel reinforcement of concrete bridge substructure elements	$450	2
Substructures 05	Preservation of steel bridge piles	$500	3

Statement #	SELECTION of PRESERVATION ACTIONS	ESTIMATED COST X 100 K	DURATION (Years)
Selection 01	Implementation of Preservation Practices on Highway Bridges by State DOTs	$500	3
Selection 02	Develop bridge design guidelines to enhance Constructability and Maintainability	$300	2
Statement #	**PERFORMANCE of PRESERVATION ACTIONS**	**ESTIMATED COST X 100 K**	**DURATION (Years)**
Performance 01	Quantify the information necessary to guide bridge preservation decisions	$1,125	2
Performance 02	Develop deterioration models that account for the performance of preservation actions	$300	3

Conclusions and Recommendations

The recommended needs statements, as ranked, reflect a broad-based consensus of the most critical needs for research, development and implementation in bridge preservation. The participants at the workshop represented a suitable cross-section of preservation practitioners across agencies, geographical regions, climatic regions and levels of experience with preservation activities. They also represented a cross-section of disciplines including system management design, maintenance, research and suppliers of materials and equipment. Based on experience, knowledge, and the synergy of brain-storming sessions, the group identified and articulated the need for a comprehensive, R&D program that will require a substantial investment in money, expertise, and time.

In reviewing the results of the workshop and this bridge preservation R&D needs list, there are several key issues that stand out:

- There is a lack of reliable, useable data on:
    - The degree of preservation that is accomplished by applying a particular treatment on a bridge element with variations due to such factors as:
        - material used in the existing element
        - pre-existing condition of the element
        - quality control of the treatment application
        - weather
        - traffic loads
    - The actual costs of the treatment
    - How effective the preservation treatments is in preserving the element
    - How long the treatment is effective

- It is difficult to determine with significant confidence:
    - How much the service life of an element is extended by the preservation treatment
    - How much life-cycle costs and user costs are lowered by the preservation treatment
- There are few established procedures, metrics, or other markers that can be used to determine optimum timing for application of preservation treatments
- The effect of preservation treatments is difficult to account for in decision-making processes, e.g., management systems
- Preservation practitioners are unable to present the benefits of preservation programs in terms that are familiar and informative to upper management and legislatures
- Securing funding for dedicated preservation programs has been and continues to be difficult in the face of tight budgets, large backlogs of necessary maintenance and rehabilitation work, demands for new capacity, and a general misunderstanding of the benefits of preservation programs. Well focused research studies, aimed at determining, calculating and documenting the safety, operational and financial benefits of preservation programs would provide the knowledge to support requests to agency leadership for dedicated funding.
- There is a lack of standard terminology and definitions for preservation, particularly as bridge preservation is only now becoming an issue of broad discussion amongst the bridge community.

A key first step towards increasing the acceptance and awareness of preservation among transportation infrastructure practitioners is to provide preventive maintenance training to civil engineering students at the University level. The typical civil engineering student in the U.S. receives only cursory foundational knowledge related to highway bridges. Such educational training generally focuses primarily upon aspects of design and construction – affording scant coverage of the importance of preserving the infrastructure investment through preservation strategies and treatment techniques. Indeed, it is widely recognized in the transportation infrastructure community that preservation education receives far less emphasis than its performance benefits should warrant. The long-term impact of deficient educational preparation in preservation strategies and techniques is widely evident amongst even seasoned transportation practitioners, many of whom lack even basic knowledge of preventive maintenance concepts.

Thus, increasing the quality and quantity of University-level preservation training is essential to provide the newly minted transportation engineer with a better foundation upon which to build his/her skills in, and acceptance of, the preventive maintenance

concept. Indeed, lacking this fundamental knowledge, professional transportation infrastructure practitioners and agency management face an often times up-hill battle when trying to integrate preservation practices into a comprehensive asset management program. Moreover, the high-turnover rates witnessed within most DOTs among experienced transportation engineers makes the need to establish the need for preservation concepts early on amongst junior staff even more essential.

The development of this roadmap has been the first step. The challenge remains for FHWA, TRB, AASHTO, and other partners to commit the resources according to its direction so that agencies have the tools and knowledge to effectively use transportation system preservation to extend the life of the nation's infrastructure.

The complete workshop report, which includes detailed bridge preservation research needs statements along with detailed pavement preservation statements developed in a parallel effort, can be found at:

http://www.tsp2.org/roadmap/RR_complete.pdf