FEDERAL HIGHWAY ADMINISTRATION BRIDGE RESEARCH AND TECHNOLOGY DEPLOYMENT INITIATIVES

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ABSTRACT

The Federal Highway Administration (FHWA) has long-standing technology programs and continues to support both short-term and long-term research needs. In the area of bridge engineering, FHWA's current bridge research and technology research and deployment thrusts include: (1) accelerated repair and construction, (2) bridge and tunnel security, (3) bridge system preservation (management, inspection, maintenance and rehabilitation), and (4) load and resistance factor design (LRFD) implementation. The FHWA is also currently developing a more formal structure for stakeholder involvement in research agenda-setting and monitoring, and in the delivery and deployment of new technologies to the bridge engineering community. This paper provides an overview of the FHWA's current bridge technology focus areas and describes a proposed approach for involvement of bridge engineering stakeholders in a formalized research and technology deployment process.

INTRODUCTION

The Federal Highway Administration (FHWA) has a long history of promoting highway technology and facilitating the construction of the network of roads and bridges within the United States. The focus on new highway construction peaked in the mid-1960s, during the development of the Interstate Highway System. With the Interstate System substantially complete, the focus of the FHWA shifted from new construction to one which has an increased emphasis on broader and more diverse U.S. highway transportation needs, in order to enhance user mobility and interstate commerce, ensure safety to the traveling public, and promote efficiency and intermodal connectivity within the system. The current focus also has FHWA providing technology solutions to its State and industry partners, which are intended to provide support in solving short-term problems, and laying the groundwork for the development of new technologies for use by the U.S. highway industry in the longer term.

In the United States, highways accommodate 90% of all personal travel and more than 80% of freight, and are thus critical for both personal mobility and commerce. Demands on the system increase annually and traffic volume growth has been dramatic both for passenger vehicles and freight. Meanwhile, the highway system infrastructure, including bridges, earth retaining structures, and tunnels, continue to age and deteriorate.

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Bridges comprising the U.S. highway system are, on average, more than 40 years old. The majority of these structures were designed with a theoretical 50-year design life and yet are assumed to have essentially an infinite life. Although these structures continue to age, demands on their use continually increase. Today, more than 25% of the inventory of nearly 600,000 highway structures contained within the National Bridge Inventory (i.e., more than 150,000 bridges with a length in excess of 20 ft) is classified as structurally or functionally deficient and in need of repair, rehabilitation or reconstruction. Sufficient funds are not available to address the current level of needs; meanwhile, we are faced with a rapidly growing increase in the number of structures requiring work and in the complexity of work required to provide the level of service required of these highway structures.

In order to meet the challenge of improving our highway bridge network in the face of increased demands, continued deterioration, and constrained funding, things must be done differently. Bridge owners must work smarter and more efficiently in their maintenance and reconstruction programs. They will, however, need technological solutions to assist in this effort, and both short- and long-term research and development efforts are required to provide these technology solutions. In the short-term, there are many recently developed technologies and innovations that can be put into practice to enhance system performance. Longer-term, higher-risk, and potentially higher-payoff research is also required to complement these short-term efforts, in order to provide the breakthrough technologies that will be needed to support the challenges of the future.

The FHWA has historically partnered with the American Association of State Highway and Transportation Officials (AASHTO), State transportation agencies, the Transportation Research Board (TRB) and its National Cooperative Highway Research Program (NCHRP), and private industry and academia in research and technology programs. These partnerships will be enhanced as FHWA continues its leading role in sponsoring, conducting, and guiding research and technology efforts to improve and sustain the Nation's highway infrastructure.

In this regard, several critical needs and priority focus areas have been identified by the FHWA for highway bridges. Among these for the short term are:

- Accelerated Repair and Construction Technologies – In order to decrease the impact on the traveling public, accelerated repair and construction technologies and approaches are required. Bridges must be repaired or replaced in less time and with less cost, in order to decrease the impact on the traveling public and maximize the use of limited available funds.

- Bridge and Tunnel Security – Vulnerabilities within the inventory of structures must be identified and mitigated to ensure adequate levels of highway system performance following the occurrence of natural or manmade extreme events.

- Bridge System Preservation – As noted above, the inventory of existing structures is aging, and limited funds are available for rehabilitation and replacement. In order to "get ahead of the deterioration curve," smart preservation strategies must be employed in order to prevent structures from becoming deficient, and decision support systems must be effectively implemented to assist decision makers in optimizing the expenditure of limited funds.

- Implementation of Load and Resistance Factor Design – Previous bridge design codes and load rating procedures only minimally considered structural safety and reliability in an explicit manner. Current design philosophies feature the use of limit states, multiple load and resistance factors, and a semi-probabilistic determination of a structure's reliability. The Load and Resistance Factor Design (LRFD) approach has been adopted by AASHTO for the design of new bridges, and AASHTO has indicated its intent to standardize on LRFD design nationwide by 2007. Efforts are underway by FHWA to facilitate and assist bridge owning agencies to effectively implement the LRFD philosophy.

Each of these priority areas are discussed in further detail below. The most critical aspect of ensuring success in the deployment of these technologies, however, is to ensure adequate stakeholder involvement at every stage in the research identification, conduct, and deployment process. As a result, FHWA has proposed an enhanced mechanism for improving stakeholder involvement in FHWA research and technology activities, which is also described below.

RESEARCH PRIORITY AREAS

Accelerated Repair and Construction Technologies

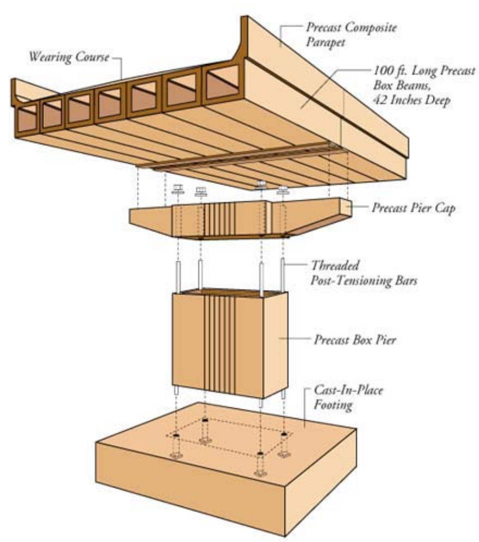
The need for accelerated repair and construction is clearly evident when considering urban environments. Traffic growth in cities throughout the country has reached levels so significant that mobility disruptions occur any time that activities are initiated. It becomes difficult to close lanes to repair a structure without causing extremely large traffic disruptions, even in the late evening hours or overnight. Rapid repair techniques are required to strengthen a structure within a shortened time-frame in order to minimize traffic disruption and the associated impacts on mobility and commerce. These techniques should also minimize the potential for future interventions by improving long-term performance. Consider that, today, a new segment of highway typically takes years to construct – sometimes as many as 10 years for a 10 mile stretch of pavement with 5 bridges on it; why can't this be decreased to 1 year or even 6 months using innovative design, contracting, and construction approaches?

It is for this reason that the current FHWA "mantra" is to "get in, get out, and stay out." A number of studies have been performed in recent years intended to address the needs of accelerated repair and construction. This has culminated in a focused program supported both by FHWA and AASHTO in accelerated repair and construction. From a bridge technology standpoint, much of the current effort is on the appropriate application of high performance materials, smart foundation construction technologies, and prefabricated bridge components and systems.

High performance materials typically include high performance concrete (HPC), high performance steel (HPS), and fiber reinforced polymer (FRP) composites. High performance does not necessarily mean, nor does it necessarily exclude, properties that relate to high strength; high performance does, however, include properties that relate to significantly improved constructability, durability, and resistance to environmental and vehicular degradation.

HPC and HPS members and structures can be made lighter and possibly simpler than those comprised of conventional concretes and steels, thereby easing construction and facilitating rapid application. These advanced structural materials can also be engineered to eliminate problems with the traditional materials; e.g., with increased density or lower permeability which reduces chloride intrusion, or with improved weldability and increased fracture toughness. HPC members can be constructed with rapid-curing properties, allowing structures to be opened to traffic more quickly, thereby minimizing the impact on the traveling public.

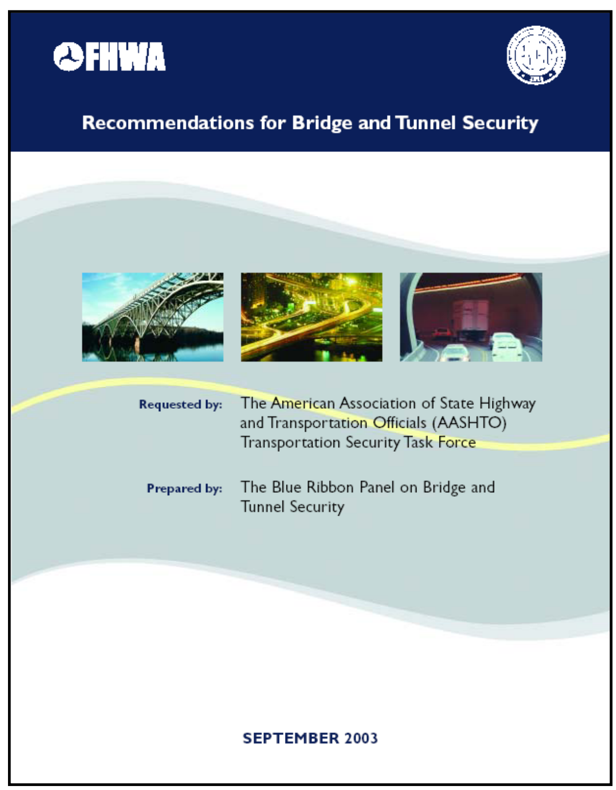
FRP composites, which are used extensively in aerospace and military structural applications, are making inroads into the civil and bridge engineering infrastructure. In its FRP composite research program, FHWA seeks to advance the technology for new construction, rehabilitation and preservation, and strengthening of the existing structural inventory. FRP composite bridge decks and structural members are typically much lighter, and can be preassembled to facilitate construction. The use of the FRP materials for repair and strengthening of structural concrete members is increasing and, when properly designed and applied, can be effective and efficient.



For a growing number of States, the use of prefabricated bridge elements and systems is also helping to achieve reduced traffic and environmental impacts, enhanced safety, improved bridge constructibility, and accelerated project completion. Prefabricated bridge elements, which range from bent caps to deck panels, and superstructure and substructure systems, are manufactured under controlled conditions and brought to the construction site ready to install. Prefabricated elements are particularly useful in situations where traditional cast-in-place construction would have to be sophisticated and expensive; e.g., at long water crossings or complex interchanges. Prefabrication also facilitates construction in urban settings, where work space is limited. Safety is improved and traffic impacts are lessened because some of the construction is moved from the roadway to a remote site, minimizing the need for lane closures, detours, and use of narrow lanes.

Bridge and Tunnel Security

For bridge engineers, protecting bridges and other structures used to mean guarding against such processes as fatigue, scour, and earthquakes. The events which occurred on September 11, 2001, changed all that as engineers are now also faced with the challenge of how to protect structures from potential terrorist attack. Bridge and tunnel engineers throughout the United States are being asked to assess the vulnerability of their structures, and to provide solutions to reduce this vulnerability. To equip engineers to answer these new and complex questions, FHWA has launched a number of structural security initiatives.



Among these is a workshop developed in cooperation with the U.S. Army Engineer Research and Development Center (ERDC). For the past 35 years, the ERDC has carried out structural vulnerability research and development work, which has included numerous full-scale explosive tests on bridges and tunnels, the analysis of complex structural data, and developing appropriate computer design and analysis tools. FHWA and the ERDC have created an ongoing workshop series intended to train FHWA, State, and private sector engineers on topics which range from bridge and tunnel vulnerability to explosive attack, structural response to blast-induced loadings, and vulnerability predictive tools and mitigation methods.

The FHWA has also been working in partnership with AASHTO under the flag of the FHWA/AASHTO Blue Ribbon Panel on

Bridge and Tunnel Security. The panel is developing short- and long-term strategies for increasing the security of critical bridges and tunnels, including implementing design and retrofit techniques, and is identifying current and future research needs. Opportunities exist for research to better understand blast loading and the effectiveness of retrofit techniques, the development of enhanced risk analysis procedures, introduction and use of information technologies to mitigate and prevent damage due to terrorist activities, and other areas to reduce the threat and the exposure. The results of this effort will be used to establish a roadmap for prudent, cost-effective measures to make our transportation system more secure.

The report of the Blue Ribbon Panel was recently completed, and has been posted on the FHWA web site at http://www.fhwa.dot.gov/bridge/security/brp.pdf

Bridge System Preservation

With an aging bridge population, appropriate decisions must be made regarding when and what type of maintenance is required for a large number of bridges; and whether rehabilitation or replacement is a more appropriate strategy for other bridges. In order to address this need, rigorous decision support systems are required and more detailed and detailed bridge inspection information is required. The FHWA has been performing research in these areas for a number of years and, through this effort, many new applications have been developed and implemented. Research continues to be conducted in order to enhance current bridge management system decision support systems and to develop and implement inspection technologies that provide improved characterization of structural damage.

Improved bridge and tunnel inspection technologies are being developed via the Non-Destructive Evaluation Validation Center (NDEVC), which is located at the FHWA's Turner Fairbanks Highway Research Center. With more accurate, non-contact and non-destructive inspection techniques, damage can be characterized at earlier stages so that life- and performance-preserving corrective actions can be taken. Among recent techniques for quantitative, non-subjective non-destructive evaluation of bridges which have been developed through the NDEVC are:

- Ultrasonic systems which send waves into the material to detect cracks;
- Eddy current testing which creates a magnetic field that opposes the magnetic field of the original material – locations of cracks will appear where the created impedance diverge;
- Bridge acoustic emission Local Area Monitoring, which can be used to track known defects, whether corrective measures are working, and to monitor structural integrity of welds and connection points;

- Laser measurement technologies to track the deformation of material under stress;
- Ground-penetrating radar is being tested for application in bridge deck inspections to identify areas of delamination; and
- Active thermographic crack detection which detects changes in temperature when heat is applied to a material – these temperature changes are a result of cracks which allow the escape of heat.

A number of other activities are also underway at FHWA to support bridge system preservation strategies. Research to develop technologies which provide relatively simple repairs for deteriorated or cracked concrete or steel members has been an ongoing program for many years. Improvement of and support for bridge management systems and approaches is an important part of the FHWA bridge program.

To support the bridge system preservation initiative, FHWA and AASHTO jointly sponsored an international scanning tour in the spring of 2003. The FHWA/AASHTO Panel on Bridge System Preservation and Maintenance, which was comprised of ten members representing AASHTO, FHWA, State transportation agencies, the National Association of County Engineers, and academia, traveled to the African and European continents and met with highway agency representatives, and bridge management and inspection technology practitioners and researchers, from South Africa, Switzerland, Germany, France, Denmark, Sweden, Finland, Norway, England, and Wales. Specific topics of interest addressed during the scanning tour included:

- Organizational, policy and administrative issues including: relationship among agencies (national, local); organization of their bridge activities (design, construction, operation, inspection); inventory ownership and management; inventory characteristics (number, type, materials, span lengths); and inspection type, frequency, and rigor;

- Status of their Bridge Management Systems (BMS) including: economic modeling and forecasting; deterioration modeling; and information technology (databases, architecture, input, and updating);

- Inspection issues and practices including: typical practices; innovative methods; use of non-destructive evaluation (NDE) technologies; use of load testing; design for inspection (e.g., accessibility) and “smart” bridges; and

- Operations issues and practices including: permit vehicles; load rating and load posting; indicators of performance and their relationship to design, maintenance, repair, and enforcement.

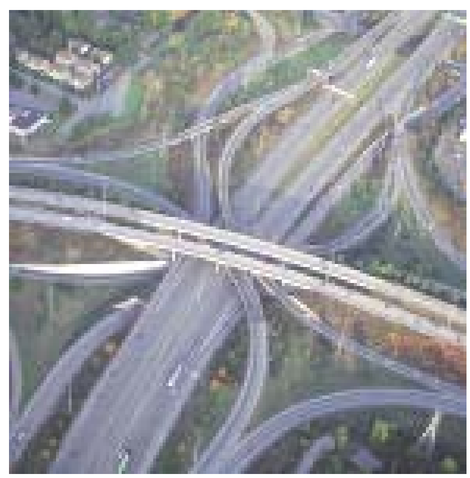
A number of important policy and operational issues that could have a significant impact on U.S. bridge management practices were identified during the scanning tour, and will be further evaluated and discussed with appropriate U.S. bridge owning and operating agencies.

Included in these are: setting a rational bridge inspection frequency based on bridge type and consequence risk; defining minimum bridge inspector qualifications and training; development of integrated highway structure management approaches which include bridges, tunnels, free-standing retaining walls, sign and light structures, etc.; and, application and use of appropriate waterproofing systems for bridge deck protection.

The AASHTO/FHWA Panel is currently preparing a draft report documenting the findings of the Scanning Tour, which should be ready for dissemination and technology implementation by AASHTO and the FHWA near the end of 2003.

Implementation of Load and Resistance Factor Design

The bridge engineering profession is currently moving to the Load and Resistance Factor Design (LRFD) philosophy. The AASHTO LRFD Bridge Design Specifications employ state-of-the-art analysis and design methodologies, and make use of load and resistance factors based on the known variability of applied loads and material properties. The load and resistance factors contained in these specifications are calibrated from statistics obtained from the inventory of existing bridges, and are intended to provide a uniform level of safety. Bridges designed with the LRFD Specifications should therefore lead to a higher level of serviceability and maintainability.



As LRFD will positively impact the safety, reliability, and serviceability of newly designed bridges, AASHTO has set a transition date of October 2007 by which time all new bridges must be designed with the LRFD Specifications. The FHWA has therefore developed a strategic plan to assist and facilitate State transitioning to LRFD by the 2007 target date. This strategic plan includes:

- Identifying past, current, and future LRFD implementation plans of States;
- Identifying and deploying a showcase of successful LRFD implementation approaches by States which have completed their transitioning;
- Developing a model implementation plan and guidelines that can be used by States to identify and prioritize items to be accomplished for successful LRFD implementation; and to make decisions, set priorities, determine actions, and review performance on a regular basis;
- Providing hands-on implementation and transition planning assistance that assists a State in initiating its detailed implementation planning process;
- Developing two comprehensive design examples – one each for a steel and concrete bridge;

- Deploying technical LRFD design training to States;
- Developing detailed, hands-on courses, to be delivered by the FHWA's National Highway Institute;
- Compiling and maintaining a comprehensive list of LRFD resources (books, software, courses, etc.); and
- Supporting LRFD research.

A wealth of information supporting LRFD transition activities can be found on the AASHTO LRFD website at http://lrfd.aashtoware.org

STAKEHOLDER INVOLVEMENT IN FHWA RESEARCH AND TECHNOLOGY

Stakeholder involvement is critical to the success of both the short- and long-term research and technology deployment efforts undertaken by the FHWA. Past efforts to involve stakeholders in bridge research and technology programs has been somewhat ad hoc in nature, although there have been fairly high levels of involvement over time. Current efforts within FHWA are focused on the creation of a more structured and proactive mechanism to ensure adequate stakeholder involvement in research agenda setting, research progress and output monitoring, metrics for measuring success, and in the effective deployment of new technologies.

FHWA's research and technology stakeholder model assumes the following characteristics: that involvement is strategic rather than tactical; long-range rather than immediate; continuous rather than periodic; provides a process that is open, visible, and transparent; and is representative of broad range of stakeholders and needs. We are looking to involve recognized leaders in bridge research and technology deployment, provide an equal voice for all participants, ensure proactive participation in the process, and for stakeholders to provide additional insights on issues of a technical, operational, political, user constraint, and cost basis.

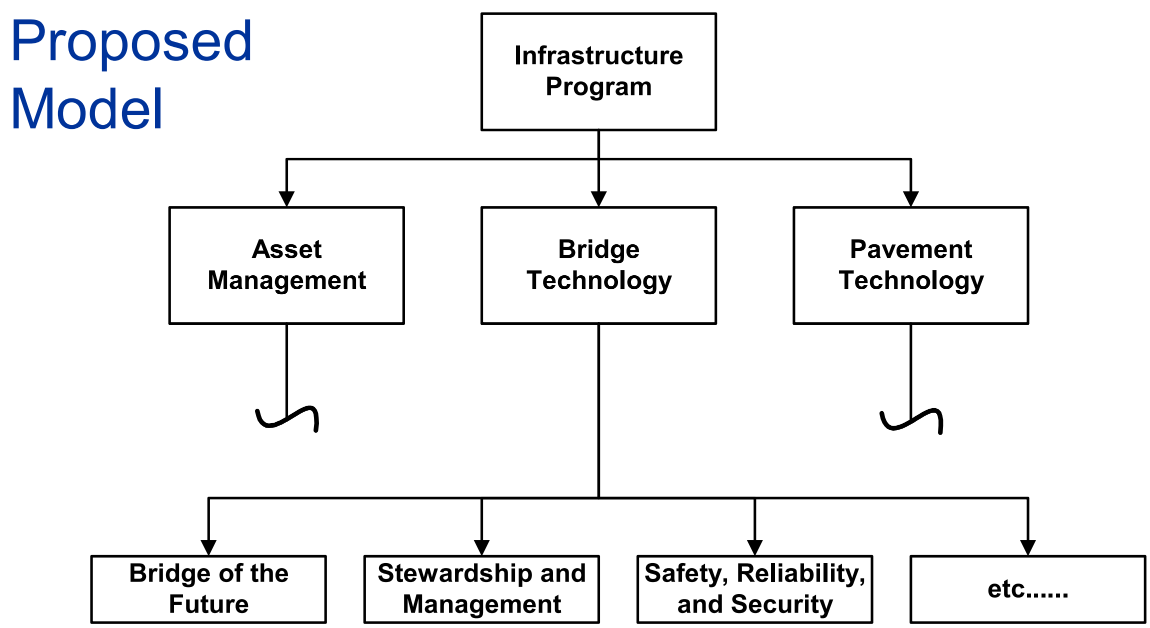
FHWA envisions the role of stakeholders in its research and technology programs as:

- Providing focus and direction for the program via a peer review process;
- Identifying needs and gaps, opportunities, and innovations;
- Setting priorities;
- Evaluating quality and value; and
- Identifying champions to assist in new technology deployment.

However, this is an evolving stakeholder involvement model and process, and there are still a large number of unresolved issues and concerns which must be addressed before the process is finalized. Among these are:

- The level and source of funding necessary to support research and technology activities, stakeholder involvement, and FHWA staff time;
- The amount of time and level of effort which will be required of stakeholders and FHWA staff;
- The size, representation, and rotation rules for stakeholder committees; and
- Whether this stakeholder structure is operated by FHWA, TRB, AASHTO, or another organization to ensure independence and effective interaction.

The FHWA is currently encouraging the bridge engineering stakeholder communities to share their thoughts regarding our proposed stakeholder involvement model.



CONCLUSION

The need for a focused highway bridge and tunnel research and technology program cannot be understated. With significantly escalating demands and reduced resources, "business as usual" is not sustainable. The FHWA has a number of high priority bridge engineering technology development and deployment areas, of which four are briefly described herein: (1) accelerated repair and construction, (2) bridge and tunnel security, (3) bridge system preservation, and (4) implementation of load and resistance factor design.

The drivers for these bridge technology programs are the needs of the bridge engineering stakeholder community. It is recognized that all of these programs require a high level of stakeholder involvement, which can provide input on the broad range of research and technology deployment activities. Among the areas for inclusion of stakeholders are: policy and agenda setting, project scoping, merit review, research evaluation, and deployment and implementation.