AASHTO/FHWA International Technology Scan: Bridge System Preservation and Maintenance

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ABSTRACT

Although much progress has been made in the United States to develop and deploy tools to effectively inspect and manage highway bridges, more can be learned from inspection and management processes and the associated systems and technologies which are employed abroad. During the period March 28 through April 13, 2003, the AASHTO/FHWA Panel on Bridge System Preservation and Maintenance, which was comprised of ten members representing AASHTO, FHWA, State and local transportation agencies, and academia, traveled to the African and European continents to meet with highway agency representatives, and bridge management and inspection technology practitioners and researchers. A number of important policy and operational issues that could have a significant impact on U.S. bridge management and maintenance practices were identified during the scanning tour. These are discussed in the following paper.

INTRODUCTION

During the 1980s, transportation professionals in the United States became increasingly aware of improved materials and innovative methods employed by other countries in their transportation programs. This awareness was in large part due to the Strategic Highway Research Program, which was one of the first U.S. highway programs to formally recognize the values of learning about practices abroad. Since then, several programs have brought foreign technology to the attention of U.S. State and local public agencies, eventually resulting in the creation of the Federal Highway Administration's (FHWA) International Technology Scanning Program (ITSP) in 1990.

The ITSP was intended to provide a means of learning from the research and technological advances of others. Since the ITSP was established, approximately 42 scans on various surface transportation topics were undertaken. Most were done in cooperation with the American Association of State Highway Transportation Officials (AASHTO), the Transportation Research Board (TRB), and TRB's National Cooperative Highway Research Program (NCHRP).
In 1998, the FHWA and AASHTO, through its Special Committee on International Activity Coordination, agreed to extend the partnerships created by the ITSP through the establishment of a Joint AASHTO/FHWA International Highway Technology Scanning Program. The new joint program is undertaken cooperatively by FHWA, AASHTO, and NCHRP. It includes a cooperative technology scanning proposal and topic selection process and joint responsibility for U.S. implementation of useful foreign practices and innovations identified as a result of the scans.

AASHTO/FHWA technology scan studies involve teams of specialists in a particular discipline that are dispatched to consult with foreign counterparts in Europe, Japan, Australia, New Zealand, Canada, and those countries where most of the advances in transportation relevant to the United States are being made. Each international scan study focuses on a topic of high interest to the domestic transportation community. Topics can concern technical, managerial, or policy matters that can be broad or narrow in scope.

While the makeup of a team varies from one scan to another, participants typically include representatives from FHWA, AASHTO, local governments and, where appropriate, transportation trade and research groups, the private sector, and academia. Personal domestic and international networking, team dynamics, and the creation of U.S. champions for promising foreign innovations are keystones of the scanning program. Successful implementation in the United States of the world's best practices is the overall goal of the program.
In many instances, scan studies add depth and cohesion to research and practice in the United States. Scan findings generally complement and enhance the existing knowledge base within the U.S. highway community, often putting innovations on the fast track to deployment.

THE BRIDGE SYSTEM PRESERVATION AND MAINTENANCE SCAN

Automation of inspection and management systems is becoming an integral part of managing a nation's transportation infrastructure. This is particularly true with processes associated with the design, inspection, maintenance, and operation of highway bridges and other highway structures – many of which are aging and deteriorating not only in the United States, but worldwide. Although progress to slow down aging and deterioration has been made in many of these areas, more can be learned from bridge inspection and management processes, and the associated systems and technologies, which are employed abroad.

During the period of 28 March through 13 April, 2003, the AASHTO/FHWA Panel on Bridge System Preservation and Maintenance traveled to the African and European continents and met with highway agency representatives, and bridge management and inspection technology practitioners and researchers from a number of countries. Among the countries represented in these meetings were South Africa, Switzerland, Germany, France, Denmark, Sweden, Finland, Norway, England, and Wales.

The AASHTO/FHWA scanning team was comprised of ten members representing AASHTO, FHWA, State transportation agencies, the National Association of County Engineers, and academia. Prior to the scan, the team identified a number of topics which they wanted to explore with their international colleagues. These topics 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, data transfer, 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.

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

The objectives of this scanning tour were to review and document innovative techniques, materials, procedures, and equipment used in the host countries and to evaluate these elements for potential application in the United States. To this end, the U.S. team had meetings with engineers and decision makers representing government agencies, private sector organizations, and universities involved with various aspects of highway bridge operations, management, and preservation, and participated in site visits to observe the preservation techniques, strategies, and new construction intended to provide longer and more reliable performance.

MAJOR FINDINGS

The following are the observations and major findings reported by the U.S. scanning team. The information reported herein is currently under review by the various host countries, for confirmation and validation.

Most of the countries visited had bridge populations significantly smaller than that in the United States. There was, however, much similarity in the composition of their bridge populations (types of materials, structural systems, and in the number and length of spans), and in the average age of their bridge populations. It was also noted that, in almost every country, the same types of problems were being experienced as those typical in the United States. Such problems included construction quality control, premature deterioration due to corrosion, insufficient resources (staffing and funding) to effectively maintain their aging bridge populations, and increasing truck volumes and loads.

A number of important policy and operational issues that could have a significant impact on U.S. bridge management and system preservation 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 were:

- Bridge inspection frequency based on bridge type and consequence risk.

- Bridge inspector qualifications, training, and level of expertise matched to the type or severity of the bridge deterioration state and risk.

- Development of corridor-based bridge management approaches which can enhance bridge preservation strategies and project decision-making.

- Successful use of waterproofing systems for bridge deck protection.

- Concrete permeability evaluation using advanced techniques and tools.

In all, many innovations and "best practices" were observed and noted, regardless of the size of the organization, and a lot was learned during the scan process.

DISCUSSION OF MAJOR FINDINGS

Bridge Inspection Frequency

Current practice in the United States is to inspect every highway bridge at least once every two years. The inspection interval can be lengthened to four years for newly-constructed bridges, and bridges considered as relatively low risk (or in very good condition) – however, a State must petition the FHWA to approve the longer inspection interval for each bridge. Comprehensive underwater inspections are required at least once every five years.

In South Africa, bridge inspection frequency varies from three to five years, depending on the type of inspection and the severity of distress. Four levels of inspection are defined: visual, principal, monitoring, and verification. Visual inspections are conducted every five years. Principal inspections are similar in scope and frequency to the routine biennial inspections conducted in the United States. Monitoring inspections involve a more in-depth look at a bridge and are conducted as needed. Verification inspections are conducted as a means of quality assurance using a random sample of bridges each year.

In France, frequency and depth of inspection vary with condition and robustness of structures, typically ranging from three to nine years. Three-year inspections are generally cursory while more in-depth inspections are performed every nine years.

Germany has defined four levels of inspection: superficial, general, major, and special. Superficial inspections, which are primarily visual, are performed by maintenance personnel on a quarterly basis and do not require any special knowledge of bridges. General inspections are conducted every three years while major inspections occur on a six year frequency. Special inspections are conducted as needed to assess known deficiencies or damage.

In Denmark, three types of inspections are defined. The principal inspection, similar to the U.S. biennial inspection, is performed every one to six years. Special inspections are carried out as necessary when damage has occurred or is suspected. Routine inspections are performed anywhere from daily to every six months.

In Sweden, five inspection types are defined with varying frequencies. Regular inspections are cursory in nature, typically performed by maintenance contractors. Superficial inspections, which are also cursory, are performed twice annually for bridges on the National highway network and once a year for all other bridges. Major inspections, similar to U.S. biennial inspections, are performed every six years. General inspections are performed between the major inspections to monitor defects noted during the last major inspection. Special inspections, typically involving use of non-destructive testing techniques and equipment, are performed every three years as necessary to assess specific damage.

Bridge inspection intervals in Finland are based on the inspector's recommendation and commonly range from four to eight years, depending on bridge condition. Meanwhile, in Norway, five inspection types are identified: acceptance, warranty, general, major, and special. Acceptance inspections occur at the completion of bridge construction projects. Warranty inspections take place three years after a bridge is opened to traffic. During an annual or biennial general inspection, a bridge is visually assessed for severe problems. Major inspections, which are more in-depth than a general inspection, are performed at the discretion of a local bridge engineer. Special inspections are performed as necessary to assess specific damage.
Finally, in the United Kingdom, general inspections are performed every two years, typically involving a cursory review for major safety defects, while principal inspections, similar to the U.S. biennial inspection, are performed every six years.

In summary, most of the countries visited during this scan base their bridge inspection frequency on specific factors such as type of structure, condition, and age, rather than on an arbitrary time interval.

The U.S. inspection interval was set in the early 1980s, and was not based on any rational assessment of structural risk. For example, relatively simple but very common slab-on-girder bridges have performed very well over time, and have not had many collapses or failures resulting from normal usage. Problems that occur in such structures are typically relatively easy to identify and repair. The relative risk of extending the inspection interval for this type of bridge is therefore considered rather low. The potential benefit, however, would be significant, as there are a large number of these bridge types in the United States, and relieving the States from having to inspect every one of these biennially would allow them to better allocate their limited resources so they could spend more time and effort inspecting and managing problem structures.

The scan recommendation resulting from this was to therefore conduct a study to determine the relative risk for typical bridge types, and to then develop a rational method for determining the frequency, associated rigor, and level of inspector expertise for bridge inspection.

Bridge Inspector Qualifications

In the United States, the National Bridge Inspection Standards, which are detailed in Federal regulations, outline minimum qualifications for individuals in charge of inspection programs and for inspection team leaders. Current bridge program qualifications require that the individual in charge of a bridge inspection team have a minimum of five years experience, and that he or she have completed a specified comprehensive training course. No minimum qualifications or training are required for other members of the inspection team. Therefore, qualifications do not currently consider varying levels of training based on the types of inspections being performed, nor do they require testing, formal certification or calibration.

Bridge inspectors in South Africa are professional engineers with at least five years of design experience (four years if inspecting culverts). Although there are no minimum training requirements, inspection courses are offered. In Germany, inspectors must have a civil engineering education, five years of bridge inspection experience, must have completed a one-week training course, and meet physical condition requirements.

In France, three levels of inspection staff have been defined: Project Manager (Engineer), Inspector, and Inspection Agent. Minimum requirements related to education, level of experience, and successful completion of various training modules have been established. A formal certification process has been implemented involving a written test and field demonstration of skills.

Denmark relies on a mentoring approach to insure that inspectors develop appropriate skills. New inspectors must work with experienced staff for an undefined period of time. In Sweden, bridge inspectors must have an engineering background, knowledge, and experience in addition to specific training, which involves three days of class work, two days of field application, and a final test. In Finland, inspectors must complete an initial training program involving four days of class work and two days of field work, and an examination. Yearly training, involving field inspection and a calibration of results, is also required. Repeated poor results during the training exercises can lead to loss of certification.

Therefore, in summary, several countries have implemented programs that qualify inspectors based on the training received for various structure types. A few programs also incorporate periodic calibration and certification processes.

As an aside, France and Germany specifically recognize that bridge management systems rely primarily on data collected during bridge inspections; therefore, the use of skilled and well-trained inspectors is vitally important to them.

The scan recommendation is to therefore develop the framework for a process of qualifying bridge inspectors based on tiered and targeted levels of training along with periodic re-certification and recalibration. In order to do this, a study will need to be conducted to investigate the costs and benefits of implementing these enhanced inspector training programs Nationally.

Corridor-Based Bridge Management Systems

Bridge management systems in the United States operate, for the most part, independent of other highway asset management systems. Although some activity is underway to integrate management systems for efficiency in data collection and storage, little effort has been made to combine related assets into a system-wide or corridor-based management scheme. Such an approach can provide significant efficiencies from a resource scheduling and cost standpoint.

The scanning team noted that two Scandinavian countries are currently developing such approaches and incorporating them in their highway system asset management systems. These were discussed with a focus on bridge preservation and project needs.

Finland is developing a network-level management system called "Hibris" which will analyze and evaluate bridge and pavement needs in an integrated environment. The system will be capable of optimizing actions using budget data and Markovian models for both pavement and bridges. Performance and planning indicators, including a "repair index" and a "rehabilitation index" are being developed for the system.

Switzerland has designed a system based on integrated asset management principles and intended to award a contract in 2003 to develop the system. Under this new system, a corridor management approach will be initiated providing management tools for planning actions on highway assets, including pavements, structures, electromechanical systems, and highway accessories. The system will allow managers to optimize actions on assets system-wide or on a corridor or section of the highway facility.

The U.S. scanning team recognized the value in a corridor-based management approach, and recommended that a study be initiated to evaluate and promote corridor-based management principles for bridge preservation and project decisions. This would start with a detailed evaluation of the corridor management approach for highway assets in Finland and Switzerland, and would then recommend a plan for integrating a corridor-based management scheme into U.S. asset management programs.

Bridge Deck Protective Strategies

In the United States, bridge deck deterioration is one of the most costly aspects of maintaining a large inventory of bridges. Any effort which can extend the service life and reduce the need to repair or replace bridge decks on a regular basis will have a significant impact on a local or regional transportation system, its efficiency in moving traffic, and in terms of the amount of money needed to maintain that bridge inventory. Waterproofing systems and corrosion resistant details (e.g., epoxy coated steels and concrete surface treatments) help protect a bridge deck from deterioration, but add costs to the initial construction of the deck and ongoing maintenance costs. These factors will influence the long-term life cycle costs of the bridge and should be reviewed to determine appropriate and cost effective strategies.

As noted in the report on a 1995 technology scan, and reconfirmed in this scan, many European countries currently rely heavily on the use of waterproofing systems and membranes to provide protection to the concrete bridge deck in order to retard and prevent deterioration. Typically, these countries then protect the membrane with a concrete wearing surface (using, for example, asphalt, modified Portland Cement overlays, or latex modified concrete thin overlays).

Meanwhile, except in relatively rare instances, the trend in the United States is to use deck protection strategies other than waterproofing and membrane systems, like the use of epoxy coated reinforcing steel and thicker concrete cover requirements. This dichotomy lead the U.S. team to ask why this may be, and to recommend a study to conduct a comprehensive review of

U.S. and European practices and the state-of-the-art in the use of waterproofing and membrane systems, and to compare their effectiveness to other deck corrosion approaches currently in use in the United States.

Concrete Permeability Evaluation

It is readily recognized that lower permeability concrete has increased resistance to the infiltration of water and chlorides throughout a concrete component. Water and chlorides can lead to accelerated corrosion of the reinforcing and prestressing steel within these components, so a number of strategies are typically used in bridge construction and maintenance practices to prevent this from happening. This is of particular concern in bridge decks and concrete roadways. A reliable, yet relatively simple, non-destructive testing procedure for testing in-situ concrete could result in a number of significant benefits.

During the scanning tour, it was noted that several countries are making advances in the technology of concrete permeability evaluation. The Swiss, for example, are developing a vacuum-based method which pulls air through pores in the concrete member. Although the size of air molecules is one-tenth of water molecules, a ratio can determine the permeability of the concrete with respect to other permeability measurements. This could become a valuable field test to quantify or determine permeability as required by specification. The goal of this approach is to determine the resistance to penetration of aggressive water and chloride ions through the concrete.

Other countries, including the United States, are also conducting research and development studies on permeability testing, and attempting to develop relationships between chloride content and corrosion resistance. However, the scan team has recommended that a more focused and organized study, that collects and assesses detailed information from a variety of countries, is needed. This study should also review both standard methods and various proposed approaches, including the AASHTO "T 259 Resistance of Concrete to Chloride Penetration" test which involves ponding with a 3% Sodium Chloride solution for 90 days, and the NORDTEST method from Finland, which measure chloride ion content that has actually penetrated a specimen rather than a coulomb measurement approach.

OTHER FINDINGS

As noted earlier, the U.S. scanning team identified a large number of concepts and approaches which they believe are worth pursuing within the United States. In addition to those discussed in Section 4 above, the following are some additional recommendations resulting from the scan.

- Assess the value of developing a risk-based bridge management approach which includes serviceability considerations.

- Promote the concept of an integrated engineered structures management approach which includes all highway structures, including bridges, free-standing walls, culverts, and sign structures.

- Define and promote approaches that can be used to incorporate inspectability and maintainability in the design process.

- Review current U.S. practice and recommend procedures for standardizing the use of trucks and systems for load testing and load rating highway bridges.

- Review, synthesize, and promote "best practice" maintenance approaches that can be coordinated with regular structure inspections.

- Assess and promote the use of simple bridge integrity monitoring and warning systems for extreme events, like vehicle or vessel collision.

These, and other, recommendations will be further pursued through the conduct of studies likely to be initiated by the FHWA, Transportation Research Board, State transportation agencies, and others.

SUMMARY AND CONCLUSIONS

The AASHTO/FHWA International Technology Scanning program is considered to be an important element of the U.S. highway industry's technology transfer and technology adoption efforts. Although the United States has readily shared it's technology and advances with other countries, it is recognized that there is much to be learned elsewhere; and this program provides one of several key mechanisms for learning from, and improving practices as a result of, the knowledge gained in other countries.

The Bridge System Preservation and Maintenance Scan is just one of many international technology scans sponsored by the program. Previous scans have already resulted in a number of newly adopted and deployed practices in highway engineering, safety, and operations. It is anticipated that many of the recommendations resulting from this scan will also result in changes to bridge system preservation, maintenance, and management policies and practices.

The U.S. scanning team would like to recognize and thank the many countries and representatives who graciously hosted our team, and who provided a wealth of information and guidance on bridge management and maintenance practices that have worked extremely well in their respective countries.

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