Tomorrow's Bridges

A Renewal Project Brief Summarizing Bridge Research in SHRP2

APRIL 2011

Durability is a problem for today's bridges. Bridge components break down. Soils become unstable. Bridge decks deteriorate, often unnoticed. Replacing bridges can be costly, time-consuming, and disruptive to traffic. And the cycle repeats as bridges age. Innovative methods have been developed for designing and constructing new bridges, repairing existing bridges, stabilizing bridge foundations, and nondestructively testing bridges; but they are not routinely used. Today's innovations, however, can become tomorrow's standards.

The second Strategic Highway Research Program (SHRP 2) is working closely with the Federal Highway Administration (FHWA) and the American Association of State Highway and Transportation Officials (AASHTO) to make today's innovations more commonplace. Resolving obstacles to implementing innovation will mean that bridges can be created and replaced faster and be much more durable. Tomorrow, it will be standard for a bridge to have a service life of more than 100 years.

Bridge Foundations

The long-term performance of bridges is directly related to the stability of the subsurface. Traditional approaches for dealing with deformation and stability are too time-consuming for rapid renewal projects. In 1996, FHWA's geotechnical group of the bridge division enhanced the transportation community's acceptance and implementation of ground improvement methods in Demonstration Project 116, "Ground Improvement Methods." However, nongeotechnical constraints—such as the proximity of utilities, project geometry, and traffic—can limit the application of potential geotechnical solutions. Many innovations have been created since the 1990s, but they are rarely used because both technical and nontechnical obstacles prevent their broad application. The obstacles include lack of simple, comprehensive, reliable, and nonproprietary analysis and design procedures; costs for design, construction, quality control/quality assurance, and maintenance; performance uncertainty; and lack of suitable model specifications.

As these obstacles are overcome, today's innovations become tomorrow's standard practice. Column-supported embankments, reinforced soil slopes and platforms, and lightweight fills will be standard methods for creating and widening bridges over unstable soils. Intelligent compaction, geosynthetic reinforced platforms, high-energy compact rollers, and chemical and mechanical subgrade stabilization will be standard tools for stabilizing bridge working platforms. These standards will be used in rapid renewal projects that cause minimum disruption to traffic and result in long-lived facilities.

To make these technologies standard, SHRP 2 is identifying innovative geotechnical solutions and developing new design guidelines, procedures, quality assurance and quality control test procedures, and performance-based construction specifications.

Bridge Design and Components

Durability is a problem for individual bridge components, such as bridge bearings, deck joints, and columns and piles. Joints and bearings are the leading maintenance costs for highway bridges. Currently, many bridge components are designed and constructed based on proven Ultimate Limit State (ULS) performance without regard for Service Limit States (SLS). In fact, in some cases, by focusing solely on ULS, performance at SLS may actually be less than optimal. Unfortunately, some of the most commonly used component details—such as bearings, joints, concrete cover, and structural steel coatings—may have inherent design flaws and limitations. Although many of the specific flaws are recognized, they have not been eliminated under current design procedures and specifications. And the environment and location in which these components are placed within a bridge often contribute to accelerated deterioration rates and reduced service life. This deterioration results in bridge components and systems that must be replaced frequently.

Tomorrow, bridge designers will have more options for reducing problematic bridge components. Designing bridge systems to deliver more than 100 years of service design life will be standard. Supplementary cementitious materials, such as pozzolans and slag, will be used to reduce chlorides permeating concrete. Improvements in steel-reinforced elastomeric bearing design will double their service life. Some bridges will incorporate improved joints into prefabricated bridge elements to increase service life. Other bridges will eliminate joints altogether or move the joints off the superstructure and into the roadway. Anticorrosion systems—such as corrosion-resistant reinforcing steel, admixtures, cathodic protection systems, and electrochemical chloride extraction—will be standard methods for protecting reinforced steel elements.

To help bring about this change, SHRP 2 research is improving existing systems, subsystems, and components that historically limit the service life of bridges. SHRP 2 is identifying and validating promising concepts for alternative systems, subsystems, and components that will have a service life of more than 100 years. SHRP 2 is also developing recommendations for load and resistance factor design and construction specifications. The models will include analysis methods, details, standard plans, and detailed design examples for bridge systems, subsystems, and components that can achieve more than 100 years of service life.

Bridge Construction

Traditional construction practices—such as erecting beams and framework, tying deck reinforcing steel, placing deck concrete, and allowing concrete to cure—are time-consuming and disruptive to traffic. Innovative design and construction solutions already exist to create new bridges and rapidly replace old bridges. These techniques make it possible to move large, prefabricated bridge elements or even major bridge systems. While total design and construction timeframes that do not affect traffic may remain significant, road closures may be limited to days or even hours using accelerated bridge construction (ABC) techniques.

Tomorrow, design concepts—such as precast abutments and piers, hybrid drilled shafts, segmental piers, complete composite steel superstructure systems, complete precast concrete superstructure systems, and space frame superstructures—will be standard. Ultra high-performance concrete (UHPC) will be used in joints. Using modern construction equipment—such as above-deck driven carrier systems, launched temporary truss bridges, wheel carriers, and self-propelled modular transporters (SPMTs)—to rapidly install bridges and bridge segments will also be standard. Standardizing these approaches will streamline the planning process. ABC Technology Test Cases 1 and 2 provide examples of how tomorrow's standards are used today.

To help turn today's innovations into tomorrow's standards, SHRP 2 is developing standardized approaches for designing, constructing, and reusing complete bridge systems that address rapid renewal needs and efficiently integrate modern construction equipment.

To showcase tomorrow's standards, SHRP 2 will conduct a field demonstration of ABC techniques in spring 2011. SHRP 2 is working in conjunction with the Iowa Department of Transportation to incorporate innovative bridge elements into a bridge located at US 6 over Keg Creek in Pottawattamie County, Iowa. While the original design for the bridge replacement would have required an estimated six-month road closure, the bridge replacement using ABC will limit road closures to two weeks. The demonstration, known as the Keg Creek Bridge Project, will showcase a prefabricated superstructure module (precast concrete deck on steel stringers), prefabricated substructure components (precast pier columns and caps and abutment stem and wing walls), and a prefabricated bridge approach (precast concrete panels and sleeper slab). This project will be the first in the United States to use UHPC to provide a full, moment-resisting transverse joint at the piers. A video of this demonstration will be posted on the SHRP 2 website.

Bridge Design Codes

Current calibrated ULS approaches cannot integrate the daily, seasonal, and long-term SLS stresses that will directly affect long-term performance. New design codes are needed that incorporate a rational approach based on SLS for durability and performance of problematic systems, subsystems, components, and details. This is in addition to traditional structural design within the framework of the current AASHTO Load and Resistance Factor Design (LRFD) Bridge Design Specifications.

Tomorrow, design codes will help bridges achieve more than 100 years of service life. Design codes will include a rational approach based on SLS for durability and performance of bridge systems, subsystems, components, and details that are critical to reaching the expected service life. Performance measures will incorporate predefined component classifications that utilize probability-based service life design criteria to help maximize the actual life of the system. Durability design and structural design will be incorporated into design procedures and specifications.

To help make tomorrow's design codes, SHRP 2 is developing bridge design procedures and proposed specification changes that include durability design in addition to structural design, as well as developing the tools required for SLS implementation. The design procedures and specifications will include information from data sets being developed and captured by national and local initiatives into new or revised design specifications.

ABC Construction Technology Test Case 1
Springboro, Ohio, Access Bridge

Project Type	Bridge Replacement
Project Description	Remove existing simple span bridge and replace with new, wider bridge with equal span length
Structure Type	Existing Bridge—Steel girder with timber plank deck New Bridge—Precast concrete girders and precast deck with cast-in-place closure joints

The project was completed within 56 hours even with a significant period of rain after the old bridge had been removed. New piles were driven before the bridge was removed. With the short span of the bridge, there was no need for special equipment so conventional construction equipment was used. Due to the tight schedule, ABC superstructure and substructure technologies such as precast abutments, precast girders, and precast deck panels were used.

ABC Construction Technology Test Case 2
Utah State Road 4500S over I-215E

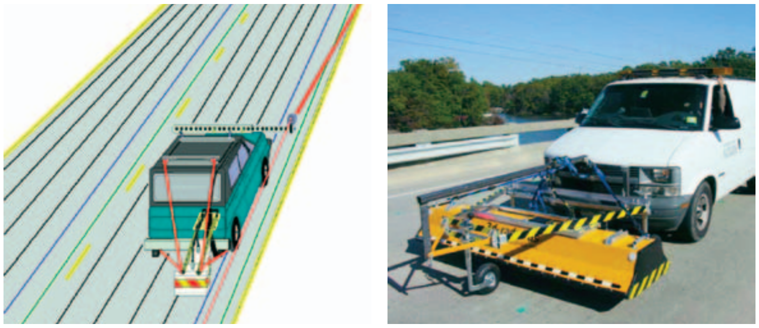
Project Type	Bridge Replacement
Project Description	Bridge replacement with minimal disruption to traffic both on main line and secondary road
Structure Type	Existing Bridge—Precast Girders, Concrete Deck New Bridge—Precast Girders, Concrete Deck

The project was performed using SPMTs for both the removal of the existing bridge and installation of the new bridge. I-215E was closed for 53 hours over a weekend and 4500S was closed only 10 days.

Evaluating Bridge Decks

It is estimated that more than $1 billion is spent on bridge decks each year in the United States. Since nearly 90 percent of bridge deck area (2.8 billion square feet) is concrete, evaluating concrete bridge decks is essential. Highway agencies need to evaluate bridge deck condition in order to optimize the effective timing of preventive maintenance, prioritize bridge deck repair and rehabilitation, determine the scope of required repairs, and make repair-or-replace decisions. Deck deterioration frequently takes place below the surface and cannot be readily evaluated by visual means, and many older decks now have asphalt concrete or portland cement concrete overlays, making subsurface deterioration conditions even more difficult to detect. Traditional deck inspection methods—such as chain drag, half-cell potentials, and chloride content—are slow, require closures, and are not necessarily effective. Over the past 10 years, innovative higher-speed nondestructive testing (NDT) technologies have been developed. These technologies, however, have not been widely adapted or accepted for three main reasons: (1) Even though a number of technologies can provide detailed and accurate information about a certain type of deterioration or defect, comprehensive condition assessment of bridge decks, at this stage, can be achieved only by using multiple technologies. (2) Speed remains a major limitation for most of the technologies and is a main inhibitor for wide adoption by transportation agencies. There are a number of initiatives to speed up the data collection and automate data analysis, but those initiatives are fragmented and still do not provide a transformational change towards comprehensive, multimodal, and rapid bridge deck evaluation. (3) Most of the technologies require a significant level of training and expertise, especially in the data analysis and interpretation components.

Tomorrow, expect NDT technologies to be a standard part of concrete bridge deck evaluation. Impact echo



Typical GPR survey of a bridge deck using a set of dual-polarization sensors requiring six passes of the survey vehicle in each lane (left) and a 2 meter-wide 3D-GPR array system (right), which operates more slowly but covers a larger deck width.

techniques will be used for detecting and characterizing deck delamination, investigating crack depth, and evaluating grouting condition in ducts. Ultrasonic pulse echo techniques and pulse velocity techniques will be used for detecting voids, grouting condition in ducts, material degradation, and other anomalies. Ultrasonic surface waves will be used to measure degradation of mechanical properties, such as modulus and strength. Impact response techniques will be used to detect deck delaminations. Ground-penetrating radar (GPR) will be used to detect deterioration caused by corrosion, indirect delamination, voids, anomalies in concrete, water-filled or epoxy-injected cracks, and debonded overlays. And infrared thermography will be used to detect overlay debonding, delamination, presence of moisture, and near-surface voids.

To bring these innovations into the mainstream, SHRP 2 is identifying, characterizing, and validating rapid NDT technologies for concrete deck deterioration to create an electronic repository, or tool box, for practitioners. This process includes evaluating the strengths and limitations of NDT technologies in terms of speed, accuracy, precision, and ease of use. The repository is being designed so that it could be incorporated into transportation agencies' inspection manuals or management systems. The repository will include documentation for test procedures, protocols, photos, sample data output, equipment features (such as cost, availability, and specifications), advantages, and limitations.

SHRP 2 Bridge Projects

R02	Geotechnical Solutions for Soil Improvement, Rapid Embankment Construction, and Stabilization of the Pavement Working Platform
R04	Innovative Bridge Designs for Rapid Renewal
R04A	Innovative Bridge Designs for Rapid Renewal (Keg Creek Bridge Demonstration Project)
R06A	Nondestructive Testing to Identify Concrete Bridge Deck Deterioration
R19A	Bridges for Service Life beyond 100 Years: Innovative Systems, Subsystems, and Components
R19B	Bridges for Service Life beyond 100 Years: Service Limit State Design

Tomorrow

Tomorrow's bridges will be built on more stable foundations. They will be created rapidly. Testing the bridge decks will be quick and easy. And the bridges will be in service for more than 100 years.

The SHRP 2 Bridge Projects Chart shows the SHRP 2 projects that are turning today's bridge innovations into tomorrow's standards. But you don't have to wait until tomorrow to find out about these innovations. You can stay ahead of the curve by following SHRP 2 research. Learn more on the SHRP 2 website: www.TRB.org/SHRP2. While there, you can also subscribe to SHRP 2 News to receive e-mail alerts about our reports, guides, webinars, conferences, videos, and more.

These bridge projects are part of SHRP 2's Renewal research. The research objective of SHRP 2 highway renewal is to achieve renewal that is performed rapidly, causes minimum disruption, and produces long-lived facilities. A related objective is to achieve such renewal not just on isolated, high-profile projects, but consistently throughout the nation's highway system.

www.TRB.org/SHRP2/Renewal

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