Integrating Research, Theory, and Practice into Building Concrete Bridges that Last

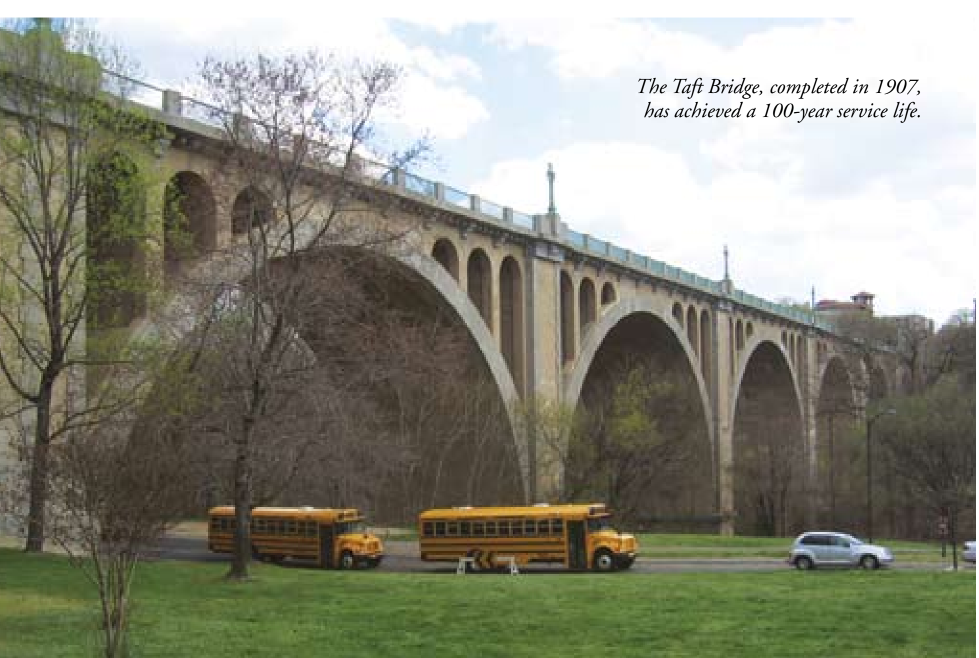
Concrete lions stand guard over the Taft Bridge.

by M. Myint Lwin

Concrete possesses some very desirable properties for the construction of bridges. Concrete is adaptable to a variety of shapes, forms, and colors, allowing engineers and architects to showcase their bold and imaginative expressions. Concrete has high compressive strength and resistance to environmental and chemical effects. It is relatively low cost, readily available, and easy to use in construction.

Cast-in-place concrete bridges can be made continuous and monolithic for improved durability, structural performance, and seismic resistance. Concrete is most suitable for superstructures with curved alignments and superelevations, piers with skews, ramps with various configurations, and structures with complex geometric forms and architectural features. Many concrete arch and tied-arch bridges built in the late 1800s and early 1900s are still in service. Some of them have undergone strengthening and rehabilitation to extend their service lives. One example is the Taft Bridge, which carries Connecticut Avenue over Rock Creek in Washington, D.C. It is an arch bridge with unreinforced concrete for the five arches and reinforced concrete for the deck. The large lion sculptures on the bridge were also made of concrete. The construction of the Taft Bridge started in 1897 and was completed in 1907. The bridge was renovated in 1990 and is expected to serve the communities for many more years.

Concrete is strong in compression but weak in tension. The true potentials of concrete were not realized until the industrial revolution in the 1800s, when structural steels were produced and readily available in large quantities and portland cement was produced in significant amounts in the United States. Ernest Ransome of California received a patent in 1884 for his invention of a twisted reinforcing steel bar. Ransome went on to design and build the first reinforced concrete bridge in the United States in 1884. The bridge is known as the Alvord Lake Bridge in Golden Gate Park, San Francisco, California. The bridge is still in service. The successful use of reinforced concrete in the Alvord Lake Bridge has led to the construction of many reinforced concrete arch bridges in other parks around the country. Robert Maillart and Eugene Freyssinet have been credited as the pioneers and champions in reinforced and prestressed concrete bridges, respectively. They set the trend for modern design and construction of cast-in-place, precast, and prestressed concrete bridges—arches, beams, box girders, segmental construction, and others. Precast and prestressed concrete members are often an integral part of modern cable-stayed and suspension bridges.



The Taft Bridge, completed in 1907, has achieved a 100-year service life.

The common goal of the FHWA bridge community is to work together with our state partners, industry, and academia to continuously improve the condition and durability of the nation's bridges and tunnels. Durability of bridges and tunnels may be considered as meeting the design life and serviceability requirements with minimal systematic preventive maintenance and low life-cycle costs. The design life, based on the AASHTO LRFD Bridge Design Specifications, is 75 years. For major bridges, the owners may specify that the bridges be designed and built for a design life of 100 years or more.

The AASHTO LRFD Specifications imposes four limit states to be satisfied by the design to achieve durability, serviceability, constructability, and safety. The limit states serve as a systematic approach to structural design to ensure low maintenance in the short- and long-term. The four limit states are:

Service Limit State: This limit state imposes restrictions on stress, deformation, and cracking under regular operating conditions.

Fatigue and Fracture Limit State: This limit state imposes restrictions on the stress range due to a design truck occurring at the number of expected stress cycles.

Strength Limit State: This limit state stipulates the strength and stability requirements to resist the specified statistically significant load combinations expected to be experienced by a bridge over its design life.

Extreme Event Limit State: This limit state ensures the structural survival of a bridge during events such as earthquakes, ice load, flood, scour, and vessel or vehicle collision.

The AASHTO LRFD Specifications fulfills a vision to design and build durable bridges for load effects with a high and uniform level of reliability.

The American Concrete Institute defines concrete durability as the ability of concrete to resist weathering action, chemical attack, abrasion, and other conditions of service. Specifically, concrete must be designed, proportioned, mixed, transported, placed, and cured properly to assure its resistance to potential freeze-thaw damage, alkali-silica reactivity, sulfate attack, chloride penetration, corrosion of reinforcing steel, abrasion, and load effects. The development of high-performance concrete (HPC) is aimed at achieving durable concrete.

Flexural test of ultra-high performance concrete beam. Photo courtesy of Ben Graybeal, FHWA.

The FHWA High-Performance Concrete Technology Delivery Team (TDT) has been created to work with the state DOTs in building more economical and durable bridges using high performance concrete. TDT members represent the FHWA, State DOTs, academia, and industry. The mission of the team is to improve the durability and cost-effectiveness of the nation's transportation infrastructure. The TDT transfers HPC technology to the states through workshops and showcases hosted by participating DOTs. The TDT maintains the "Community of Practice" website where users can post questions on HPC, participate in discussions, share documents, and review works in progress. The website address is http://knowledge.fhwa.dot.gov/cops/hpcx.nsf/home. The TDT has developed and published the HPC Structural Designers' Guide, intended to be a one-stop shopping reference for all aspects on the implementation of HPC. It is posted on the above website.

The Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) establishes several research, deployment, and education programs for improving the durability and understanding the long-term performance of concrete bridges. These programs are:

The Long-Term Bridge Performance (LTBP) Program

This 20-year program involves detailed inspection and evaluation of the performance of a large section of the nation's bridges to (1) build a quantitative performance bridge database, (2) improve knowledge of bridge performance under all physical, chemical, and environmental conditions, (3) understand the deterioration mechanisms that affect durability of bridges, (4) improve inspection and condition information through nondestructive evaluation, and (5) develop emergency response, strengthening, repair, and retrofit procedures for rapid deployment following extreme events caused by natural and man-made hazards. This program is conducted by the FHWA in partnership with the states, consultants, industry, and academia. For more details of this program, visit http://www.tfhrc.gov/structur/ltbp.htm.

The Innovative Bridge Research and Deployment (IBRD) Program

This is a 4-year program for promoting, demonstrating, evaluating, and documenting the application of innovative designs, materials, and construction methods in the construction, repair, and rehabilitation of bridges and other highway structures. One component of the program is dedicated to research, deployment, and education of technology related to high performance concrete bridges. FHWA has developed the HPC plan in response to the needs identified by members of AASHTO, TRB committees, NCHRP, industry, academia, and others. Details of the HPC program are posted on the FHWA website. A major part of the IBRD program is to provide funds to the state and local highway agencies for incorporating innovations into construction projects for improved safety, reduced congestion, and greater durability. Annual solicitation of applications is issued for proposed projects that meet the goals of the program. FHWA will make its funding determinations through a merit-based selection process. For more details of this program, visit http://www.fhwa.dot.gov/bridge.

Ultra-high performance concrete, as used in this test bridge for FHWA, is a new material for bridge construction. Photo courtesy of Ben Graybeal, FHWA.

Highways for Life Pilot Program

The purpose of this program is to advance longer-lasting highways using innovative technologies and practices to accomplish the fast construction of efficient and safe highways and bridges. This program includes demonstration construction projects, technology transfer, technology partnerships, information dissemination, and monitoring and evaluation. HPC, including self-consolidating concrete and ultra-high performance concrete, has a definite place in this program in support of faster construction and longer-lasting structures. For more details of this program, visit http://www.fhwa.dot.gov/hfl.

The state-of-the-knowledge is such that we understand the factors that affect the durability of concrete, and we have the knowledge for preventive measures that must be taken to improve the durability of concrete for meeting the design life and serviceability requirements of a project. The key then is to integrate research, theory, and practice to assure quality workmanship in construction and defect-free bridges and tunnels that can withstand the test of time with minimal maintenance and low life-cycle costs.

U.S. Department of Transportation
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