STATE

Virginia's

Developments in the Use of Concrete in Bridges

by H. Celik Ozyildirim, Virginia Transportation Research Council and Julius F. J. Völgyi Jr., Virginia Department of Transportation

The use of HPC in the Richlands Bridge allowed the number of beams per span to be reduced from seven to five. All photos VDOT unless specified otherwise.

In the mid 1990s, the Virginia Department of Transportation (VDOT), in cooperation with the Federal Highway Administration (FHWA), initiated a program focused on the development and implementation of high performance concrete (HPC). Prior to that time, many improvements had been made in design, materials, and construction practices in VDOT, establishing the foundation for the HPC program. Initially, the HPC program entailed work with normal weight concretes and focused on mix designs that yielded high strength, low permeability, and temperature control. Efforts progressed to the development of mix designs using lightweight aggregate to produce lightweight HPC with high strength and low permeability. VDOT has also evaluated the use of self-consolidating concrete. This concrete has very high flow characteristics, enabling consolidation without mechanical vibration. Finally, HPC efforts have led VDOT to investigate ultra-HPC fiber-reinforced concrete in bulb-tee beams with no conventional steel shear reinforcement, very high compressive strength, and negligible permeability.

High Performance Concrete

Since 1992, Virginia has been requiring protection against alkali-silica reactivity (ASR). If the alkali content of cements is currently more than 0.45 percent, various combinations of slag or pozzolans are required by VDOT to inhibit ASR. The addition of pozzolans or slag leads to low permeability in concretes and protection against chemical attack.

In the mid 1990s, in cooperation with the FHWA, new bridge projects were planned under the experimental HPC program. These bridges had high strength concrete beams and/or a concrete permeability requirement. The first HPC construction project was completed in 1995. This structure carrying Route 40 over Falling River, in Campbell County, consists of four 80-ft-long spans with AASHTO Type IV beams. The beams were fabricated with HPC with a specified compressive strength of 8000 psi and a maximum chloride permeability of 1500 coulombs. The bridge deck was constructed using HPC with a specified compressive strength of 6000 psi and a maximum chloride permeability of 2500 coulombs. The HPC design resulted in a reduction in the number of beams per span from seven to five.

Soon after, another HPC structure was constructed carrying Virginia Avenue over the Clinch River in Richlands with beams having 0.6-in.-diameter prestressing strands. The bridge consists of two 74-ft-long spans of AASHTO Type III beams. The specified concrete compressive strength was 10,000 psi at 28 days and the maximum chloride permeability was 1500 coulombs. The deck was constructed with HPC having a specified strength of 5000 psi and a maximum chloride permeability of 2500 coulombs. Again, the use of HPC resulted in reducing the number of beams per span from seven to five.

By 1999, VDOT had 76 bridge structures in the HPC program. The specified strength of the concrete ranged from 7000 to 10,000 psi. The low-permeability requirements were a maximum of 1500 coulombs for the prestressed concrete girders, 2500 for the cast-in-place concrete decks, and 3500 for cast-in-place concrete in the substructures.

Lightweight HPC

The economic benefits of HPC combined with a reduction in dead load make lightweight HPC (LWHPC) a very attractive material choice. In bridge beams, the use of LWHPC results in reduced dead loads that enable longer span lengths and reduced substructure loads. Bridge deck replacement using LWHPC reduces dead load thereby allowing greater lane capacity. The high quality concrete is expected to extend the service life of the structure.

The first LWHPC bridge was constructed in 2001. The bridge carried Route 106 over the Chickahominy River near Richmond, Virginia. It was constructed using 84-ft-long AASHTO Type IV beams fabricated with LWHPC with a minimum specified compressive strength of 8000 psi and a maximum chloride permeability of

The Route 106 Bridge over the Chickahominy River was the first use of lightweight high performance concrete.

1500 coulombs. The LWHPC deck had a specified strength of 4000 psi and a maximum chloride permeability of 2500 coulombs.

Two very long structures that carry Route 33 over the Mattaponi River (total length 3454 ft) and Pamunkey River (total length 5354 ft) near West Point were recently completed. For both bridges, the specified concrete strength for the beams was 8000 psi and maximum chloride permeability was 1500 coulombs. The deck on the LWHPC beams used a LWHPC, with a specified strength of 5000 psi and a maximum chloride permeability of 2500 coulombs. The mass concrete used in the footings and bent caps had 40 percent fly ash to control the temperature rise.

Self-Consolidating Concrete

In 2001, VDOT used self-consolidating concrete (SCC) in an arch bridge carrying traffic over a creek on the Stafford Lakes Village Parkway, near Fredericksburg. A total of 25 precast arch segments were placed side-by-side to create a single 30-ft span across the creek. In 2005, VDOT placed 40 beams with SCC in the Route 33 bridge over Pamunkey. Bulb-tee beams were fabricated using SCC with a specified strength of 8000 psi and a maximum chloride permeability of 1500 coulombs. Before casting the actual bridge beams, test beams were fabricated and loaded to failure to ensure that the specified properties were obtained and the bond between the steel and concrete was satisfactory. Recently, VDOT used SCC for 24 to 48-in.-diameter drill shafts on the Route 28 over Broad Run project in Manassas. The shafts range in length from 18 to 28 ft with a specified concrete strength of 4000 psi to provide

Self-consolidating concrete was used in the drilled shafts of the Route 28 Bridge over Broad Run.

a minimum capacity of 200 tons per shaft. VDOT is currently studying the performance of SCC in bulb-tee beams and the substructure with plans to construct a bridge through the Innovative Bridge Research and Construction (IBRC) program. VDOT is extending SCC to lightweight concrete in beams. A bridge project has been selected, a test beam has already been evaluated, and another one planned.

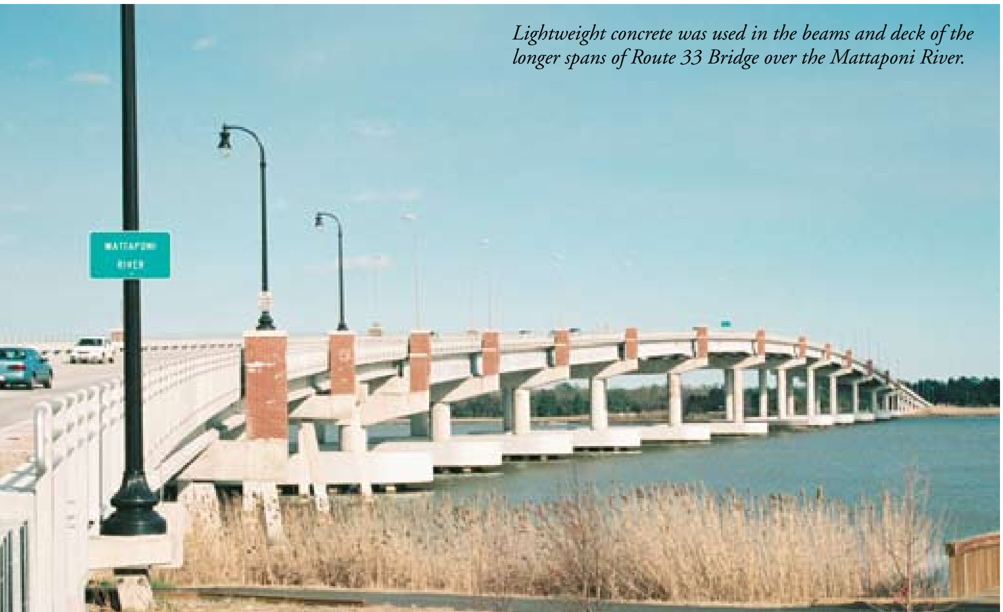
Bulb Tees and Spliced Beams

Until 2001, Virginia used AASHTO/PCI prestressed concrete beams Types II through VI although the Types III and IV were the mainstay. Virginia developed its prestressed concrete bulb-tee sections through the Precast Concrete Economic Fabrication (PCEF) Committee with depths ranging from 29 to 93 in. in 8-in. multiples and a web width of 7 in. to accommodate the harping of two rows of strands. The sections were modeled after the New England bulb-tee. Virginia uses specified concrete strengths of 5000 to 10,000 psi.

The first spliced beams were utilized on Route 123 over the Occoquan River project, which has a total bridge length of 1181 ft and a width of 123 ft 6 in. Bulb-tee sections, 77 in. deep were used for the four 144 ft units. Post-tensioned spliced members with section depths varying

The first spliced beams were used on Route 123 Bridge over the Occoquan River.

from 79 to 150 in. were used for the 180-, 240-, and 180-ft span lengths. Specified concrete strength was 8000 psi. The last phase of this project was opened to traffic in August 2006. The next two projects, completed in 2006 and 2007, with spliced bulb-tee sections were on Route 33 over the Pamunkey and Mattaponi Rivers. On both projects, spliced girders with depths ranging from 96 to 126 in. were used to form two units with span lengths of 200, 240, 240, and 200 ft. Lightweight concrete with an 8000 psi specified compressive strength and 6000 psi release strength was used.



Lightweight concrete was used in the beams and deck of the longer spans of Route 33 Bridge over the Mattaponi River.

Spliced girders with lightweight concrete were used on the Route 33 Bridge over Pamunkey River.

Ultra-High Performance Fiber-Reinforced Concrete

Ultra-high performance, fiber-reinforced concrete (UHPFRC) has compressive strengths reaching 30,000 psi with flexural strengths above 7000 psi. UHPFRC is virtually impermeable to liquids. Two of the primary sources of these enhancements are the use of finely graded and tightly packed ingredients with no coarse aggregate and the use of steel or synthetic fibers. UHPFRC is ideal for use in bridge construction, enabling lighter, thinner, and more durable applications. The fibers in UHPFRC provide tensile capacity across cracks, resulting in high shear capacity in flexural members. Typically, reinforcement for shear is not required. One of the 10 spans of the bridge over the Cat Point Creek in Richmond County, now under construction will contain UHPFRC. The 45-in.-deep prestressed concrete bulb tees are 81 ft 6 in. in length. Special provisions were developed for the UHPFRC for a specified compressive strength of 23,000 psi and 12,000 psi required at release of the strands.

Overlays

Latex-modified concrete (LMC) has been successfully used in overlays since 1969 to resist the intrusion of chlorides. LMC provides low permeability. In the 1980s, silica fume (SF) was introduced for low permeability and high strength concrete. Evaluation of SF indicated that it was a viable alternative to LMC, and, in 1987, the first silica fume overlay was placed on a bridge deck. Both the LMC and SF concretes in overlays are limited to a maximum water-cementitious materials ratio of 0.40. Recently, very early strength LMC has been introduced. These overlays can be opened to traffic after three hours of curing, thereby reducing traffic congestion. Additionally, slag and fly ash alone or in combination with silica fume are also permitted in overlays if low permeability values are achieved. Another effort with overlays has been the introduction of porous aggregate soaked with deicers for winter maintenance.

Aesthetics

No one wants to look at "ugly" bridges. While every bridge cannot necessarily be a "signature" bridge, there are many ways to enhance the visual appearance of a bridge structure. While the Route 60 over Pretty Creek project in Norfolk with five 68-ft-long prestressed concrete AASHTO Type III beams was a routine structure, enhancements were made to improve the appearance of the structure. The beams were "hidden" by an exterior arched reinforced concrete beam with an orange color with architectural dentils across the top to provide continuity as the channel span could only allow a straight section to provide channel clearance. The arching effect was continued through the retaining walls in which brick pavers were used on the face to match the salmon pink brick pavers used in the sidewalks and raised median areas. The three-pipe aluminum rail was painted green. Various tones of sand-colored architectural cladding panels were attached to the exteriors of the piers while the interior of the piers was also arched.

Another bridge opened to traffic in October 2003 is the southbound Route 29 (South Main Street) over Dan River in the city of Danville. The overall bridge length is 821 ft. AASHTO Type III beams were used with four pairs of precast post-tensioned arch ribs 6 ft 0 in. wide by 3 ft 6 in. deep to form open spandrel arch spans. The bridge replicates the existing Luten open spandrel arch of the northbound structure, which was rehabilitated on the same contract.

Route 60 over Pretty Creek, Norfolk, Va. Photo: Brad Sindle, Crow's Nest photography.

Four pairs of precast post-tensioned arch ribs of the Dan River Bridge replicate the existing Luten spandrel arch.

Conclusions

Virginia's work with HPC in different applications has led to concretes that are more workable and have lower permeability than conventional concretes. These improvements are expected to provide longer service life, cost savings, reduction in construction time, and lower maintenance requirements. These concretes have a high potential for improved service; however, care needs to be exercised in their production to ensure that these benefits can be achieved. More work in this area will ensure the realization of the full potential of these concretes.

H. Celik Ozyildirim is Principal Research Scientist with the Virginia Transportation Research Council and Julius F. J. Völgyi Jr. is Assistant State Structure and Bridge Engineer with the Virginia Department of Transportation.

For more information on Virginia's bridges, visit www.virginiadot.org.