VDOT Virginia Department of Transportation

Virginia Center for Transportation INNOVATION & RESEARCH

Research Brief
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Bridge With Lightweight Self-Consolidating Concrete Bulb-T Beams and a Lightweight High-Performance Concrete Deck

Perspective For decades, the Virginia Center for Transportation Innovation and Research (VCTIR), the research division of the Virginia Department of Transportation (VDOT), has shepherded new high-performance concrete mixtures through design and testing to effective field implementation for use by VDOT.

These new concrete mixtures have high strength, high durability or high workability, or some combination of these qualities. VDOT bridges and other transportation structures constructed with high-performance concretes can have improved quality, last longer and be more cost-effective compared to those constructed with conventional concrete.

This study outlines VCTIR's field introduction of a combination of lightweight high-peformance concrete and self-consolidating concrete. Known as lightweight self-consolidating concrete, it has a low ratio of water to cementitious material, which provides high strength. Slag cement is included in the mixture to provide low permeability (needed for high durability). Admixtures — certain chemicals added to aid the properties of the concrete — provide such easy flowing workability that it requires no vibration to remove entrapped air in the freshly placed concrete. The concrete mixture flows easily through closely spaced steel reinforcement and self-consolidates leaving few air voids near the steel.

VDOT used lightweight self-consolidating concrete in prestressed bulb-T beams — which have tightly spaced steel strands and shear reinforcement — for a bridge in a grade-separated flyover interchange near Opal, Va., in Fauquier County. The flyover (a type of bridge) carries southbound traffic exiting U.S. 15/29 — via a loop ramp from the right travel lane — over the highway to merge onto southbound U.S. 17. The bridge has two spans, each 128 feet long, with four 61-inch-deep bulb-T beams in each span. The bridge deck is lightweight high-performance concrete with conventional workability.

The distinctive section of the bulb-T beam is evident in this photograph of the beam at the plant.

The beams and deck of this bridge have performed well for three winters. The VCTIR principal investigator (PI) expects that lightweight self-consolidating concrete will be used in future VDOT structures to reduce bridge weight, improve durability and provide high strength. The self-consolidating property of this concrete mixture will also benefit VDOT by minimizing large air voids and the problems they can cause in concrete structures. The study also shows that the lightweight high-performance concrete used in the bridge deck can minimize cracking compared to conventional concretes. The PI expects lightweight concrete's property of minimal cracking to extend the service life of this and other decks.

The lightweight high-performance concrete deck on the U.S. 17 flyover interchange bridge has weathered three winters with no cracks detected.

VDOT will begin to bring this VCTIR research into standard practice with project-specific "special provisions" — documents that specify the use of new materials and methods. VDOT includes these documents in construction contracts for appropriate new projects. VDOT's construction, materials, and structure and bridge divisions work in concert with VCTIR to develop special provisions for the use of normal-weight and lightweight self-consolidating concrete in beams and the use of lightweight high-performance concrete in decks.

For the full report, search 14-R15 at vtrc.virginiadot.org. For more information about the study, contact Celik Ozyildirim, Ph.D., P.E., VCTIR principal research scientist, Celik@vdot.virginia.gov.

Background VCTIR first took incremental steps to prove the field success of both lightweight high-performance concrete and normal-weight self-consolidating concrete before using lightweight self- consolidating concrete in the U.S. 17 flyover interchange bridge.

Lightweight high-performance concrete contains aggregates that weigh much less than those used in a normal-weight concrete. The high durability and strength of lightweight high-performance concrete result from added pozzolans (fly ash or silica fume) or slag cement and a low water–cementitious material ratio, respectively. In 2001, VDOT and VCTIR first successfully pilot-tested lightweight high-performance concrete on a bridge on Route 106 over the Chickahominy River near Richmond, Va. (see VTRC 06-R12).

Placing self-consolidating concrete requires less labor and can be accomplished faster than with conventional concrete; it flows easily and workers do not need to vibrate the placed concrete. VDOT and VCTIR confirmed normal-weight self-consolidating concrete's benefits in some of the prestressed bulb-T beams of a bridge over the Pamunkey River on Route 33 in West Point, Va., which opened to traffic in 2007 (see VTRC 09-R5). A VDOT special provision requires use of normal-weight self-consolidating concrete in drilled shaft foundations; it can be used in other new construction and repairs, when approved. There are plans to include normal-weight self-consolidating concrete as a hydraulic cement concrete option in the next edition of VDOT's *Road and Bridge Specifications* (expected in 2015).

VDOT and VCTIR used and tested prestressed bulb-T beams made with lightweight high-performance concrete on other spans of the Pamunkey River Bridge and on another bridge on Route 33 in West Point, this one over the Mattaponi River. The Mattaponi River Bridge opened in 2006. Both bridges needed the reduced weight of lightweight high-performance concrete on both the beams and the deck because soil conditions at the bridges' foundations were poor and span lengths exceeded 120 feet (see VTRC 09-R22).

VCTIR monitored the Route 106 and Route 33 bridges after construction and found minimal cracking in the concrete and no other signs of distress. VDOT's Structure and Bridge Division and Culpeper District then provided the opportunity to field test the combination of lightweight high-performance concrete and self-consolidating concrete in the Opal flyover interchange.

Research and Recommendations Before the lightweight self-consolidating concrete bulb-T beams for the U.S. 17 flyover interchange bridge were cast, the research staff studied trial batches and a test beam. We tested the concretes in the fresh state for slump flow, air content and density. Tests at the hardened state included compressive strength, elastic modulus and permeability.

After the initial trial batches, VDOT arranged for a prestressed concrete plant to cast a 65-foot-long test beam with the same cross section as the actual beams. Virginia Tech's Structures and Materials Laboratory formed and placed a lightweight concrete deck on the beam. The lab's staff tested this composite system with different loading configurations to failure. They added instrumentation to determine behavior during testing, which showed successful results (see VTRC 09-CR11).

Placement of self-consolidating concrete into beam at the plant

Eight lightweight self-consolidating concrete bridge beams, cast in early August 2012, were covered with insulating blankets and subjected to a radiant heat cure. Concretes tested for all eight beams met the VDOT specification requirements of a minimum 28-day compressive strength of 8,000 pounds per square inch and a maximum permeability of 1500 coulombs.

In the fall of 2012, the contractor erected the beams and placed a lightweight high-performance concrete deck with low permeability on them. Researchers conducted a conditions survey of the bridge in its initial years and found no visible cracks in the deck and beams. The lightweight concretes used in the bridge are performing well. The bridge opened to traffic before its second winter, in November 2013.

The study recommends that VDOT's Structure and Bridge Division and Materials Division use 1) lightweight self-consolidating concrete containing pozzolans or slag cement to lessen engineering challenges including the weight of long beams, deflections in long beam spans, poor soil conditions at a bridge foundation and beams with congested steel reinforcement, and 2) lightweight high-performance concrete to reduce cracking on bridge decks. These concretes may now be used on VDOT bridges with project-specific special provisions and appropriate bridge design considerations.

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Virginia Center for Transportation Innovation and Research—VDOT's research division since 1948
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