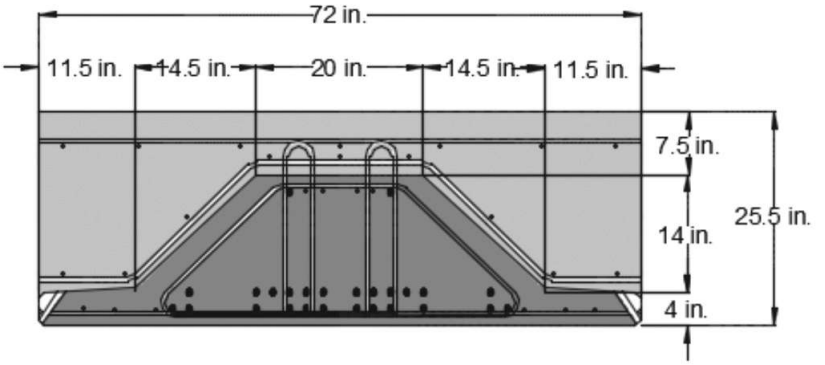
Virginia's Development of an Inverted-tee Beam Bridge Superstructure System

by Dr. Carin L. Roberts-Wollmann, Virginia Polytechnic Institute and State University, and Andrew M. Zickler and Dr. Michael C. Brown, Virginia Department of Transportation

Researchers at Virginia Polytechnic Institute and State University, with the support and cooperation of the Virginia Department of Transportation (VDOT), have developed an innovative bridge superstructure design using optimized inverted-tee prestressed concrete beams. Working with VDOT's Structure and Bridge Division and its research division at the Virginia Transportation Research Council, the team adapted a design based on concepts of the "Poutre-Dalle" section pioneered in France and variations that had been evaluated in Minnesota.

The system comprises a series of shallow prestressed concrete beams with broad shallow flanges at the bottom face that can be placed tip-to-tip as adjacent beams; a reinforced cast-in-place concrete topping is placed to unify the beams into a single slab system. The intent of the concept is to prevent development of longitudinal cracks along the joints between the adjacent prestressed concrete beams. Virginia's enhancement of this concept aimed to reduce the propensity for cracking and to increase the ease of fabrication and placement. Through interaction with fabricators and VDOT designers, the investigators arrived at a cross section that incorporates a sloped rather than a vertical web profile to decrease the concentration of stresses at the top corner of the web and to better accommodate reinforcement in the cast-in-place concrete topping. The design also eliminated horizontal reinforcement that penetrated the sides of prestressed concrete beams in previous designs. Further innovations included development of alternatives with and without welded continuous tension connections between adjacent beam flanges. The decision to use the welded connection is based on the anticipated magnitude and frequency of truck loading on the bridge. Finally, several mixture proportions were investigated for use in the concrete topping.

The proof-of-concept tests were conducted on short cross sections of the beam segments that were joined into two-beam bonded sections with topping and subjected to load testing to emulate transverse bending and shear behavior that correlate to loads in a full-scale finite-element model of a pilot structure. Alternatives both with and without welded bottom flange ties performed better than predicted.



Typical composite cross section dimensions of a inverted-tee beam used for the US 360 Bridge, Figure: Virginia Department of Transportation.

Based on modeling and physical testing, recommendations were made for a full-scale field pilot bridge.

VDOT completed two structures in 2014-2015 with the inverted-tee beam design: one on a high-volume primary highway (US 360 over the Chickahominy River in Henrico County) and one on a suburban secondary road (Towlston Road over Rocky Run in Fairfax County).

The US 360 over the Chickahominy River project incorporated two bridges with identical geometry. One bridge superstructure was constructed using conventional adjacent voided slabs with a composite 7½-in.-thick deck; the second featured the adjacent inverted-tee beam superstructure. Both bridges have two 42-ft-long spans and are jointless; each is constructed with normal-weight concrete in the beams and the deck.

The inverted-tee beams incorporated welded continuous tension ties at the flanges. The 113-ft-wide bridges were built in three stages to meet the maintenance of traffic requirements for this busy primary highway. There is narrow map cracking of similar density in the bridge decks of both bridges that has been attributed to early-age drying shrinkage. The bid price per linear foot for the 6-ft-wide inverted-tee beam was 50% higher than for the 4-ft-wide voided slabs, resulting in the same price per square foot.

The Towlston Road over Rocky Run bridge was a 42-ft-long simple-span two-lane structure with an 11-degree skew and used lightweight concrete in both the inverted-tee beams and in the topping. For the low volume of traffic on Towlston Road, welded flange ties were not deemed necessary. In all other respects the bridge was the same as the US 360 bridge.

One fabricator noted, "The system is certainly much easier to cast than the voided slabs. With some additional refinements. . .this will be the preferred product from the fabricator's perspective." Both inverted-tee beam structures are in excellent condition after the first full year of service with no evidence of cracking in the topping over the prestressed beams related to traffic or environmental loads.

Dr. Carin L. Roberts-Wollmann is a professor at the Charles E. Via Jr. Department of Civil and Environmental Engineering, Virginia Polytechnic Institute and State University in Blacksburg, Va. Andrew M. Zickler is the complex bridge design and ABC support program manager in the Structure and Bridge Division of the Virginia Department of Transportation in Richmond, Va., and Dr. Michael C. Brown is the associate director of the Virginia Transportation Research Council of the Virginia Department of Transportation in Charlottesville, Va.