ROUTE 198 (DUTTON ROAD) OVER HARPER CREEK

STAGED SUPERSTRUCTURE REPLACEMENT USING LIGHTWEIGHT CONCRETE AIDS PROJECT GOALS

by Jeremy Schlussel, Caroline Hemp, and Timothy Beavers,
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When the Virginia Department of Transportation (VDOT) selected the bridge carrying Route 198 (Dutton Road) over Harper Creek for a superstructure replacement, many challenges had to be resolved. VDOT desired to widen the superstructure on this important rural primary route while minimizing the impact on nearby sensitive brackish-water wetlands.

These challenges led the design team to investigate the reuse of the original gravity-style abutments on timber piles. To reuse the substructure, the dead load of the replacement superstructure had to be less than or equal to that of the existing superstructure. Additionally, one lane of traffic was required to remain open during construction, which resulted in a tight working area for the contractor.

With all of these issues in mind, the design team concluded that the most efficient solution would be a staged superstructure replacement using lightweight concrete for both the prestressed bulb-tee beams and cast-in-place deck. Sheet-pile walls were used to accommodate the minor widening of the approach roadway, minimizing impact on the wetlands. All details and material selections for this bridge met VDOT's goal of reducing long-term maintenance.

Project History

Existing Bridge

The bridge carrying Route 198 (Dutton Road) over Harper Creek is located in Gloucester County, Va., in VDOT's Fredericksburg District. Completed in 1941, it was part of the realignment of the original roadway to improve poor roadway geometry. The bridge structure consisted of one 40-ft simple span for a total length of 42 ft 6 in. (end-of-slab

Aerial view of the new bridge and approach roadway on Route 198 in Gloucester County, Va. Photo: Whitman, Requardt & Associates.

profile

ROUTE 198 (DUTTON ROAD) OVER HARPER CREEK / GLOUCESTER COUNTY, VIRGINIA

BRIDGE DESIGN ENGINEER: Whitman, Requardt & Associates LLP, Richmond, Va.

PRIME CONTRACTOR: Bryant Contracting Inc., Toano, Va.

PRECASTER: Atlantic Metrocast Inc., Portsmouth, Va.—a PCI-certified producer

SURVEYOR: NXL Construction Services Inc., Richmond, Va.

to end-of-slab) and was on a tangent alignment with a 0% gradient.

The superstructure was 27 ft 4 in. wide (out-to-out), which included a roadway width of 24 ft from curb to curb and a 1-ft 8-in. combination curb/concrete rail. The superstructure consisted of four haunched cast-in-place reinforced concrete T-beams with a reinforced concrete deck, which was placed integrally with the T-beams. The reinforced concrete deck had an asphalt overlay of approximately 2½ in. The existing superstructure did not have bearing pads, per the original plans.

The bridge substructure units are parallel to each other and perpendicular to the centerline. The abutments are concrete gravity-style with minimal reinforcement supported on timber piles approximately 35 ft in length. Connecting the two abutments are three reinforced concrete struts below the waterline. The wingwalls are oriented 45 degrees to the backwall.

Need for Rehabilitation

In 2011 the bridge structure was identified as requiring maintenance. The bridge safety report revealed the general condition of the existing concrete deck to be structurally deficient due to delaminations up to 2½ in. deep throughout the concrete deck, with the bottom of the deck also having delaminations and cracks. In addition, the concrete slab overhangs and railings had delaminated and spalled, exposing corroded reinforcing steel. It was also noted that the exterior beams had cracks, delaminations, and spalls along the sides and bottoms. After preliminary discussions with VDOT, a full bridge replacement was determined not to be a viable option due to its location within existing wetlands and the necessary permits required for such an extensive project. VDOT concluded that the most appropriate solution to rehabilitate the 70-year-old bridge structure was a superstructure replacement.

An in-depth field investigation of the existing substructure was conducted to determine its condition and suitability to support the new superstructure. All of the visible concrete on the abutments was hammer sounded to record areas of delaminated and spalled concrete. A probing rod was used to determine the extent of features that were under water, such as the concrete struts.

Design Aspects

Various superstructure replacement options were evaluated, including prestressed hollow-core slabs with a reinforced concrete deck, VDOT precast concrete bulb-tee beams with a reinforced concrete deck, and galvanized structural steel girders with a reinforced concrete deck. To determine the most appropriate solution, several factors were evaluated, including geometry, final conditions, maintenance of traffic, environmental issues, and structural design. Ultimately, the final decision centered on which option would not increase the dead load applied to the existing abutments while providing the best long-term, low-maintenance solution.

The VDOT concrete bulb-tee beams met the geometric requirements and provided a much more durable option than a structural steel superstructure.

While the structural steel option did offer the most lightweight superstructure, it was determined not to be an appropriate long-term, low-maintenance solution for this location due to its proximity to the brackish water. The use of the hollow-core slabs per VDOT design guidelines would have required a reinforced concrete deck for this roadway classification. While this solution was efficient, the geometry and high dead load for this option did not meet the requirements for using the existing substructure.

The VDOT concrete bulb-tee beams met the geometric requirements and provided a much more durable option than a structural steel superstructure in this tidal environment, but the use of normalweight concrete increased the dead load on the existing substructure.

Therefore, to minimize the dead load, the designers evaluated the use of various densities of lightweight concretes for both the bulb tees and the concrete deck. After discussions with VDOT and industry professionals, the bulb tees were designed using VDOT Class A5 lightweight concrete with a maximum density of 115 lb/ft^3 and a minimum compressive strength at 28 days of 5 ksi. The beams were designed for a minimum compressive strength

Two 29-in.-deep lightweight concrete bulb tees prior to deck placement. Photo: Virginia Department of Transportation.

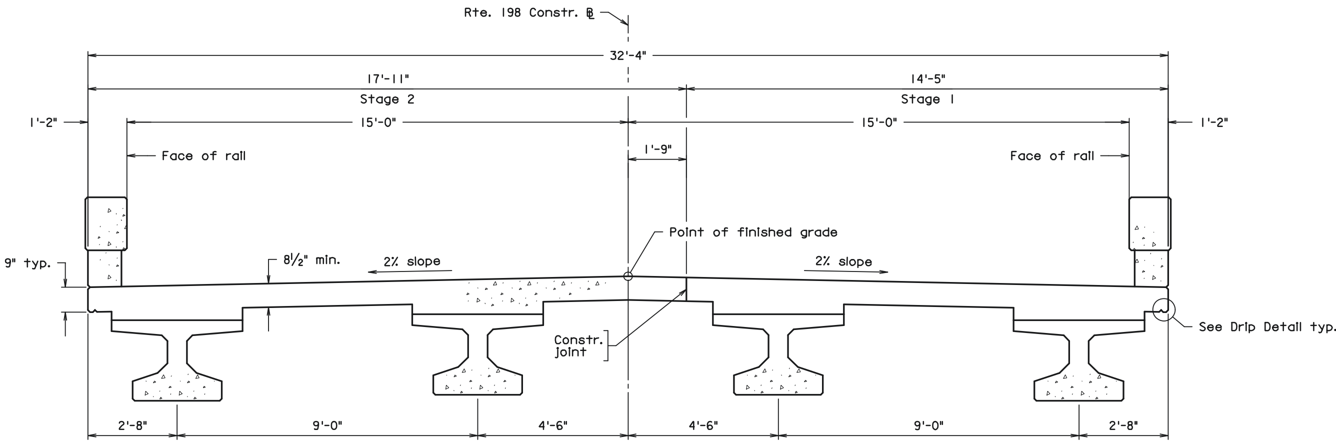
VIRGINIA DEPARTMENT OF TRANSPORTATION, FREDERICKSBURG DISTRICT, OWNER

BRIDGE DESCRIPTION: A 45-ft 2-in.-long, lightweight concrete prestressed bulb-tee beam bridge

OTHER MATERIAL SUPPLIERS: Lightweight aggregate supplier: Carolina Stalite Co., Gold Hill, N.C.; Stainless-steel reinforcement supplier: SteelCON Supply Company, Jacksonville, Fla.

STRUCTURAL COMPONENTS: Four lightweight concrete prestressed 29-in.-deep bulb-tee beams with an 8½-in.-thick cast-in-place lightweight concrete deck and a lightweight concrete semi-integral backwall and substructure modifications

BRIDGE CONSTRUCTION COST: $526,880 ($360.78/ft^2)



Transverse section of new superstructure showing staged construction. Figure: Whitman, Requardt & Associates.

at the time of transfer of 4 ksi. The deck, semi-integral backwalls, parapets, and substructure modifications were designed using VDOT Class A4 lightweight concrete with a maximum density of 105 lb/ft^3.

To reach these lower densities, the concrete mixture proportions for the beams required the use of lightweight coarse aggregates, while the concrete deck contained both lightweight coarse and fine aggregates. Fly ash and silica fume were also incorporated into the beam concrete mixture proportions. The only pozzolan included in the deck concrete was fly ash.

The concrete test results indicated permeability values of less than 900 coulombs for the reinforced deck concrete. According to ASTM C1202, these results correspond to a “very low” permeability. This added benefit of the lightweight concrete will provide protection to the reinforcing steel from chloride attack. Low-permeability concrete will, in turn, contribute to the long-term low-maintenance of the structure. Tests on the beams’ concrete revealed another benefit: although the design required a 28-day compressive strength of 5 ksi, on average the concrete of the beams had compressive strengths between 8 and 9 ksi at 28 days.

In addition to the lightweight concretes, corrosion-resistant reinforcing steel was used throughout the project, following VDOT design procedures. The mild reinforcing steel located in the bulb tees and substructure modifications was designated as Class I (ASTM A1035, low-carbon/chromium reinforcing steel) and the reinforcing steel located in the superstructure, including the semi-integral backwall, was designated as Class II (stainless-steel clad deformed). However, because these bars are not domestically produced, the project used Class III (ASTM A955, solid stainless-steel) bars for concrete reinforcement.

The new superstructure configuration is 45 ft 2 in. from end-of-slab to end-of-slab and 32 ft 4 in. out-to-out of parapet. The bridge maintains the same horizontal alignment, and the vertical gradient was modified to be approximately 0.3% to ensure drainage. The final cross section consists of four 29-in.-deep prestressed, lightweight concrete bulb-tee beams spaced at 9 ft with an 8½-in.-thick concrete deck. The bridge has a final curb-to-curb width of 30 ft, which provides two 12-ft-wide lanes with 3-ft-wide shoulders. An open-curbed, Kansas corral-type parapet was chosen to facilitate deck drainage and semi-integral backwalls were detailed at each end of the superstructure to make it a jointless structure. The existing abutments and wingwalls were modified to support the new superstructure width and bearing pad elevations.

In addition to the superstructure constraints, the project needed to accommodate the wider superstructure with only minor widening of the approach roadway. To achieve this widening without impacting the designated wetlands, marine-grade sheet-pile walls were designed and constructed. The sheet piles facilitated the approach roadway widening and grading that was necessary along the shoulders. The widening also slightly increased the work space for the contractor and enabled the project to maintain 11-ft lanes for the duration of the project.

Construction Sequencing

To facilitate reconstruction of the bridge structure and to maintain traffic, staged-construction methods were used for this project. This consisted of permanent single-lane closures and maintaining one lane of traffic with temporary signals. To shift traffic, the existing shoulders required upgrading to accommodate traffic for a period of time. Due to the geometry of the bridge superstructure, the minimum lane width was only 11 ft from curb to curb, requiring a detour for over-width vehicles.

Construction

In general, the construction of this project went smoothly. After discussions with the contractor, the only issue mentioned, besides the tight working constraints, involved the placement of the lightweight concrete bridge deck. The concrete was difficult to finish because of its sticky nature; the exact cause of this texture was undetermined. After experimenting with different types of trowels for finishing, the contractor noted a granular texture was left on the surface of the deck. This did not affect the final product because the concrete deck was grooved upon completion.

In addition to the challenges of finishing the deck, it was noted that the lightweight concrete in the deck took longer than usual to reach 28-day strength. This did not affect the schedule for this project; however, the contractor indicated that it could have caused a delay if the bridge had been larger.

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