PROJECT

Laurel Fork Creek Bridge Replacement

by Jerry Pfuntner,
COWI North America Inc.

Main span completion over Laurel Fork Creek. Photo: Vannoy Construction.

When the existing Blue Ridge Parkway steel truss bridge over the Laurel Fork Creek in Ashe County, N.C., deteriorated to the point that it would no longer meet modern safety standards, the Eastern Federal Lands Highway Division of the Federal Highway Administration (FHWA) concluded that a full bridge replacement would provide the safest, most durable, and cost-effective solution. The Eastern Federal Lands Division developed a design for a new three-span (155, 235, 155 ft) precast concrete segmental bridge using a typical balanced-cantilever construction sequence with three segment end span units. The post-tensioning layout consists of internal cantilever tendons and a mix of internal continuity tendons anchored in bottom slab blisters and external continuity tendons anchored in the pier segment and routed through deviation segments.

Project Redesign and Construction Modifications

As is typical for a complex bridge, the successful bidder applied their means and methods to finalize the construction sequence so that it would best suit their equipment, experience, and schedule. Members of the construction engineering and contractor teams had just begun construction of a similar precast concrete segmental bridge—the Blue Ridge Parkway over Interstate 26 (I-26) in Buncombe County, N.C.—and the contractor realized that they could effectively reuse construction details from the I-26 bridge on the Laurel Fork project. As a result, several significant design and construction modifications were made on the Laurel Fork project. (For more information on the Blue Ridge Parkway Bridge, see the article in the Summer 2024 issue of *ASPIRE*®.)

Revision from Precast Concrete to Cast-in-Place Piers

The original design called for precast concrete segmental piers. However, the contractor determined that the benefits to the schedule of using a precast concrete approach did not outweigh the requirements for setting up precast concrete operations and the transportation costs. Therefore, the design team developed a cast-in-place design using the same dimensions as the original pier column to mimic the appearance of the existing bridge.

Revised Box-Girder Cross Section

The cross section for the Blue Ridge Parkway I-26 project was very similar to the Laurel Fork Bridge cross section. Both bridges have the same roadway width of 26 ft, but the Laurel Fork Bridge does not have a sidewalk so it is slightly narrower (30 ft $3\frac{5}{8}$ in. wide) than the I-26 bridge. With minor modification to the existing casting machines from the I-26 project, a revised cross section for the Laurel Fork project was developed; its properties deviated from the original design by less than 1%. The new cross section also met project design requirements with the original post-tensioning layout and reinforcement design. (See the Spring 2025 issue of *ASPIRE* for more information about the precast concrete segments.)

profile

LAUREL FORK CREEK BRIDGE / ASHE COUNTY, NORTH CAROLINA

ORIGINAL BRIDGE DESIGN ENGINEER: Federal Highway Administration Eastern Federal Lands Division

BRIDGE DESIGN ENGINEER: COWI North America Inc., Tallahassee, Fla.

CONSTRUCTION ENGINEER: COWI North America Inc., Tallahassee, Fla.

PRIME CONTRACTOR: Structural Technologies/Vannoy Joint Venture, Jefferson, N.C.

PRECASTER: Coastal Precast Systems, Wilmington, N.C.—a PCI-certified producer

Anchorage of an unducted continuity tendon. Photo: Vannoy Construction.

A revised precast concrete box-girder segment is lifted during erection. Photo: COWI North America.

Updated Post-Tensioning Details Using Diabolos

To simplify the casting of the concrete segments and post-tensioning installation, the original design for bent steel pipes was revised to use diabolos. Diabolos permit a wide range of tendon geometries from a single bell-shaped opening in the deviators. This decision also allowed for unducted epoxy-coated strand (ECS) to be selected and installed later in the project.

Adoption of Ground Crane Erection Methods

The original design assumed the use of segment lifters for the main span and erecting the back-span segments on falsework towers. The contractor chose to use a large-capacity crane to erect segments in full cantilever to minimize the requirement to create prepared ground surfaces in this environmentally sensitive project site. Based on the proposed modifications, the FHWA decided that the construction engineer would become responsible for the new bridge and serve as the engineer of record for the concrete segmental bridge portion of the project.

FHWA Demonstration Project: Unducted Epoxy-Coated Strand External Continuity Tendons

During the initial stages of construction, the FHWA approached the construction and bridge design engineer about the opportunity to use the Laurel Fork project as a demonstration for the use of unducted ECS as a substitution for the grouted external continuity tendons. (See the Fall 2025 issue of *ASPIRE* for more about the ECS demonstration project.) The traditional grouted external tendon system provides three levels of protection for the post-tensioning strand: the box girder, high-density polyethylene (HDPE) duct, and grout. An unducted ECS system provides two levels of protection: the box girder and the epoxy-coated sheathing on the strand. However, the ECS system mitigates the lack of a third protection level by allowing for direct inspection of the ECS. The unducted ECS tendon system employs epoxy coating on the exterior and interior of the steel strands that provides an impermeable barrier against moisture and corrosion, allowing strands to be left ungrouted and directly exposed within the protective enclosure of the box girder. This system offers considerable advantages:

- Direct inspection: Maintenance staff can visually monitor tendon conditions for corrosion or damage to the epoxy coating without costly nondestructive testing equipment or intrusive grout removal.
- Simplified replacement: Damaged tendons can be replaced efficiently and simply with significantly less cost and effort than would be needed to replace grouted external tendons.
- Reduced maintenance costs: Eliminating grout and ducts removes the risk for latent grouting defect issues. The strand epoxy coating can also be repaired in place at any time with minimal equipment.

Evaluation and Adoption of Epoxy-Coated Strand Tendons

As part of their due diligence before modifying the continuity post-tensioning design, the bridge design engineer undertook a comprehensive assessment of the ECS system, including a review of experiences in Japan with similar systems, which have been successfully used for more than 17 years. The assessment process also included meetings with ECS manufacturers and participation in an FHWA workshop on ECS.

Given that Laurel Fork Bridge primarily consists of bonded internal tendons, the design engineer determined that the project was an ideal candidate for demonstrating the feasibility and benefits of ECS use for external continuity tendons. The ECS tendon system can easily meet service and strength-level load requirements.

NATIONAL PARK SERVICE, OWNER

POST-TENSIONING CONTRACTOR: Structural Technologies, Columbia, Md.

OTHER MATERIAL SUPPLIERS: Bearings: CONSERV, Georgetown, S.C.; epoxy-coated strand: Sumiden Wire, Dayton, Tex.

BRIDGE DESCRIPTION: 545-ft-long, three-span, precast concrete segmental bridge

STRUCTURAL COMPONENTS: Sixty-two precast concrete box-girder segments, cast-in-place concrete piers, drilled shaft foundations

BRIDGE CONSTRUCTION COST: $29 million

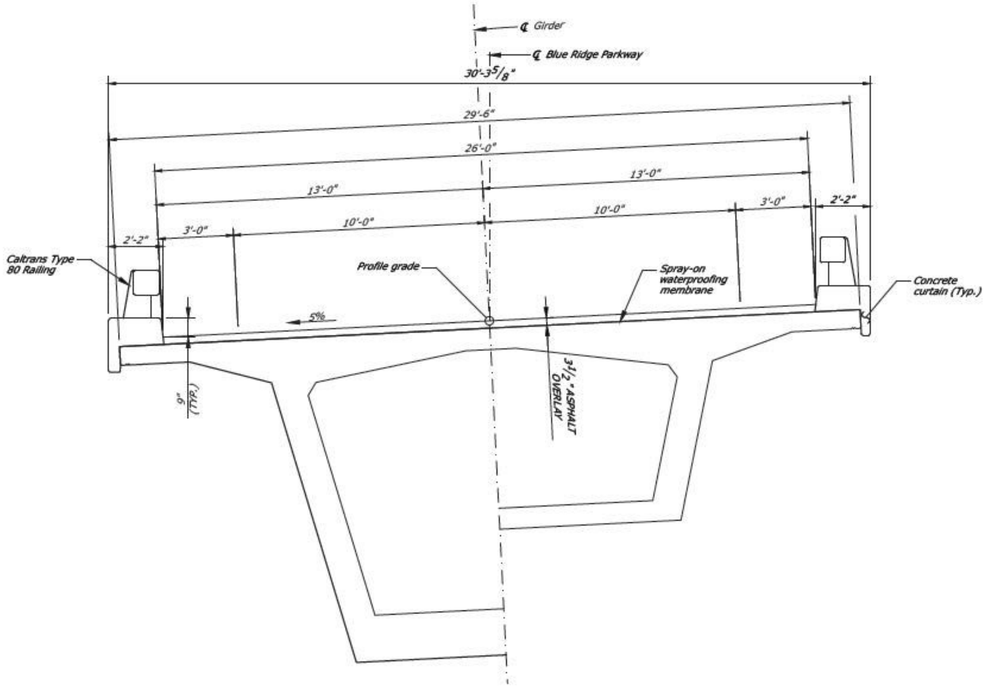
During construction, before the closure pour, the cantilever is supported by temporary towers. Photo: COWI North America.

Design Adaptations for Epoxy-Coated Strand Tendons

Implementing the unducted tendon system entailed a few considerations for the modified design:

- Anchor-set increase: ECS requires a unique set of strand anchorage wedges to anchor each strand in the anchor head. The wedges must also "bite through" the epoxy coating into the post-tensioning steel. This requires anchorage wedges that are specifically designed for ECS and are typically ⅛ to ¼ in. longer than a standard wedge. Given the length between deviation points with the external tendons, this requirement had a small impact on the final tendon force after stressing.
- Coefficient of friction: Engineers in Japan have the most experience with unducted ECS post-tensioning systems, and they noted a higher coefficient of friction (up to 0.30) compared with grouted duct systems. The higher friction was considered in the Laurel Fork design; however, actual elongation measurements correlated with a coefficient of friction of 0.17, similar to that for HDPE duct. Design calculations predicted only a minor reduction (~2%) in residual midspan precompression due to increased anchor-set and friction effects, consistent with design experience in Japan. Field verification during initial tendon tensioning confirmed the anchor-set values, with actual elongations consistent with theoretical values, although there was a somewhat greater variation in the anchor set than would be typical for bare strand post-tensioning systems. The additional friction noted by Japanese engineers, however, was not observed, and a typical friction coefficient of 0.17 was consistent with the elongation results.

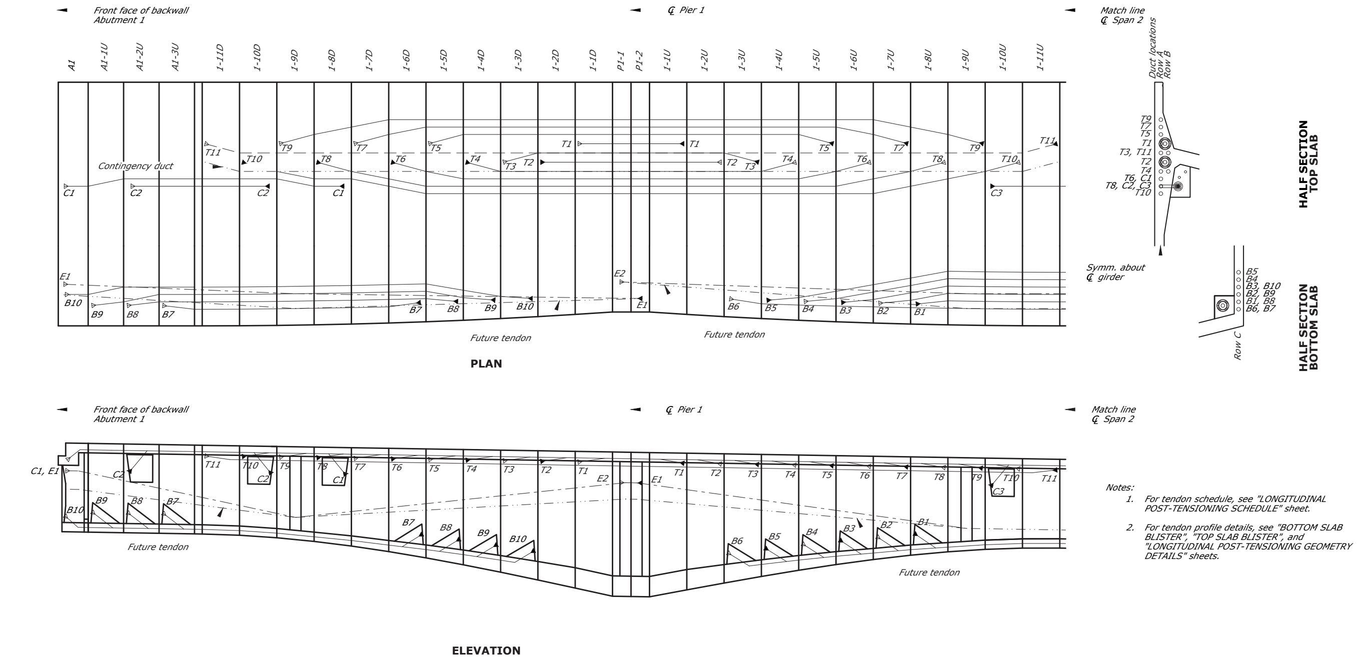
Bridge typical section. Figure: COWI North America.



Tendon Vibration Assessment

Typically, unducted ECS tendons experience greater sensitivity to vibration after installation than grouted systems. Without the damping effect of grout, vibrations are more readily induced; for example, striking the tendon with just a fist produces noticeable vibrations of the strand bundle.

Because long-term fatigue due to vibration can jeopardize tendon integrity, the design engineer conducted dynamic analyses comparing the first vibration frequency of unbraced tendon lengths to the bridge's first vertical vibration frequency. Results showed that the tendon frequencies are approximately double those of the bridge span vibrations, demonstrating



Post-tensioning layout for the Laurel Fork Bridge. Four types of tendons were used—top slab cantilever tendons, bottom slab continuity tendons, top slab tendons across the closure pour, and external tendons. Each tendon used 12 strands. Figure: COWI North America.

that span deflections will not induce resonant tendon vibrations.

Before the bridge was opened to traffic, in situ observations during construction vehicle crossings showed no significant adverse vibrations. Accordingly, the design engineer recommended against installation of intermediate tendon supports, which could introduce local restraint stresses on the ECS. Ongoing monitoring will evaluate long-term performance.

Conclusion

The Blue Ridge Parkway Laurel Fork project exemplifies how an effective concrete segmental bridge design allows the contracting team to adapt their methods and successfully complete the project. When owners, engineers, and contractors collaborate closely to achieve the best overall outcome, significant milestones can be reached. This project notably accomplished the successful implementation of unducted ECS for external tendons. This achievement, along with valuable lessons learned, demonstrates the usefulness of an additional post-tensioning option that can be incorporated into segmental and other bridge types.

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