Demonstration Workshop for Unducted External Post-Tensioning Using Epoxy-Coated Strand

by Gregg Freeby, American Segmental Bridge Institute, and Tim Christle, Post-Tensioning Institute

On March 27, 2025, the National Concrete Bridge Council (NCBC), in conjunction with the Concrete Bridge Engineering Institute, and the Federal Highway Administration (FHWA), hosted a workshop in Boone, N.C., titled Construction of Unducted External Post-Tensioning with Epoxy-Coated Strand in the Laurel Fork Bridge. This one-day workshop was an opportunity for attendees to learn about the state-of-the-art use of epoxy-coated steel strands and a demonstration of how the technology is applied at the Laurel Fork Bridge, which is located on the Blue Ridge Parkway in Laurel Springs, N.C.

Epoxy-coated strand (ECS) technology is part of the evolution of industry solutions focused on the durability of prestressing steel strand used in post-tensioning (PT) tendons in bridges and other structures. Progressive strategies developed by the industry have included continuous improvement in the quality of PT systems, grout materials, and installation for ducted, bonded PT tendons; the use of alternative wax "flexible fillers" for ducted, unbonded PT tendons; the implementation of electrically isolated tendon technology for long-term condition monitoring; and advancements in techniques to allow for the replacement of tendons over time. Today's version of ECS in an unducted tendon offers excellent protection of the steel strand, while also facilitating in-service inspection as well as the future replacement of the tendon, if needed.

View of Laurel Fork Bridge under construction. The workshop was held after the post-tensioning was installed. Photo: Gregg Freeby, American Segmental Bridge Institute.

Need for Post-Tensioning Innovation

At an international PT technology exchange hosted by the American Segmental Bridge Institute in November 2022, a group of 58 worldwide industry experts convened in Austin, Tex., to discuss the current state of PT practice and identify areas for potential improvement. One of the six technology goals identified by the group was to "expand the use of un-ducted epoxy-coated (flow-filled) external PT tendons."[1] In support of that goal, FHWA organized the recent workshop to foster the use of the latest ECS tehcnology.

Modern Epoxy-Coated Strand Technology

ECS was developed in the United States more than 40 years ago, and the

LAUREL FORK BRIDGE, BLUE RIDGE PARKWAY / ASHE COUNTY, NORTH CAROLINA

BRIDGE DESIGN ENGINEER: U.S. Department of Transportation, Eastern Federal Lands Highway Division, Washington, D.C.

ENGINEER OF RECORD AND CONSTRUCTION ENGINEER: COWI North America Inc., Tallahassee, Fla.

PRIME CONTRACTOR: A Joint venture of Vannoy Construction, Jefferson, N.C., and Structural Technologies LLC, Fort Worth, Tex.

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

POST-TENSIONING CONTRACTOR: Structural Technologies, Fort Worth, Tex.

Classroom instruction by Jon Cornelius, Sumiden Wire Products Corporation. The workshop consisted of a morning classroom session followed by a site visit in the afternoon. Photo: Gregg Freeby, American Segmental Bridge Institute.

technology has significantly advanced since its inception. Today's ECS is much more than just seven-wire steel strand coated with a surface layer of epoxy. The modern manufacturing process completely encapsulates each individual wire in epoxy, as well as the spaces between them. This advanced epoxy-coating technology achieves exceptionally strong adhesion between the steel wire surfaces and the epoxy, resulting in a material that is highly resistant to both corrosion and fatigue. The enhanced fatigue resistance is due to the reduction of fretting movements among the individual wires. Typically, the external epoxy layer has a thickness ranging from 0.5 to 0.7 mm on the crowns of the outer wires. For bonded applications, aluminum oxide grit is impregnated into the epoxy coating to enhance bonding capacity, matching or surpassing that of traditional bare strands. The modern unducted ECS introduces four key improvements over current PT practices: increased durability, simplified installation, easier condition assessment of the coating, and the possibility of tendon repair or replacement, if necessary. The use of ECS has been somewhat limited in the United States over the past four decades. However, for more than 30 years, ECS has been used in Japan for hundreds of bridge projects, all without issues.

Epoxy-Coated Strand Manufacturing and Testing

In the United States, ECS is manufactured and tested in accordance with ASTM A882, *Standard Specification for Filled Epoxy-Coated Seven-Wire Steel Prestressing Strand*.[2] After the bare strand is manufactured, the strand is splayed open and an electrostatically charged epoxy powder is sprayed within a containment chamber such that each wire is individually coated and all internal voids are filled with epoxy. After coating, the strand is inspected using a 3000-volt dry spark pinhole detector, and any holidays or defects are then repaired. This manufacturing of a "filled" strand is one of the improvements distinguishing modern-day ECS from the earlier-generation, nonfilled versions of this product. In addition, new bite-through PT wedges are used in tendon anchorages, eliminating the need to strip off the epoxy coating to grip and tension strands. ECS, especially when used in unbonded external tendon systems with bite-through wedges, provides a high-performance, durable, and inspectable alternative to traditional grouted tendon systems. (For more information on ECS, see the Spring 2020 issue of *ASPIRE*®.)

Tendon Design and Detailing for Replaceability

A major benefit of unducted ECS for external PT tendons is that it facilitates designs and detailing allowing for the installation, removal, and replacement of the external PT tendons in bridges, thereby improving the durability, service life, and ease of maintenance of these structures. The use of diabolos is a key component of the removable tendon system. Diabolos are trumpet-shaped

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OTHER MATERIAL SUPPLIERS: Epoxy-coated strand: Sumiden Wire Products Corporation, Dickson, Tenn.; post-tensioning system: Structural Technologies, Fort Worth, Tex.

BRIDGE DESCRIPTION: A 565-ft-long, three-span (155-235-155 ft) precast concrete, balanced-cantilever segmental bridge. Each of the 56 segments are 30 ft 3⅝ in. wide, and the roadway width is 29 ft 6 in. The segments vary in depth from 8 ft at midspan to 13 ft at the piers. Segments are 10 ft 1 in. in length. The bridge is in a constant vertical grade and constant horizontal curve. The structural design made use of internal and external post-tensioning tendons with diabolos used in place of bent steel pipe for deviating external post-tensioning tendons. The substructure consists of cast-in-place concrete H-shaped piers with heights of 70 and 53 ft.

STRUCTURAL COMPONENTS: 56 precast concrete box-girder segments

View inside the Laurel Fork Bridge showing the external epoxy-coated-strand tendons. Workshop participants were able to walk through the inside of the bridge and view the hardware and details of the unducted post-tensioning system. Photo: Gregg Freeby, American Segmental Bridge Institute.

Site-visit group photo. Photo: Gregg Freeby, American Segmental Bridge Institute.

formed voids in deviators or diaphragms used to guide the tendon. They also improve alignment, stress distribution, and replaceability. (For further information about diabolos, see the Fall 2015 issue of *ASPIRE*.)

To learn more about replaceable PT tendons, refer to the Summer 2020 issue of *ASPIRE*. Another resource is the FHWA report *Replaceable Grouted Post-Tensioned Tendons*.[3] While that report focuses on grouted PT tendons, much of the guidance on detailing also applies to unbonded systems such as ECS.

Unducted Post-Tensioning

Traditionally, external tendons in a concrete segmental box girder are carried inside a polyethene duct, which is also grouted. For the Laurel Fork Bridge, the strands for the external tendons were epoxy coated and unducted. The advantages of this system are that no duct or grout is needed, and the corrosion protection, in the form of the epoxy coating, is applied before installation. For the Laurel Fork Bridge, the decision to use unducted ECS tendons was made well into the construction phase; however, because the project was already making use of diabolos, the change was fairly easy to incorporate. The unducted, external tendons with ECSs that were ultimately installed on this project are fully inspectable and replaceable.

Laurel Fork Bridge Design and Construction

The Laurel Fork Bridge is a three-span (155-235-155 ft) precast concrete, balanced-cantilever segmental bridge. It includes six unducted tendons with twelve 0.6-in.-diameter ECSs per tendon. (See the Perspective article in the Spring 2025 issue of *ASPIRE* for more about the precast concrete segments for the Laurel Fork Bridge.)

Custom hardware and wedges were used to specially adapt the PT anchorages for ECS. Custom anchor heads were also developed and tested specifically for ECS. This testing included two fatigue tests—one consisting of 500,000 cycles at 60%–66% guaranteed ultimate tensile strength (GUTS) and a second, more extreme test with 50 cycles at 40%–80% GUTS—as well as static tensile tests at 97.8% of actual ultimate tensile strength (AUTS; that is 101.7% GUTS).

Tendon installation was adapted to site constraints. For example, strands were delivered on wooden reels and uncoiled with care. Also, given their short lengths, the unducted tendons were hand-pushed into place, one strand at a time. (Note: On larger ECS external tendon installation projects, the use of preassembled tendons is recommended, instead of the strand-by-strand method used on this smaller demonstration project.) Bundling, taping, and alignment were critical for protecting the epoxy coating. For strand tensioning, existing equipment was adapted with new wedge grippers and seating chucks. The wedge-recess plate depth and wedge seating required special consideration.

Workshop Summary

The workshop on March 27 provided 67 participants from across the United States with the opportunity to learn more about the use of ECS for unducted external PT through a classroom session in the morning and an afternoon site visit to the bridge. The morning session included 55 people in person and 12 participating virtually. Fifteen state departments of transportation were represented. Due to the limited size of available classroom facilities and limited access to the bridge site, attendance was limited to representatives of select departments of transportation and private sector organizations.

The workshop kicked off at the campus of Appalachian State University with presentations by industry experts on ECS technology. Vendors and producers of these materials and components provided tabletop displays to further enhance the attendees' experience.

After the morning classroom educational session, the participants traveled by bus to visit the Laurel Fork Bridge under construction. This two-hour visit was an opportunity for participants to tour

Workshop attendees view the unducted epoxy-coated strand inside the Laurel Fork Bridge. Photo: Jon Cornelius, Sumiden Wire Products Corporation.

the overall construction site and gain access inside the concrete segmental box to observe the unducted ECS in place. The abutment backwall had not yet been placed, so participants could easily walk through the opening in the abutment end diaphragm and then roam inside the bridge to observe the hardware and details necessary for unducted ECS, including the previously installed and tensioned tendons. Near the bridge, a learning station was set up for participants to observe the equipment and process for performing repairs should damage to the coating occur during construction. Opportunities to view the structure from above and below were also afforded. Many participants indicated that the site visit was the highlight of the workshop and enhanced the classroom learning experience.

Resources from the workshop are available to allow interested individuals to learn more about the application of this PT technology in future projects. Links to video recordings of the morning sessions, copies of the presentation documents, and additional resources can be found on the NCBC website (www.nationalconcretebridge.org).

Acknowledgments

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