All-precast concrete bridge demonstrates UHPC connection durability

About a decade ago, PCI-certified precast concrete producer Precast Systems Inc. of Allentown, N.J., fabricated box beams with a new Federal Highway Administration shear key design for the Delaware Department of Transportation (DOT). The company was helping state bridge engineers test whether connecting the beams with ultra-high-performance concrete (UHPC) instead of grout, welded shear connector plates, and post-tensioned tie rods would eliminate longitudinal cracking and joint leaks.

The agency's diamond-shaped shear keys reinforced with lap splices can transfer forces across the connections between the precast concrete components. Filling those joints with UHPC eliminates the need for transverse post-tensioning and a structural concrete overlay.

This design, which turns precast concrete's greatest vulnerability into an asset, is now standard practice for Delaware's adjacent box beam bridges. In 2017, when the DOT built a 50 ft (15 m) long, two-lane bridge over Blackbird Creek near Townsend, Del., the connections' 22,000 psi (152 MPa) concrete compressive strength allowed engineers to replace a cast-in-place concrete deck with a much faster UHPC overlay.

Precast Systems manufactured all structural components. These include 10 prestressed box beams, each 52 ft (16 m) long, 4 ft (1.2 m) wide, and 2 ft (0.61 m) deep with the tops tined to facilitate overlay adhesion. Keyways are 7 in. (180 mm) high, 1.875 in. (48 mm) wide at the beam top, and 6.375 in. (162 mm) at the widest section, with a 0.375 in. (9.5 mm) joint opening between the beams.

A full-height concrete barrier end section that is 5 ft (1.5 m) long, 1 ft 8 in. (0.5 m) wide, and 2 ft 8 in. (0.81 m) high was cast into each end of the two outside beams. A 7 in. (180 mm) curb was cast between the two end sections and used embedded anchor bolts at 9 ft 3 in. (2.8 m) on center to attach a prefabricated metal railing. The two outer beams have two more (16 altogether) prestressing strands than the other eight beams to combat differential camber of the inner and outer beams caused by detail weight.

Precast Systems fabricated test piles and 12 prestressed concrete piles, each 45 ft (13.7 m) long, 14 in. (360 mm) wide, and 14 in. deep, simultaneously.

Six piles support a 46 ft long (14 m) variable-height stub abutment on each side of the creek. To reduce weight for transportation and placement, the company fabricated each abutment in two 23 ft (7 m) sections with three 27 in. (690 mm) diameter vertical openings for pile connections.

The company also fabricated four wingwall sections, two 6 ft 1 in. (1.85 m) wide by 6 ft 2 in. (1.88 m) tall and two 6 ft 1 in. (1.85 m) wide by 8 ft 2 in. (2.5 m) tall.

Replacing a corrugated metal pipe arch bridge with precast concrete joined with fast-curing ultra-high-performance concrete (UHPC) allowed the Delaware Department of Transportation to reopen the Blackbird Station Road 1-438 bridge in one-third the time of traditional construction methods. Courtesy of Delaware Department of Transportation.

End diaphragms were cast on-site by pouring UHPC directly onto the ends of the box beams. UHPC backwalls were poured simultaneously with the shear key joints.

When cast-in-place concrete abutments are used, projects of this size take three months and cost about $750,000. Joining precast concrete components with UHPC took one month and cost $1,025,801. Precast concrete elements cost $369,140, representing 36% of total project cost. UHPC joints cost $84,000, representing 8%.

In 2025, Precast Systems fabricated beams with the same FHWA shear key detail for another Delaware DOT project over Blackbird Creek.

—Stephanie Johnston

Precast UHPC U girders save bridge developer materials, cost

Yen Lei Voo, the chief executive officer of Dura Technology, created the company in 2006 to offer project owners in Malaysia an even faster, more durable, and lower-carbon construction material than traditional precast concrete: precast ultra-high-performance concrete (UHPC).

Precast UHPC is up to 10 times stronger—21.7 ksi (150 MPa) compressive strength at 28 days—than traditional concrete, capable of withstanding 18,000 to 30,000 psi (124,110 to 206,850 kPa) forces compared with 3000 to 5000 psi (20,685 to 34,475 kPa). These characteristics empower designers to engineer bridges with fewer and thinner girders, decreasing superstructure weight and lengthening spans without increasing cross-sectional dimensions.

Serving as engineer of record and precast concrete supplier, Dura Technology saved Malaysian developer Bonus Essentials 30% in 2023 by proposing that a four-lane bridge in an expanding industrial park in Kuala Langat, Selangor, Malaysia, be built with precast UHPC U girders topped with a reinforced cast-in-place concrete deck instead of steel plate girders.

Known globally for specializing in long-span bridges using precast UHPC, Voo's team fabricated the world's longest U girders—344.5 ft (105 m) long—to cross a river at a 44-degree angle in a single span.

The patented DURA brand of UHPC is a mixture of portland cement, silica fume, fine silica sand, high-range water-reducing admixture, and high-carbon steel fibers with a minimum tensile strength of 363 ksi (2500 MPa). For the Langat River bridge, the company fabricated nine DURA UBG4000 (UBG stands for *U bridge girder*), each requiring 250 yd^3 (191 m^3) of UHPC and weighing 560 tons (508 tonnes).

Each girder was assembled from 14 post-tensioned segments ranging in length from 21.3 to 26.2 ft (6.5 to 8.0 m). Concrete for each segment had to be placed continuously, which required using a 15.7 yd^3 (12 m^3) mixer. To ensure alignment, the fabricator match cast every other segment along the girder's entire length on a long bed. Each segment cured at 194°F (90°C) for 48 hours and then was transported to the site for reassembly and post-tensioned and the tendons were grouted.

Unlike conventional concrete girders, UHPC girder webs don't require shear reinforcement. Each Langat River U girder has two webs, each 6 in. (150 mm) thick, and a 9 in. (229 mm) thick bottom flange with seven tendons, each with thirty-seven 0.6 in. (15.2 mm) diameter strands tensioned up to 80% of their breaking load. Each top bulb has one 13-strand tendon tensioned to the same load. The tendons guaranteed compression across joints after transfer to the jobsite and for service loading.

A sister company, Dura Construction, erected one girder in less than two days using a single launching operation off of a barge. Although the superstructure's mass is 18% greater than the proposed structural steel design, embodied energy and embodied carbon are 55% and 48% lower, respectively.

Voo says that he believes bridges built with precast UHPC have a potential lifespan of several hundred years. The U girders represent $3.33 million, or 16.7%, of the $20 million project. Project size was 126,090 ft^2 (11,714 m^2).

—Stephanie Johnston

More than 380 bridges in Malaysia have been built with ultra-high-performance concrete (UHPC), including this new bridge over the Langat River in Kuala Langat. Precast UHPC specialist Dura Technology set a world record despite pandemic-era material shortages by fabricating the world's longest precast UHPC U girders at 344.5 ft (105 m) long. Courtesy of DURA.