I-91 BRATTLEBORO BRIDGE IMPROVEMENTS

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The new I-91 Brattleboro Bridge (Fig. 1) replaced two aging steel bridges that were built in 1958. The steel truss bridges were structurally deficient and functionally obsolete; therefore, needed to be replaced. The best value selected, design/build (D/B) project was designed and built for the Vermont Agency of Transportation (VTrans).

The project includes a new three-span, 1036 ft (315 m) arching bridge with a 515 ft (157 m) main span soaring 100 ft (30 m) above the West River, built using segmental concrete balanced cantilever construction (Fig. 2). The new concrete segmental bridge (a first in the state) features landmark aesthetics and structural features for over a 150-year service life. The new bridge carries four lanes of traffic but has the capacity to carry eight lanes of traffic. There are two lanes of traffic in each direction, along with inside and outside safety shoulders, providing drivers with open views of the West River Valley. The project also included replacement of Bridge 8, which carries the northbound and southbound lanes of I-91 over a local road using Northeast Extreme Tee (NEXT) Beams..

The bridge design was inspired by the natural beauty of Vermont. This signature bridge, which is the largest bridge in Vermont's history, creates a special gateway into the state. Coming into the state, people are treated to beautiful green mountains connecting rivers and valleys. The Designer worked closely with the community and VTrans on the aesthetic and functional design centered around a theme of "Vermont: A Bridge to Nature" (Fig. 3).

Functionality and Durability

The balanced cantilever method facilitated construction to rise above the site constraints on the ground below and allowed the long spans to be formed in a self-supported manner during construction. This was an important benefit for the unobstructed use of the West River and West River Trail for recreation. Using self-advancing formwork (form travelers), segments of the bridge were cast-in-place

Fig. 1—Brattleboro Bridge.

Fig. 2—Construction of the Brattleboro Bridge using segmental concrete balanced cantilever construction.

Fig. 3—Bridge design inspired by natural beauty of Vermont.

16 ft (4.9 m) at a time, alternating from one side of the pier to the other, until each cantilever arm reached 257 ft (78 m). When the adjacent pier's cantilever was completed using the same process, a small closure segment was cast to connect the two cantilever arms and form the span. For the two cantilevers to meet at a precise mid-air target, surveying and geometry control were a full-time endeavor. Given the total bridge length (1036 ft [315 m]), longitudinal jacking operations were designed to mitigate the long-term effects of creep and shrinkage.

The D/B team's design provided reduced maintenance and enhanced durability, including:

- The decks for both Bridges 8 and 9 were placed monolithically without longitudinal joints, providing a more durable deck and better protection for reinforcement, beams, bearings, and diaphragms.
- The Bridge 9 deck has post-tensioning running both transversely and longitudinally, providing biaxial compression and enhancing the deck's long-term durability.
- The stain used for the barriers became part of the concrete and will never require reapplication, unless the concrete is damaged. The stain was also mixed with a substance that uses nanotechnology-containing particles that eat pollution, assisting the surface to remain clean and maintenance-free. In addition to

the superstructure, calcium nitrite was added to the footing and pier concrete mixture to inhibit the corrosion process in the Bridge 9 components.

Innovative Technical Features and Constructability

To support the bridge deck width of 104 ft (32 m) carrying two lanes of traffic in each direction, a two-cell, three-web trapezoidal box girder was used (Fig. 4). A variable depth profile was used for structural efficiency and provides a natural aesthetic as the spans move across the valley. With a depth of 12 ft (3.7 m) at midspan and 28 ft (8.5 m) at the piers, the segments are very large to the human scale. The biggest segments contain 180 yd^3 (138 m^3) of concrete and took 6 hours to cast. Another unique feature to the box girder section is the 20 ft (6.1 m) constant width barrel in the bottom slab that helps break up the large width of the bottom soffit.

The D/B Team used very sophisticated three-dimensional (3-D) finite element models with time-dependent effects to design the bridge to not only withstand the appropriate standard loadings but to also account for the time-dependent effects on the concrete as it creeps and shrinks throughout the 150-year design life of the bridge. The concrete was also engineered to be more durable than standard mixtures to ensure the desired design life.

Travelers along Route 30, the route which travels under the bridge, experience this distinctive bridge from a side vantage point as they then travel under the bridge. They see the arch barrel (Fig. 5), which is a concave curve in the bottom slab of the superstructure. This area was stained with a blue color to mimic the sky. The arching superstructure box girder, with a 12 ft (3.7 m) depth at midspan (half as deep as the former bridge), opens up the viewshed of the surrounding landscape. A permanent concrete earth-toned tan stain was applied to all sides of the bridge superstructure, matching the surrounding environment. The piers are covered with a beautiful form liner mimicking Vermont stone and creating a dramatic look with different natural colors along the 70 ft (21 m) piers.

Functionality and Aesthetics

The focal point of the bridge is the two "quad wall" piers, which represent stone trees emerging from the ground and supporting the arching concrete spans. The quad wall piers are comprised of four concrete columns that each curve outward in two directions symmetrically. The 3-D design and detailing of the columns was very complex with a constantly changing cross section and rein-

Fig. 4—Trapezoidal box-girder section.

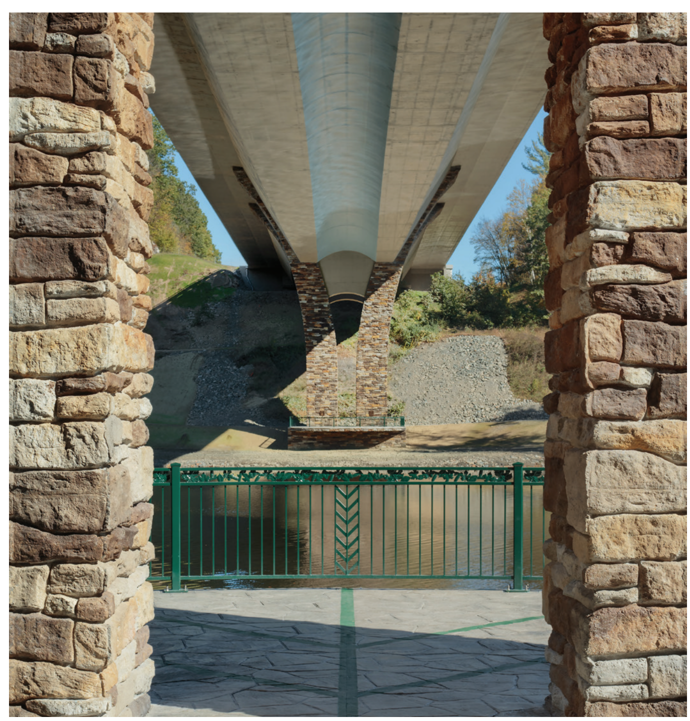

Fig. 5—Stained arch barrel on the bottom of the superstructure.

Fig. 6—515 ft (160 m) long main span arching over the West River.

forcing pattern. Workshops were held with the designer, contractor, reinforcing fabricator, and formwork provider to ensure all details were considered and to provide the most efficient design. The quad wall system of the piers provides stability and allowed for the balanced cantilever segmental construction of the bridge superstructure to be constructed from above, without temporary props in the river, minimizing impacts to the thoroughfares below.

The contractor shaped more than 18,000 yd^3 (13,800 m^3) of concrete into a curvy, elegant bridge supported on either side of the West River by arching "cathedral piers." The 70 ft (21 m) tall concrete piers feature observation platforms. These platforms provide access to view the Gallery of the Natural Habitat and people can walk around the base of the massive quad walls. The platform space is formed from the top of each footing with a stone texture and a pattern that represents a white pine tree with 14 branches. This is inspired by the Vermont State Seal with the white pine with 14 branches because Vermont was the 14th State. From the top of the platform, curved quad wall pier columns rise to directly support the concrete box girder superstructure. The underside of the superstructure is a concave dome shape that runs the length of the bridge and was stained blue to match the landscape of the sky. Standing on the observation platform and looking up between the stone textured columns of the pier gives the feeling of being in an outdoor cathedral. The bridge is both structure and symbol, both function and sculpture. The main span is a 515 ft (157 m) long arching form over the West River (Fig. 6).

Location: Brattleboro, VT
Owner: Vermont Agency of Transportation
Engineer: FIGG Bridge Engineers, Inc.
Contractor: PCL Civil Constructors, Inc.
PT Supplier: DYWIDAG-Systems International
Other Contributors: Sebago Technics; Golder Associates; VT Compliance Monitoring; and Carroll Concrete Co.