STATE

Washington

The Washington State Department of Transportation addresses unique challenges through the use of innovative design, materials, and programs

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Known for its rugged Pacific coastline and the Cascade Mountains, Washington state is a study in contrasts when it comes to climate and geography. The state has the largest ferry operation in the United States as well as 8421 bridges carrying public roads that are subject to the Federal Highway Administration inspection requirements; 3345 of these bridges are state owned.[1]

WSDOT employs innovative programs and a creative workforce. The agency pilots new materials and designs to help advance efforts to create and maintain a transportation system that meets safety, reliability, resiliency, accessibility, and affordability requirements.

Innovative Programs

WSDOT completes roughly half of the state's design work in-house. From this work, the agency has acquired unique insight regarding the complexities of bridge design, construction, and asset management. They understand aspects of construction and material availability. The agency considers not just the current design and construction stages but also the longevity of the structure, and how it will serve the community for years to come.

WSDOT, in partnership with the Texas Department of Transportation, created PGSuper (www.wsdot.wa.gov/eesc/bridge/software), which is open-source software to design and load rate precast, prestressed concrete girder bridges in accordance with the American Association of State Highway and Transportation Officials' *AASHTO LRFD Bridge Design Specifications*[2] and WSDOT criteria. The agencies also developed PGSplice, an open-source program for the design of precast, post-tensioned concrete spliced-girder bridges. Girders are evaluated for stress and stability during handling and transportation as well as strength limit state requirements. WSDOT maintains both programs to accommodate the state's particular challenges, including strategies to mitigate issues related to top flange fit-up (differential camber), camber predictions, and stability.

The colors and textures on the East Trent Bridge over the Spokane River reflect community input about the structure's aesthetics. On every bridge project, the Washington State Department strives to meet the needs of the community and fulfill a "visual level of service." All Photos: Washington State Department of Transportation.

Lightweight Concrete to Extend Spans

Washington state is home to some of the longest precast, prestressed concrete girders in the United States. WSDOT experts are actively involved in the development of guidelines that address the design of bridge girders for lateral stability during handling and transportation. WSDOT has implemented practices that are in the latest edition of the AASHTO LRFD specifications, as well as those that are being included in the forthcoming second edition of the Precast/Prestressed Concrete Institute's (PCI's) *Recommended Practice for Lateral Stability of Precast, Prestressed Concrete Bridge Girders*.[3]

The successful use of mega-girders in Washington is facilitated by the use of lightweight concrete. The record-breaking, limit-pushing girders were made possible by lightweight aggregates. Now WSDOT frequently uses lightweight concrete in its bridge designs to extend span length. Limiting the weight of the girders is critical to ensure components can be hauled to the jobsite by truck. Because western Washington is a high-seismic region, lightweight concrete also helps reduce the bridge mass and substructure earthquake loads.

Puyallup River Bridge

One recent project over the Puyallup River involved the state's longest prestressed concrete girders (223 ft long). These massive girders support southbound Interstate-5 (I-5) traffic in Tacoma over the Puyallup River and adjacent rail lines. To meet the handling and shipping requirements, lightweight concrete was used for a modified WSDOT WF100G girder section with a widened top flange to improve stability. (For

The longest prestressed concrete girders in Washington state are installed on southbound Interstate 5 Puyallup River Bridge in Tacoma. These girders measure 223 ft in length and almost 9 ft in height, and each weighs more than 246,500 lb.

For the North Spokane Corridor project, local artists helped identify community-based themes. In the Euclid Undercrossing, images evoking native culture and natural elements from the surrounding community are embedded in the concrete abutment.

more information on this project, see the Fall 2019 issue of *ASPIRE*®.)

The Puyallup River Bridge is part of the larger Tacoma/Pierce County corridor program, which is adding high-occupancy vehicle lanes and other operational improvements along I-5, State Route 16, and State Route 167 (SR 167). The second stage of construction, on the SR 167/I-5 to the SR 509 New Expressway phase of the project, began in the summer of 2022. That project also includes structures that use both lightweight concrete and long-span girders. WSDOT coordinates with local precast concrete manufacturers and haulers to determine the logistics of transporting these large components to the site and installing them. Route investigation for hauling typically includes checks on horizontal clearances during turning movements, vertical clearances to overhead structures and utilities, and rotational stiffness requirements for the hauling equipment.

Galvanized Reinforcement in a Coastal Environment

For the crossing of U.S. Route 101 over Steamboat Creek, which is in a coastal environment, WSDOT used galvanized reinforcement in the precast, prestressed concrete spliced girders, and the concrete deck and barriers. This pilot project in Jefferson County near the Pacific Coast used post-tensioned, spliced prestressed concrete girders. This was the first WSDOT project to use plastic ducts in precast, prestressed concrete girders as standard practice. The ducts, which are made from high-density polyethylene, are intended to protect tendons from corrosion and provide adequate space for post-tensioning tendons and hardware. The post-tensioning ducts were grouted with prepackaged Class C cementitious grout, which is WSDOT's standard practice.

In addition to the galvanized reinforcement throughout the bridge, WSDOT included other corrosion-protection measures to withstand the marine exposure. WSDOT recently adopted the requirements of the Post-Tensioning Institute's PTI Performance Level 2 for post-tensioned bridges to enhance the service life of these structures. Based on the success of this galvanized reinforcing bar pilot project, the option will be considered for other projects, such as the U.S. Route 395 North Spokane Corridor.

Precamber Geometry

Prestressed concrete girder bridge systems continue to evolve. One advancement is the use of precambered girders. Building an intentional vertical curve (precamber) into girders is an effective method to accommodate challenges with vertical alignment and bridge geometry. However, precamber has design and fabrication challenges that must be addressed. WSDOT engineers, working with local fabricators, documented these challenges and a solution in the May–June 2020 issue of *PCI Journal*.[4] Several bridges have been constructed with precambered girders for vertical clearance. This method can also be used when there is a potential for sag in long-span girders.

Modest spans with steep vertical curves lend themselves to the use of precambered precast concrete girders. The practice reduces the concrete placed for the deck and improves aesthetics. It is also helpful when there is a vertical clearance requirement underneath the structure. One project example is Thorne Lane bridge over I-5 in Lakewood, Wash., where precambered girders were used to meet

To improve stability during handling, hauling, and erection, the top flange of a lightweight concrete girder for the Puyallup River Bridge was widened to 5 ft 1 in. and ten 0.6-in.-diameter pretensioned temporary top strands were placed in the top flange.

A culvert under State Route 9 through Gribble Creek in Skagit County is replaced with a new precast concrete culvert as part of the statewide fish passage imperative. This project required only a five-day road closure.

The replacement of the existing bridge deck on the Interstate 90 Vantage Bridge aims to maintain the structural integrity and extend the life of the bridge. While allowing traffic on adjacent lanes, construction is currently underway using precast concrete bridge deck panels and ultra-high-performance concrete in the longitudinal and transverse keyway joints.

The crossing of U.S. Route 101 over Steamboat Creek used spliced, post-tensioned precast concrete girders and was the first Washington State Department of Transportation project to use plastic ducts in prestressed concrete girders. The high-density polyethylene ducts are intended to protect tendons from corrosion. Shown here is a closure joint before the duct couplers, additional reinforcement, and post-tensioning are installed and concrete cast.

the vertical clearance requirements over the interstate and adjacent Sound Transit railroad.

The Importance of Aesthetics

Communities play an important role in determining bridge aesthetics. People expect bridges to provide durable, resilient, safe, and economical transportation while also reflecting the communities they serve. WSDOT has a dedicated state bridge and structures architect on staff with a team that provides oversight and guidance for bridge aesthetics that suit the state's diversity.

Color palette and formliner technology are used to imbue concrete with different colors and textures. In Spokane, the SR 290 East Trent Bridge over the Spokane River is one example of striving for a harmonious and balanced solution. Context is critical—a concrete finish suitable for Seattle may be out of place in Spokane. Many state highways incorporate tribal arts into the aesthetics of supporting structures and abutments.

The I-405 corridor team developed guidelines for aesthetics to define their image across current and future projects. They use four color palettes as well as distinct column shapes and custom concrete finishes to develop their own corridor identity.

The new North Spokane Corridor connects north and south areas of Spokane. The corridor encompasses several locales with unique community identities, and it has both isolated interchanges and elevated structures contiguous to neighborhoods, business districts, and the Spokane Community College. To create a unifying aesthetic for the project, WSDOT asked local artists to assist the agency in identifying community-based themes for the structure. Images based on those themes were then cast into the concrete.

Complete Streets

Community engagement is important for all projects, regardless of their size. Since 2022, the "Complete Streets" requirement has directed WSDOT to provide access for multimodal users, including pedestrians, bicyclists, and public transportation users. For the many Washingtonians who do not drive, WSDOT incorporates input from landscape architects and urban planners to make sure that structures are contextually relevant and fit into the surrounding landscape.

Ultra-High-Performance and High-Early-Strength Concrete

WSDOT uses ultra-high-performance concrete (UHPC) primarily to fill joints between precast concrete components. On the San Poil River and Swauk Creek bridge deck girder projects, the longitudinal sides of the top flanges were joined with UHPC. Also on these projects, two mats of no. 5 reinforcing bars at 6-in. spacing were extended from each flange and joined with a noncontact lap splice.

The Coastal 29 progressive design-build project is the first WSDOT project to use UHPC to connect adjacent slab-girder bridges. Those adjacent slabs are connected with a single mat of reinforcement with a noncontact lap splice in the joint. For the deck replacement of the I-90 Vantage Bridge over the Columbia River, WSDOT is using UHPC to connect precast concrete deck panels while allowing traffic to remain on adjacent lanes of the bridge during construction.

The PGSuper software was recently updated to support the design of UHPC pretensioned bridge girders for the recently published *AASHTO Guide Specifications for Structural Design with Ultra-High-Performance Concrete*.[5]

High-early-strength concrete (HESC) is being researched by WSDOT for rapid bridge deck overlay preservation. Bridge engineers are investigating the use of calcium sulfoaluminate (CSA) cement as a permanent bridge overlay material to speed up construction time. Researchers at the University of Washington are evaluating prepackaged, manufactured products for the potential use of HESC for long-term durability. While these products are used by WSDOT highway maintenance crews for fast repair and short-term fixes, they have not been used for large repair projects. CSA cement shows the potential to help crews work within tight construction windows and reduce the greenhouse gases associated with portland cement.

Fish Passage Imperative

Washington has 4037 highway crossings on fish-bearing waters. Of those, 2074 are documented fish passage barriers, with 1531

For the replacement of the San Poil bridge, the Washington State Department of Transportation used wide-flange deck girders with a thicker than standard top flange. The prestressed concrete girders eliminated the need for deck formwork. Ultra-high-performance concrete was used in the top-flange connections between adjacent WF39DG girders.

culverts blocking upstream habitat. Over the last several years, WSDOT has accelerated work to comply with the requirements of a U.S. District Court injunction to correct impediments to fish migration. To date, WSDOT has completed nearly 500 fish passage barrier corrections, restoring more than 570 miles of potential salmon and steelhead habitat. WSDOT is using several strategies to facilitate the effort to accomplish this daunting task by 2030. Specifically, the agency is bundling fish passage projects by geographic regions; using progressive design-build contracts to expedite delivery; and creating standard details and drawings for these types of projects.

The fish passage program requires the replacement of hundreds of structures. Precast concrete and accelerated bridge construction methods offer economical and efficient options to quickly replace the structures that block fish migration. Given the urgent need for standard plans, WSDOT sought input from local precast concrete fabricators regarding constructability. The standard plans include buried structure split boxes, three-sided buried structures, and precast reinforced concrete retaining walls. Implementation of the new standards generated policy changes regarding hydraulic design, load distribution, seismic design, and traffic control. Ultimately the standard drawings will streamline the design and construction process and improve efficiencies. (See the Spring 2022 issue of *ASPIRE* for a Concrete Bridge Technology article about WSDOT's precast concrete buried structures for fish passage.)

WSDOT is tasked with the critical mission of maintaining infrastructure, restoring habitat, connecting communities, and saving lives. It achieves that goal through the use of innovative materials, design, research, and programs.

Artistic touches to the concrete substructure were added to the skyway portion of North-South Corridor (U.S. Route 395) near the Spokane Community College and Spokane River structures.

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