PROJECT

ONE OF ELEVEN, BUT ONE OF A KIND

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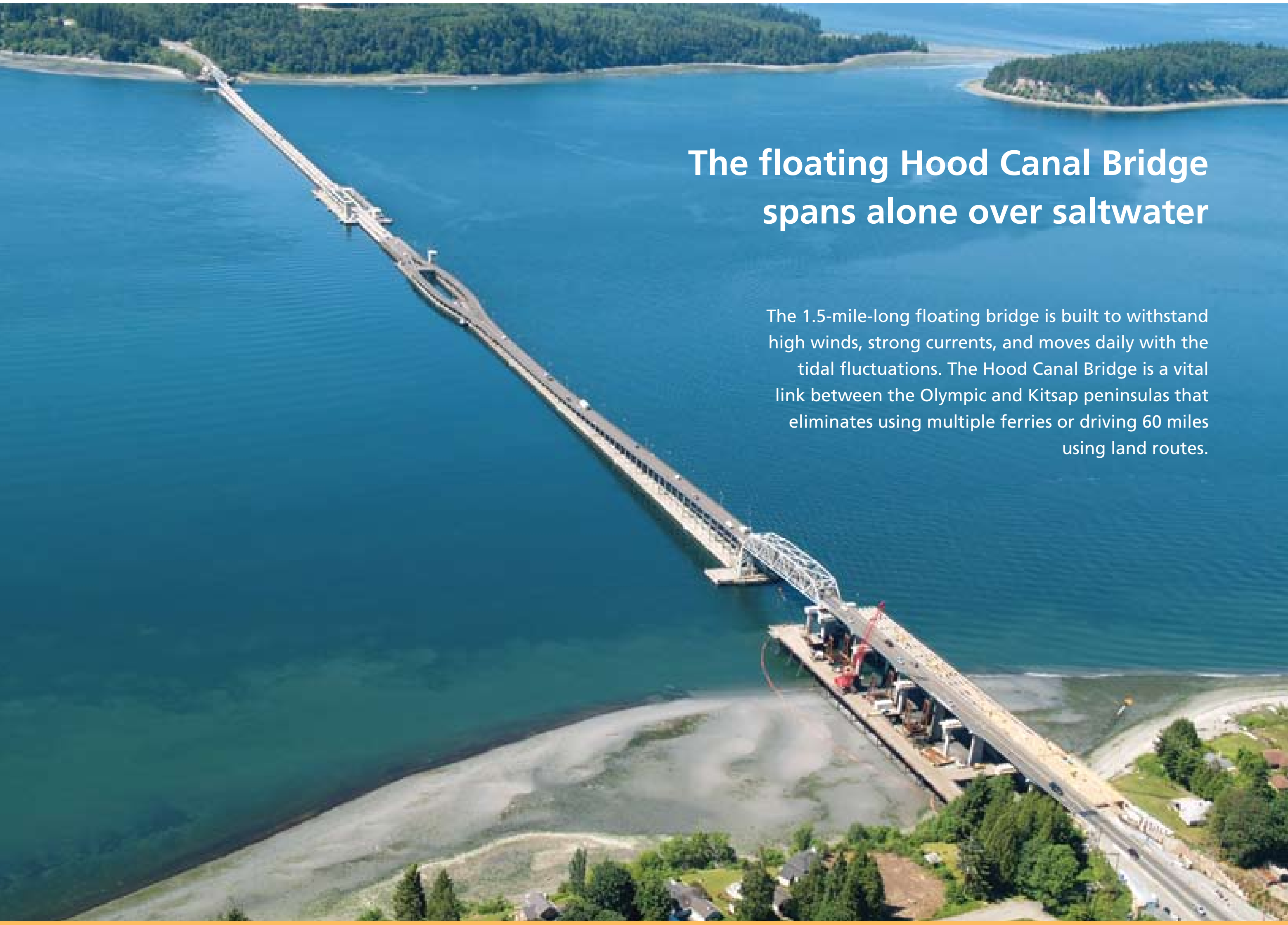


The floating Hood Canal Bridge spans alone over saltwater

The 1.5-mile-long floating bridge is built to withstand high winds, strong currents, and moves daily with the tidal fluctuations. The Hood Canal Bridge is a vital link between the Olympic and Kitsap peninsulas that eliminates using multiple ferries or driving 60 miles using land routes.

profile

HOOD CANAL BRIDGE / KITSAP AND JEFFERSON COUNTIES, WASH.

ENGINEER: Washington State Department of Transportation, Olympia, Wash.

PRIME CONTRACTOR: Kiewit-General (a joint venture), Poulsbo, Wash.

CONCRETE SUPPLIER: Glacier Northwest Inc., Seattle, Wash.

POST-TENSIONING SUPPLIER FOR STRAND TENDONS: AVAR Inc., Campbell, Calif.

POST-TENSIONING SUPPLIER FOR BAR TENDONS: Williams Form Engineering Corp., Portland, Ore.

PRECASTER FOR PRESTRESSED GIRDERS, STAY-IN-PLACE DECK PANELS, AND VOIDED SLABS: Concrete Technology Corporation Inc., Tacoma, Wash., a PCI-certified producer

The pontoons are heavily reinforced and post-tensioned in all three principle directions. Tight tolerances on placement of formwork and reinforcement are required to maintain the design height of the pontoon deck above the water surface.

A total of 14 floating pontoons are being constructed in four separate cycles in approximately 2-1/2 years in the graving dock.

The scene is the epitome of the Pacific Northwest: evergreen trees, dark blue water, and majestic mountains. But the natural beauty of the Hood Canal hides a beast's heart. As winter descends on the region, it brings icy rains, gale force winds, and white-capped waves that blow and crash through the area almost unimpeded.

At the northern end of the waterway, the Hood Canal Bridge spans across the divide to connect the Kitsap and Olympic peninsulas, fluctuating in elevation daily with tidal shifts up to 16.5 ft. Its elevated roadway, like bridges everywhere, allows drivers a more direct route to their destinations. Yet, the bridge is one of only 11 floating bridges in the world. With a length of 7869 ft—approximately 1.5 miles—the bridge is the longest of its kind over saltwater. It hasn't been an easy existence, either.

The 1979 Storm

The original Hood Canal Bridge's west half sank in 1979 after less than 18 years of service. With the wind blowing from the south and a very strong current flowing from the north, the west-half floating structure overturned at the most exposed part of the canal. That half was replaced in 1982, but now the east half, completed in 1961, is reaching the end of its service life.

Why Build a Floating Bridge?

At the bridge site, the canal is up to 340 ft deep. A concrete floating bridge provides a cost-effective solution for crossing a channel with very deep, soft soils in a high seismic region. While a high-level structure was evaluated during design, the exorbitant costs for the site conditions could not be justified.

Not only must the bridge float in a harsh marine environment, it must also permit marine vessels to navigate the canal. Essential hydraulic, electrical, and mechanical components housed in key pontoons allow the bridge to open its 600-ft-wide draw span for marine traffic. With a naval submarine base to the south of the structure and the mouth of the canal to the north, this function is critical for national security.

Two pontoons incorporated precast segments and closure pours to facilitate placement of large, heavy embedded mechanical components of the draw span that required maximum tolerances of 1/16 in. in 500 ft.

Construction Progress

The Hood Canal Bridge West-Half Retrofit and East-Half Replacement Project was started in June 2003 and will be completed by the end of 2010. The new east half is expected to be operational until 2084. To ensure this 75-year lifespan, high-performance

PRECAST CONCRETE FLOATING BRIDGE / WASHINGTON STATE DEPARTMENT OF TRANSPORTATION, OLYMPIA, WASH., OWNER

EPOXY-COATED STRAND SUPPLIER: Sumiden Wire Products Corp., Stockton, Calif.

BRIDGE DESCRIPTION: 1.5-mile-long floating bridge with fixed approach spans and movable transition spans between fixed piers on land and structures floating on tidal saltwater

CONCRETE STRUCTURAL COMPONENTS: Prestressed concrete pontoons; reinforced concrete anchors; two-column reinforced concrete piers; 32-in.-deep and 42-in.-deep, precast, prestressed concrete I-girders; and precast, prestressed concrete stay-in-place deck panels topped with a cast-in-place concrete roadway

BRIDGE COST: $471 million

WSDOT Moving Towards Performance-Based Concrete Specifications

Although the concrete has performed well overall, future projects similar to this will use performance-based concrete specifications. This will allow WSDOT to include additional performance requirements such as shrinkage and scaling resistance. Some potential improvements that could be made to this mix include reducing cementitious materials content, adding shrinkage-reducing or corrosion-inhibiting admixtures, or perhaps moving to self-consolidating concrete. Shifting to performance specifications will allow contractors to develop mixes that meet performance requirements yet are tailored to the forming, placement, consolidation, and the form removal methods they prefer.

The WSDOT is currently considering use of the performance-based specifications for the next floating bridge project, which will likely be the State Route 520 floating bridge replacement across Lake Washington. This project is currently in the design phase, with pontoon construction expected to start late 2009. Pontoon construction on this project shares many similarities with the Hood Canal project. The WSDOT is incorporating valuable experiences from Hood Canal into the design of the State Route 520 Bridge to further improve performance and constructability, and reduce construction costs.

materials and tight construction tolerances are required. Widening and improving the bridge's west half was completed in 2005, Since then, the Washington State Department of Transportation (WSDOT) has been constructing a new east half, which will be moved into place in May-June 2009, and further upgrading the west half.

The work is underway at multiple construction sites in western Washington. Since early 2006, construction progress includes successfully building and floating 12 of the 14 new east-half pontoons, joining the draw span pontoons together, and rehabilitating three 1980 pontoons. The original elevated roadways were removed from these pontoons, and wider roadways with a new profile grade were constructed in their place. Also, 20 gravity anchors have been constructed and were placed on the canal floor in summer 2007. Other large operations in various stages of construction include fabrication of the transition spans and specialized supports, lift spans, large spherical and cylindrical bearings, major mechanical components, and outfitting of the draw span assembly with buildings, access ramps, and the hydraulic, mechanical, and electrical systems.

All of these elements of work set the stage for the closure of the bridge in May-June 2009, when the east half of the bridge and the west transition span will be replaced. The bridge will be open to traffic while new anchor cables are installed and west half mechanical and electrical upgrades are made.

Pontoon Construction

The prestressed high-performance concrete (HPC) pontoons are being constructed in four separate cycles at Concrete Technology Corporation's graving dock in Tacoma, Wash. The largest of the cellular box structures is 60 ft wide, 18 ft tall and 360 ft long. The pontoons are heavily reinforced with both conventional epoxy-coated reinforcing steel and longitudinal, transverse, and vertical post-tensioning tendons.

The HPC used for the pontoons was originally developed in the 1990s for the I-90 Lacey V. Murrow (LVM) floating bridge across Lake Washington and includes the following components:

Type I/II cement: 625 lb/yd^3

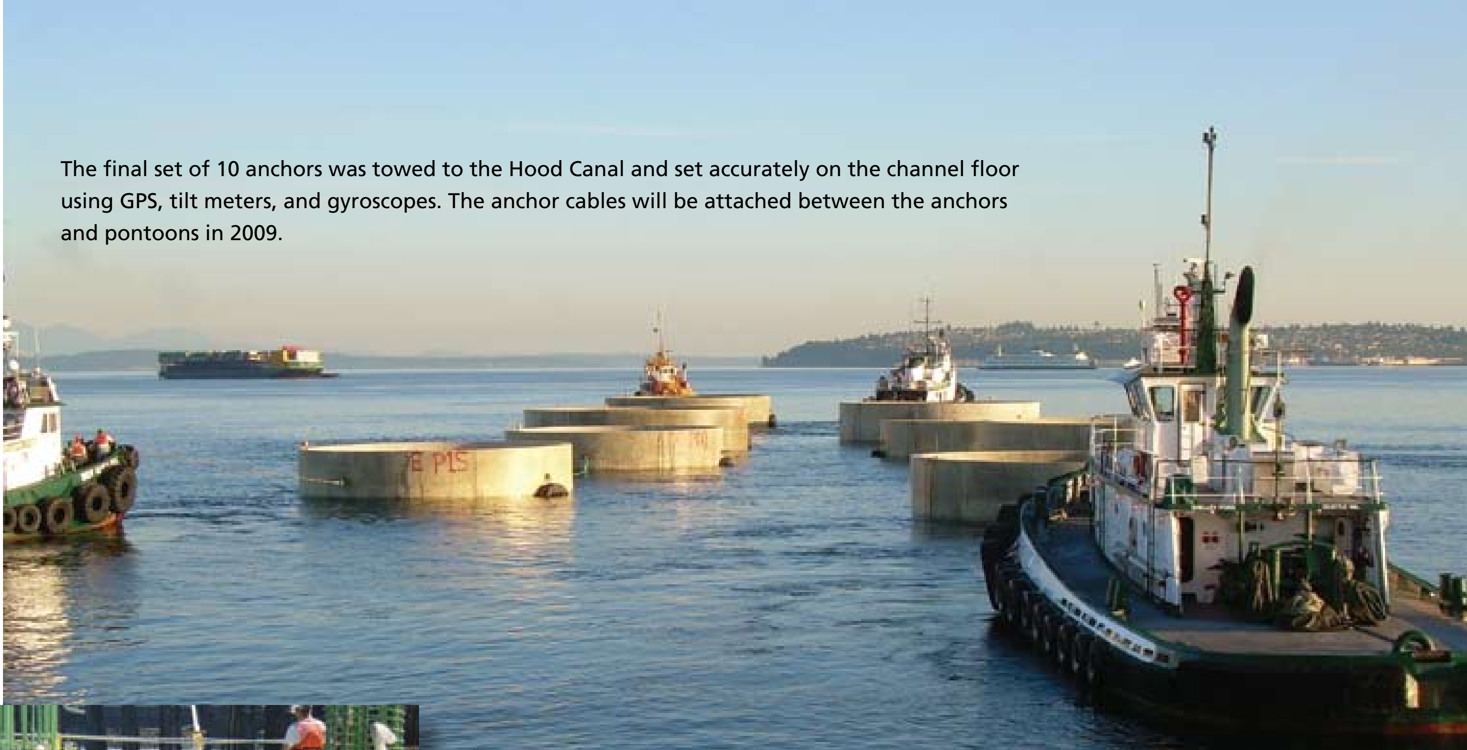
Class F fly ash: 100 lb/yd^3

Silica fume: 50 lb/yd^3

Aggregates: 1/2-in. maximum size

The approximately 31,000 yd^3 of pontoon concrete have a minimum specified 28-day compressive strength of 6500 psi, and a maximum 56-day chloride permeability of 1000 coulombs. The actual 28-day compressive strengths have been approximately 11,000 psi and the 56-day permeability less than 800 coulombs. Early in the project, the contractor realized that the LVM concrete placement in the pontoon walls would be challenging because the walls are up to 21 ft tall; 6 in., 8 in., and 10 in. thick; and heavily congested with reinforcing steel and post-tensioning ducts. To improve concrete placement and consolidation, the contractor requested approval to exceed the maximum 9-in. slump that was allowed by the contract. This was achieved by using additional high-range water-reducing admixture within manufacturer's allowances. After

The elevated roadway was constructed at Terminal 91 at the Port of Seattle on three existing pontoons. These three pontoons were used temporarily in the west draw span until 1982 to open the Hood Canal Bridge quickly after the 1979 storm sunk the west half. These pontoons were successfully rehabilitated in 2007 after 25 years of storage in the Puget Sound and are used in the new east half.



The final set of 10 anchors was towed to the Hood Canal and set accurately on the channel floor using GPS, tilt meters, and gyroscopes. The anchor cables will be attached between the anchors and pontoons in 2009.

Pontoons are assembled together with spliced post-tensioning tendons before being towed to the Hood Canal Bridge to replace the old pontoons.

A concrete floating bridge provides a cost-effective solution.

conducting a series of qualification tests and constructing a mock-up pontoon wall, the contractor successfully demonstrated that this "new" mix could be placed without segregation. Testing and acceptance of this concrete was accomplished using the flow test that is common with self-consolidating concrete (SCC).

Another innovation implemented was to precast portions of two pontoons that make up the moveable draw pontoons. These pontoons have heavy mechanical components cast into the walls 21 ft overhead. The precasting operation improved overall safety in supporting these massive guides and facilitated the tight alignment tolerances needed for the mechanical draw span operations. The precast elements consisted of portions of the exterior walls with all necessary reinforcement and post-tensioning to tie into the top and bottom slabs. Once the precast pieces were set into place, reinforcement and post-tensioning was tied into the base slab and the wall closure regions. The base slab, wall closures, and top slab were then constructed with cast-in-place concrete. By precasting portions of these pontoons, construction time was reduced. Precasting also allowed much of the work to be shifted off-site and away from the heavily congested graving dock facility.

Elevated Roadway Construction

To withstand the regular pounding of saltwater waves that crash over the bridge during the storm season from October through April, the elevated roadway built atop the pontoons is constructed primarily of reinforced and precast, prestressed concrete. With project activities since early 2006 focusing on constructing pontoons and anchors and assembling the draw span section, the elevated roadway remains a main element of work to be accomplished.

The elevated roadway on a floating structure compels the designer to select an optimal span length to minimize the dead loads and to evenly distribute column loads to the pontoon structure, which behaves like a beam on elastic foundation from water buoyancy. For the Hood Canal Bridge, this equates to shallow I-girders with 60-ft span lengths. Built on two-column piers, the two-span continuous units have a hinge diaphragm at the center pier. The floating structure is isolated from seismic events with special connections to the fixed structures, so the floating bridge is governed by dynamic loads from wind, waves, and currents instead of seismic loads.

The prestressed concrete I-girders are typical WSDOT 32-in.- and 42-in.-deep sections, but all reinforcement and 0.5-in.-diameter prestressing strands are epoxy coated and the bottom flange concrete clear cover is 1-1/4 in. The 7-1/2-in.-thick roadway deck consists of 4 in. of reinforced concrete cast on 3-1/2 in.-thick, stay-in-place precast, prestressed concrete deck panels. Using stay-in-place panels significantly decreased the time required to construct the deck and increased safety when working over water.

Girders on the draw pontoons, where the profile grade drops to the lowest point, use dapped ends and end blocks—with some cantilevering over piers. To open the navigation channel, three lift spans are raised to allow the draw pontoons to retract underneath. The draw span necessitates minimizing the deck elevation while maintaining sufficient vertical clearance for maintenance vehicles underneath and to clear most storm waves.

Temporary ballast water is used in the pontoon's internal cells to balance the pontoons as the superstructure loads are added. Regular monitoring of the pontoon freeboard (distance from top of the deck to water line) is needed to maintain a level and stable structure at dockside. Specialized survey equipment tracks the top plane of the deck as it moves with the wind, waves, and the addition of new loads. Construction measurements are then referenced to this fluctuating theoretical plane. Permanent rock ballast is used to make final adjustments.

The draw spans open for large vessels and submarines in the Hood Canal.

Gravity Anchor Construction

From the public's perspective, the reinforced concrete gravity anchors were said to look like giant "tea cups," measuring 29 ft tall and ranging in diameter from 46 ft to 60 ft. The anchors are massive, stout vessels that must float initially. Built in Seattle, the large bowl-like structures were towed 50 miles to Hood Canal, then lowered to the canal floor and filled with crushed rock ballast.

The ballasting is required to attain the final submerged anchor weight, keeping the pontoons in alignment during storms without shifting the anchors on the soft soil slopes. While the geometry of the anchors is complex, the general design details are straightforward. The anchors have 3 in. of concrete clear cover to all reinforcement and a low-permeability, 4000 psi concrete mix made with pea gravel. Vertical post-tensioned bar tendons are used in the walls at the picking eye locations to distribute the shear forces from the setting operations.

After the new east half of the bridge is floated into place, 3-in.-diameter anchor cables will be threaded through the 27-in.-diameter pipe cast inside 4.5-ft-thick, heavily reinforced walls and attached to the pontoons to complete the anchorage connections for the floating bridge. Some of the gravity anchors are offset nearly 2000 ft from the bridge alignment and rest in water as deep as 340 ft below mean tide. Cathodic protection systems are used to protect the anchor cables, thereby protecting the pontoons and the anchors.

The elevated roadway uses precast, prestressed concrete I-girders, and stay-in-place deck panels. This construction method reduced formwork efforts and improved safety for the over-water construction activities.

Floating into the Future

From the anchors 340 ft below the waterway's surface to the pontoons and elevated roadway, the concrete of the new Hood Canal Bridge will be tested regularly by the elements. High-performance concrete and the extensive use of pretensioning and post-tensioning will ensure that it passes its daily trials. The WSDOT has been able to learn from its past experience to create a new structure that has set the standard for floating bridges in the Washington state highway system and beyond. The new Hood Canal Bridge is a balance of form and function, putting innovative ideas into action and paving the way for improved transportation well into the future.

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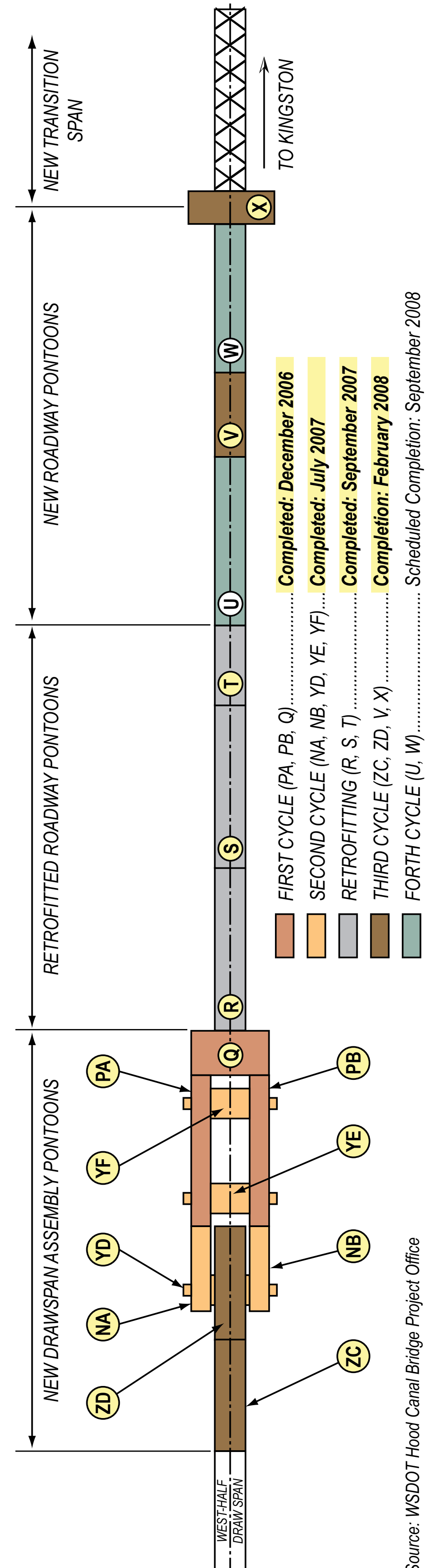
For more information on this or other projects, visit www.aspirebridge.org.

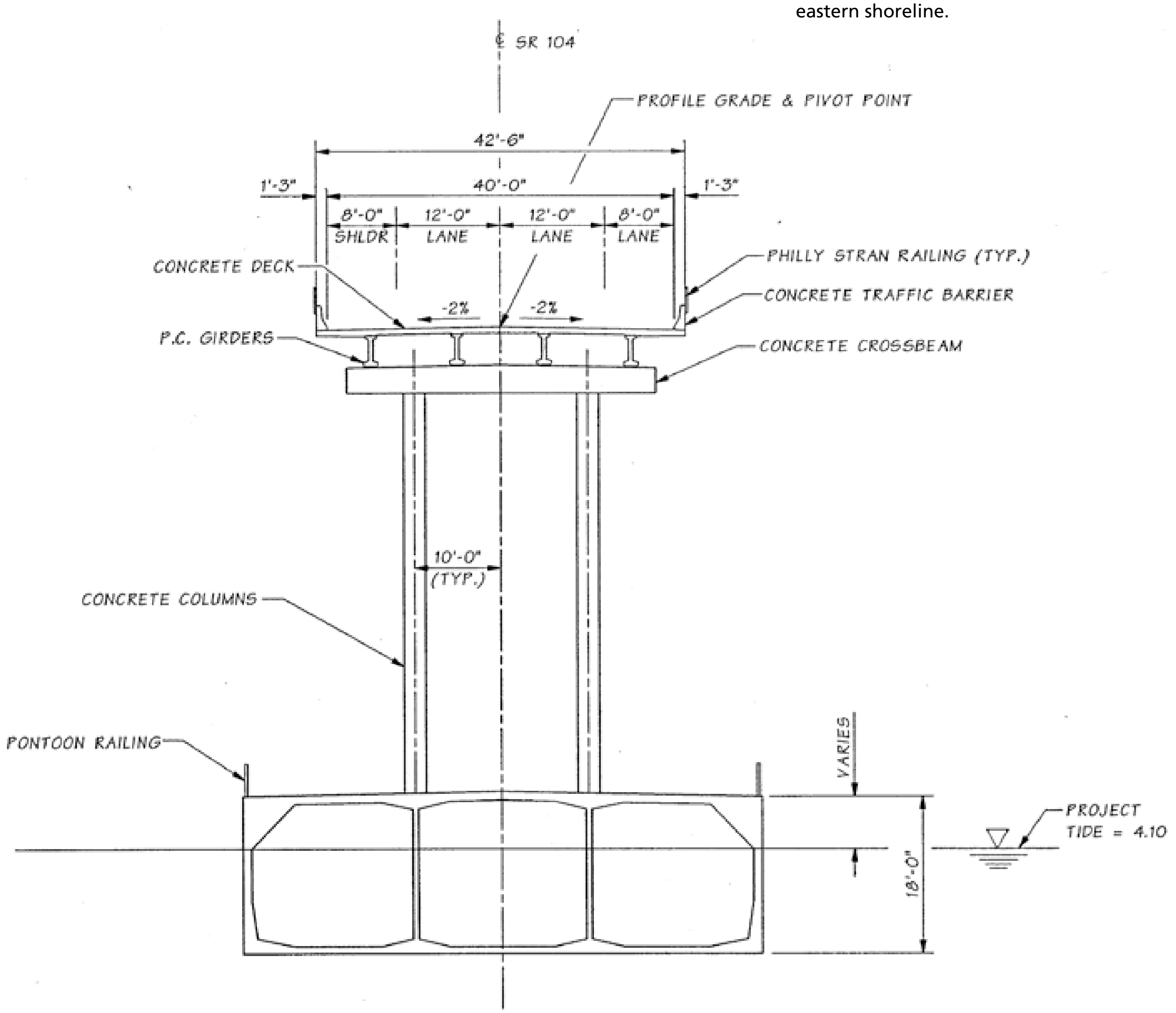
The 20 anchors built for the East half are 29 ft tall and range in diameter from 46 ft to 60 ft.

Hood Canal Bridge Pontoon Construction Cycles



Hood Canal Bridge pontoon construction cycles.

Once the pontoons are joined into subassemblies of multiple pontoons, the elevated roadway is constructed on top of the floating pontoon foundations. The roadway deck towers over the top of the pontoon decks as high as 52 ft near the eastern shoreline.



TYPICAL SECTION @ PONTOONS U & W