PROJECT

Marion Street Pedestrian Bridge Replacement: A New Icon for the Revitalized Seattle Waterfront

by Don Nguyen and Bethy Clark, HDR Inc., and Stephen Wilson, Seattle Department of Transportation

The project to replace one of the busiest pedestrian bridges on the West Coast, the Marion Street Pedestrian Bridge servicing the Colman Dock Ferry Terminal, has been a collaboration between the City of Seattle, Wash., the Washington State Department of Transportation (WSDOT), and bridge design engineers. The new bridge is located in a high-seismic region, in the dense urban area of Seattle's Central Waterfront adjacent to the Elliott Bay seawall. The project, which is part of the Waterfront Seattle Program's overall transformation of Seattle's downtown waterfront, includes a main-span bridge over a major arterial, an approach bridge above a sidewalk, and a transition to an existing pedestrian bridge that remains in place.

Project Background

In 2019, the State Route 99 (Alaskan Way) double-decker viaduct freeway structure, which posed a barrier between Seattle's downtown corridor and the waterfront, was replaced with a tunnel as part of the waterfront improvement efforts. The city is constructing a park promenade along the water and building a new surface street where the viaduct once stood. The Colman Dock Ferry Terminal has been reconstructed, and the adjacent attached building is slated for demolition and replacement.

Along with those changes, the city needed to replace the Marion Street Pedestrian Bridge to provide improved waterfront access. The existing bridge was a combination of bridge types using various materials, with some segments dating back to the 1930s. It included steel through-plate girders as well as an aluminum truss and concrete and

Photo from 2019 showing the previous pedestrian structures, which included a section that traveled beneath the State Route 99 (Alaskan Way) viaduct. The double-deck viaduct has since been demolished and replaced with a tunnel.

profile

MARION STREET PEDESTRIAN BRIDGE / SEATTLE, WASHINGTON

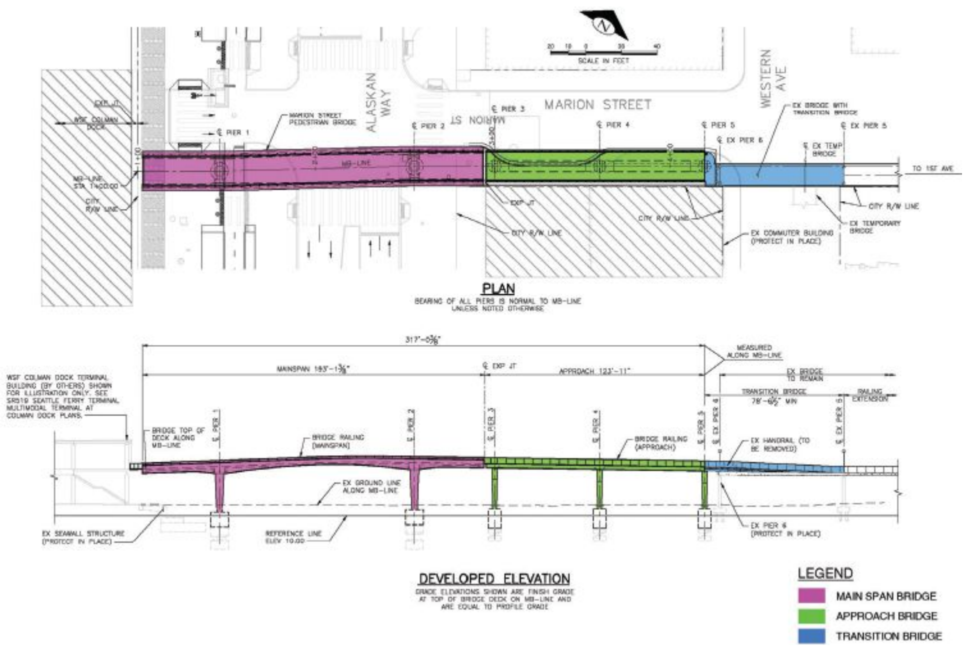
BRIDGE DESIGN ENGINEER: HDR Inc., Bellevue, Wash.

OTHER CONSULTANTS: Architecture: Rosales + Partners, Boston, Mass.; electrical engineering: Reyes Engineering, Portland, Ore.; construction engineering: Ott-Sakai & Associates, Mountlake Terrace, Wash.; geotechnical consultant: Shannon & Wilson, Seattle, Wash.

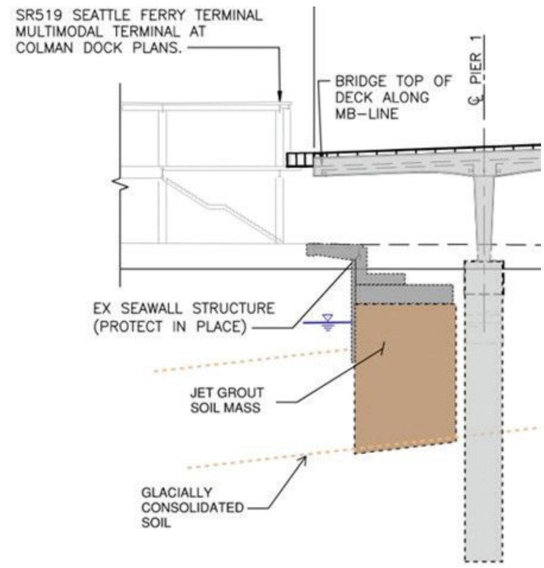
PRIME CONTRACTORS: Superstructure and columns: Flatiron, Renton, Wash.; approach foundations: Walsh, Seattle, Wash.; main-span bridge foundations: Gary Merlino Construction Co., Seattle, Wash.

POST-TENSIONING CONTRACTOR: Schwager Davis, San Jose, Calif.

CONCRETE SUPPLIERS: Superstructure and columns: CalPortland, Seattle, Wash.; foundations: Cadman, Seattle, Wash.



The Marion Street Pedestrian Bridge project is part of the Waterfront Seattle Program's overall transformation of Seattle's downtown waterfront. It includes a main-span bridge over a major arterial, an approach bridge above a sidewalk, and a transition to the existing pedestrian bridge. All Photos and Figures: HDR Inc.



An elevation view of the west cantilever of the Marion Street Pedestrian Bridge, its connection to the ferry terminal, and the proximity of the bridge's foundation to the seawall structure and its foundation.

steel superstructure that hung off the sides of neighboring buildings in some places and shared foundations with adjacent structures in others. One particularly uninviting section of the bridge snaked under the viaduct. During peak commuting times, the bridge would become very congested, and its steep grades did not meet the accessibility requirements of the Americans with Disabilities Act (ADA). Goals for the bridge project included ADA compliance, a walkable width to meet projected levels of use, enhanced user experience, and an aesthetic design suitable for the structure's prominence and context within the new Seattle Waterfront.

Early Design Considerations

The first consideration for the new bridge was to determine possible foundation locations that would avoid existing utilities and structures. Notably, the bridge had to cantilever over the Elliott Bay seawall and its improved soil mass to connect to the Colman Dock Ferry Terminal.

Once an optimal span configuration was set, three superstructure alternatives—cast-in-place concrete, extradosed concrete, and steel Fink truss—were analyzed from visual, structural, constructability, cost, and long-term maintenance perspectives. Ultimately, the cast-in-place concrete option was recommended because it best fulfilled the project goals by combinging cost, aesthetic, and constructability objectives into a balanced, cohesive, and clear structural system.

The geotechnical consultant provided recommendations for the design of the drilled-shaft foundations and designed the Elliott Bay seawall's improved soil mass. The placement of the foundations, the foundation type, the construction tolerance and risk, and the unique soil-structure interaction led to the use of drilled shafts and a long span over the arterial with cantilevers on either side. The geotechnical analysis, originally completed for the seawall design, was used to determine lateral spreading and liquefaction design parameters for the drilled-shaft foundations. The models determined that liquefaction occurred after peak ground motions and provided a peak ground acceleration concurrent with liquefaction. That finding reduced the overall demand on the foundations, and a total of 19 loading combinations were analyzed to account for the various strength, service, and seismic cases.

Main-Span Bridge Design

The three-span, cast-in-place concrete superstructure of the main-span bridge includes a gracefully arched center span with cantilevered end spans and angular V-shaped columns. To design this signature feature of the revitalized downtown waterfront, the bridge architect also incorporated suggestions from the Seattle Design Commission and considered the planned aesthetics of the

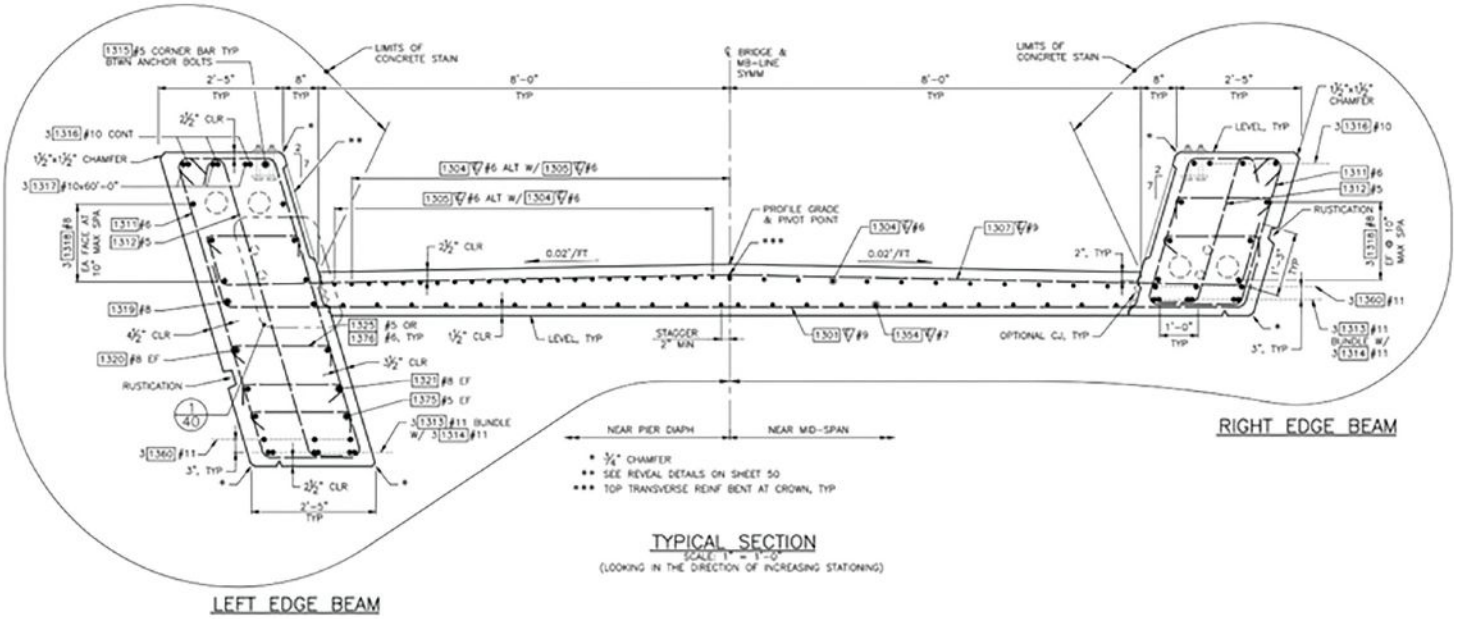
SEATTLE DEPARTMENT OF TRANSPORTATION, OWNER

OTHER MATERIAL SUPPLIERS: Rebar International, Edgewood, Wash.; Rainier Welding, Redmond, Wash.

BRIDGE DESCRIPTION: The main-span bridge is a cast-in-place, post-tensioned concrete structure with two edge beams and a concrete deck slab. It is 192 ft 6 in. long including a 43 ft 7 in. cantilever, a 110 ft center span, and a 38 ft 10 in. cantilever. The approach bridge is a cast-in-place, post-tensioned concrete slab bridge. It is 123 ft 3 in. long with two 59 ft 3 in. spans.

STRUCTURAL COMPONENTS: Concrete edge beams and deck slab for the main-span bridge; concrete slab superstructure for the approach bridge; cast-in-place concrete columns supported on drilled shafts for both bridges. The project used 450,000 lb of structural reinforcement and 800 yd^3 of concrete.

BRIDGE CONSTRUCTION COST: $9.4 million.

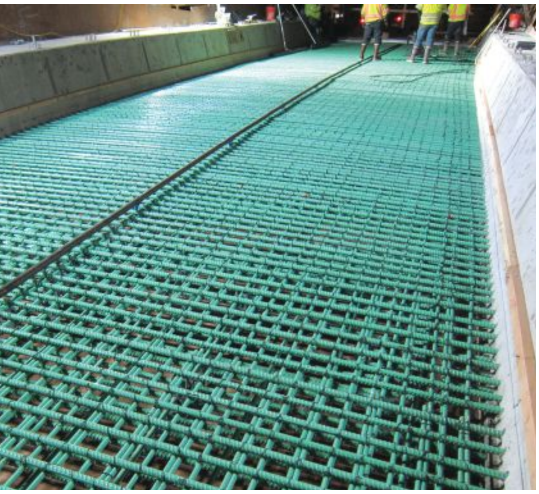


Cross section of the Marion Street Bridge showing the variable-depth, post-tensioned edge beams connected by a reinforced concrete deck slab.

new ferry terminal building. The length of the main-span bridge is approximately 192 ft 6 in. from the cantilevered west end at Colman Dock to the cantilevered east end at the approach bridge, not including the expansion joints. The span 1 (west) cantilever is 43 ft 7 in. long. The center span's length between piers 1 and 2 is approximately 110 ft. The span 3 (east) cantilever is 38 ft 10 in. long.

The cast-in-place, post-tensioned concrete structure includes two post-tensioned concrete edge beams connected by a reinforced concrete deck slab. Diaphragms connect the deck, edge beams, and columns at the piers. The edge beams vary in depth, from the maximum depth of 6 ft 3½ in. for the edge beams at pier 1 to the minimum depth of 4 ft 6 in. at the cantilevered ends. There are two tendons in each edge beam, and each tendon has twenty-seven 0.6-in.-diameter strands. The concrete for the edge beams was placed, then the deck was placed, and the edge beams were later post-tensioned. The concrete design strength was 5000 psi. Epoxy-coated reinforcement and increased concrete covers were used to minimize corrosion risk due to the proximity of the bridge to seawater and the use of deicing salts during cold weather. The substructure consists of integral V-shaped piers supported by 9-ft 10-in-diameter drilled shafts. The shapes of the piers as well as the superstructures contribute to the bridge's aesthetics. The piers taper in two directions, which made detailing for the reinforcement as well as construction a challenge because the stirrups also taper in two directions. Given the two arms of the V-shape, the longitudinal reinforcement had to

The cast-in-place concrete edge girders of the main-span bridge were placed first and then used as work platforms during the deck placement. Epoxy-coated reinforcement and large concrete covers were used to minimize corrosion risk.



With 5 million users passing through the Colman Dock Ferry Terminal each year, the new Marion Street Pedestrian Bridge enables pedestrians safe passage over multiple streets to access downtown Seattle.

The two-span approach bridge, a cast-in-place, post-tensioned concrete slab structure, connects to the east cantilever of the main-span bridge.

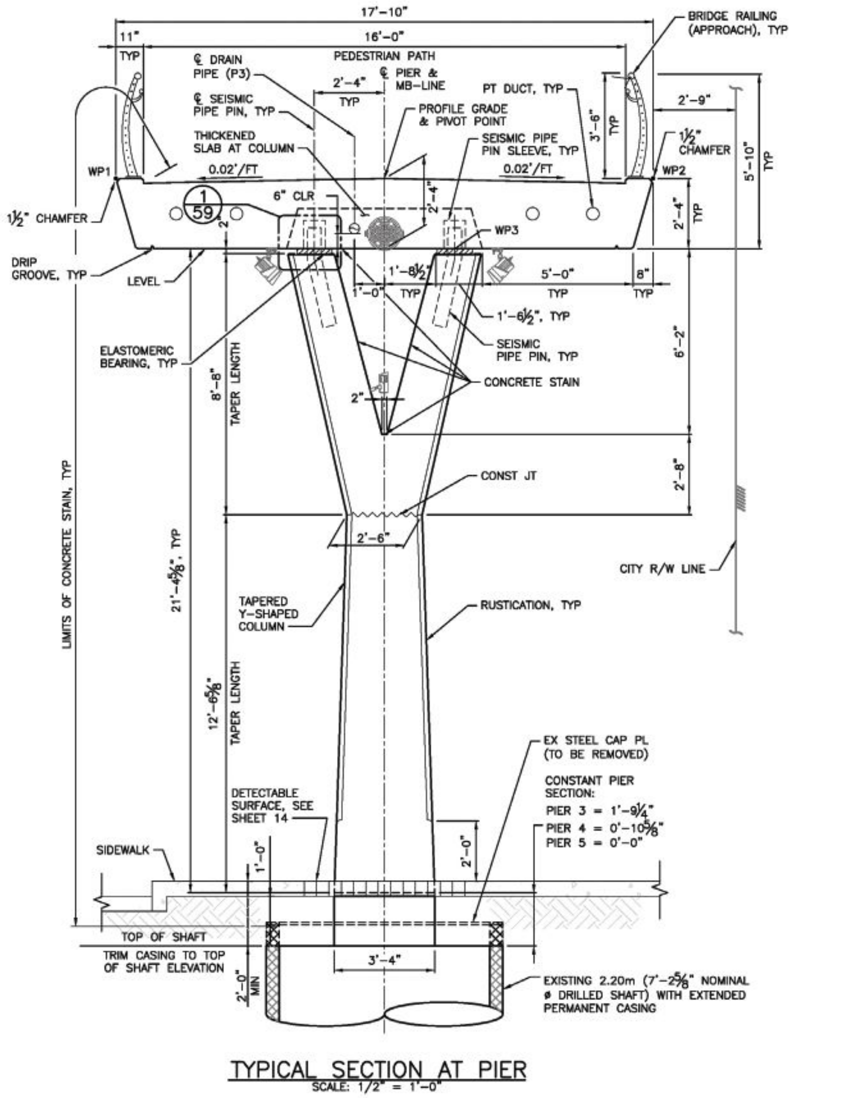
View from the top of the main-span bridge showing the stainless steel railing, pod lights, and a scenic view of the Seattle Waterfront.

weave from one face to the other to provide connectivity.

The site constraints and bridge geometry presented a few design and construction challenges to overcome. With the varying-depth edge beams tying into the deck at different elevations, the reinforcement as well as the post-tensioning duct placement had to be carefully coordinated with the contractor. The bridge was constructed on falsework, the design of which required special consideration to avoid impacts (such as unanticipated loading or settlement) to sensitive utilities and the seawall. In addition, the construction of the main-span bridge required concrete to be placed over a main overheight route through Seattle. Much of the work on the project had to be accomplished within the limited allowable closures for the main arterial and the exit lane for vehicles using the ferry terminal.

Seismic Movement Considerations

The expansion joint at the west end of the main-span bridge connects to the second story of the ferry terminal. The joint must accommodate very large movements while maintaining ADA accessibility. At this interface, there is a 3-ft gap between the end of the superstructure and the start of the building. Under the design earthquake event, the bridge moves only 18 in. longitudinally; however, total longitudinal movement exceeds 6 ft 6 in because the entry building movement includes the two-story



The approach bridge structure type is a cast-in-place, post-tensioned concrete slab. To maintain a relatively thin superstructure-to-column connection at the approach bridge, the design team took a unique approach using a seismic pipe-pin system, which would not transfer moment from the column into the superstructure.

The new Marion Street Pedestrian Bridge offers a width to meet projected levels of use, enhances the user experience, and showcases a bridge design suitable for the structure's prominence and context within the new Seattle Waterfront.

building as well as the movement from the lower trestle. There is also 5 ft of lateral movement and 1 ft 6 in. of vertical movement. Many expansion-joint options available today can either comply with ADA requirements or allow the level of movement needed here, but cannot do both. The solution was a 1-in.-thick stainless steel plate that spans the gap with a series of tensioned springs to clamp down the plate. The plate bears on an ultra-high-molecular-weight polyethylene bearing bar that slides on an embedded steel plate to accommodate the required range of motion. The plate thickness was governed by deflection limits rather than strength. At the ends of the plate, a hinge plate is attached to reduce the height drop to ¼ in. for ADA compliance. The bridge design team worked closely with the ferry terminal designers to design a safe, serviceable transition between the two structures.

Approach Bridge Design

The approach bridge length is approximately 123 ft 3 in., not including the expansion joints. The approach bridge consists of two spans, each measuring 59 ft 3 in. between piers. The structure type is a cast-in-place, post-tensioned concrete slab using 5000-psi concrete and four post-tensioning tendons with 14 strands per tendon. The depth of the concrete slab ranges from 2 ft 4 in., measured at the center of the crown at the pier locations, to 1 ft at the crown away from the piers.

The substructure consists of Y-shaped piers supported by 7-ft 2.5-in.-diameter drilled shafts. These piers are smaller than the V-shaped piers of the main-span bridge but use the same family of shapes to create a harmonious ensemble. The Y-shaped piers had similar detailing and construction challenges as the V-shaped piers. The columns are not integral with the superstructure. The design team took a unique approach using a seismic pipe-pin system to maintain a relatively thin superstructure-to-column connection at the approach bridge. The seismic pipe-pin connections were used for the approach bridge column-to-superstructure connection in lieu of integral connections to limit the moment that could be transferred from the columns into the superstructure during a seismic event. A pipe-pin detail similar to one used by the California Department of Transportation and WSDOT was used on this bridge. This detail allows service-level moments, but it does not transfer moment from the columns into the superstructure in a seismic event. During post-tensioning of the superstructure, setting the gaps for the pipe-pins was important to account for both long- and short-term movements.

Conclusion

Despite the many complex design requirements, this bridge will exude a clean, sleek appearance and be a landmark for the Seattle Waterfront. The structure helps unify the waterfront pedestrian routes and ties in with existing structures to the east. The remainder of the existing bridge has been modified to slightly increase the walkable width by about 1 ft 6 in.; this extra width was achieved by replacing the existing railing and concrete curb with a side-mounted, custom stainless steel railing to match the approach bridge railing. In future projects, Alaskan Way will be redeveloped to replace a surface road and include a bicycle path and a park promenade along the seawall. The new linear park will improve access to the docks and activities on the waterfront.

Visit waterfrontseattle.org for more information about the Marion Street Pedestrian Bridge and the planned changes for the Seattle Waterfront.

Don Nguyen is a senior bridge engineer and the bridges and structures sustainability leader and Bethy Clark is the Washington-area bridge and structures lead for HDR Inc. in Bellevue, Wash. Stephen Wilson is a supervisor in the Seattle Department of Transportation structural engineering services group.