A NEW LEGACY
Vancouver Land Bridge
RECONNECTS LAND AND RIVER, PEOPLE AND HISTORY

by Tim Shell and Stephen Whittington, KPFF Consulting Engineers

Over 15 curved and tiered retaining walls support the approach pathways leading to the bridge. Photo: Pete Eckert.

The Vancouver Land Bridge is a landscaped interpretive work of art that reconnects the Fort Vancouver National Historic Reserve to the Columbia River over the six-lane State Highway 14 (SR14) in Vancouver, Wash. One of six art pieces comprising the Confluence Project along the Columbia River Basin, the pedestrian bridge sews together severed lands that once were the end of the Klickitat Trail—a trading center and gathering place for more than 35 Native American cultures. With the project's severe physical constraints, archeological artifacts on site, and a unique design that reflects the tribal heritage of the area, the team faced an array of complex challenges for the winding, cast-in-place concrete structure.

Siting that Respects Past, Present, and Future Concerns

The land north of the project contains the historic Fort Vancouver and Kanaka Village. Archeological excavations on site were completed prior to the start of construction. The bridge and retaining wall foundations were designed to avoid possible artifacts that may lie deeper in the soil.

The chosen site is constrained both horizontally and vertically by competing interests. An operational mainline railroad line just a few yards away runs parallel to the southwest approach. Officials of a nearby municipal airport had concerns over the long-term height impacts of the oak trees, lights, and trellises on the bridge.

The available site was restricted by SR 14 and the BNSF Railroad.

In addition, the bridge placement had to account for a variety of off-ramp alternatives being considered for the future I-5 Columbia River Crossing, a major interstate project of regional significance. (See Page 11.) The land bridge's 23-ft clearance above SR14 was needed to accommodate the future I-5 interchange ramp and helped to raise visitors away from the influence

profile

VANCOUVER LAND BRIDGE / VANCOUVER, WASHINGTON

STRUCTURAL AND CIVIL ENGINEERS: KPFF Consulting Engineers, Portland, Ore.

ARCHITECT AND LANDSCAPE ARCHITECT: Jones & Jones Architecture and Landscape Architecture, Seattle, Wash.

ARTIST: Maya Lin Studio, New York City, N.Y.

PRIME CONTRACTOR: Kiewit Pacific Co., Vancouver, Wash.

AWARDS: *Clark County Community Development, 2008 Community Pride Design; American Council of Engineering Companies, Oregon Chapter, 2009 Engineering Excellence Grand Award; Oregon Concrete and Aggregate Producers Association, 2009 Excellence in Concrete Award; Portland* Daily Journal of Commerce*, Top Project 2008* of the traffic below. The Washington State Department of Transportation (WSDOT) provided invaluable assistance to the team by "bracketing" the range of potential ramp alignments under consideration and helped fit the land bridge into a space that would not restrict future ramp options.

With so many critical issues at stake, the team closely coordinated with the City of Vancouver, WSDOT, the Federal Aviation Administration, the BNSF Railroad, and the National Park Service. Financed through private donations; federal, state, and local funds; and slated for opening in time for the Lewis and Clark Bicentennial, the team was charged with keeping costs down and achieving the aggressive schedule while facilitating the landmark project's unusual construction.

Complex Geometry

The circle represents the life cycle for many Native American tribes, so the designer used this symbol as the basis of the Vancouver Land Bridge's form. The project includes 3100 linear feet of pathway, and the effect creates a serpentine sculpture that meanders through wetlands, culminating in a 190-ft-long, two-span structure curving over the highway. Three overlooks provide views of Kanaka Village, Fort Vancouver, the Columbia River Waterfront, Mount Hood, and the Cascade Mountain Range.

The tight radius and semicircular shape of the bridge met project aesthetic criteria and cost objectives, but eliminated a number of conventional structural options. The team selected cast-in-place concrete for the substructure and superstructure, and developed innovative solutions for the tailored deck and bents.

Reducing the Dead Load

Intended to be an organic extension of its surroundings, hundreds of native plantings line the land bridge. Deep soils were placed on the bridge deck to support the extensive landscaping, which created heavy dead loads. The architect wanted the bridge to appear "slender," gracefully arching over the highway. The engineers had to devise a structural system that could span the six lanes of traffic below, carry significant additional dead loads, and still maintain a slender structure that provided the required vertical clearance above the existing SR14 roadway and the future I-5 interchange ramps. These conditions alone were challenging, however, the designers also had to analyze and model the complexities associated with the unique, tightly curved geometry and variable soil loading patterns.

The design team attacked the challenge two-fold: first, seek creative ways to decrease the dead weight of the structure; and second, optimize the load-carrying ability of the bridge structure through careful analysis and detailing.

Boardwalks made with recycled plastic lumber span wetlands alongside the approach pathway. Overhead steel trellises lend a more personal scale. Photo: Natural Pave Photos.

Meandering pathway leading away from the bridge. The walking surface is decomposed granite with a clear aggregate binder. Colored pavers were laid in symbolic Native American patterns. Photo: KPFF Consulting Engineers.

CAST-IN-PLACE REINFORCED CONCRETE PEDESTRIAN BRIDGE / CITY OF VANCOUVER, OWNER

CONCRETE SUPPLIER: Cemex, Vancouver, Wash.

BRIDGE DESCRIPTION: Curved, cast-in-place, 41-ft 6-in.-wide by 190-ft-long, two-span, landscape pedestrian bridge with a unique "lightweight" foam core deck, shallow longitudinal upturned edge girders, and pier walls with decorative designs

BRIDGE CONSTRUCTION COST: $12.25 million

Forms for checkered basket-weave patterns are attached to deck falsework. Photo: KPFF Consulting Engineers.

The bridge consists of a cast-in-place, voided concrete deck spanning between transverse reinforced concrete deck crossbeams laid out in a radial pattern spaced at an average of 6 ft on center. The deck crossbeams are supported by a pair of upturned cast-in-place, 6-ft 6-in.-deep, concrete edge girders to create a U-shaped cross section. The horizontally curved edge girders are continuous and frame into end abutments and intermediate pier walls founded on spread footings.

Reinforcing in place for deck soffit and radial crossbeams. Rigid foam was placed between crossbeams after the soffit was cast.

The tightly curved bridge precluded the practical use of precast or post-tensioned concrete. Steel girders with precast cladding panels were also considered. However, this option was eliminated due to long-term maintenance and inspection concerns associated with the multitude of connections required. The team selected conventionally reinforced concrete as the preferred structure type. Maintaining the thin structure depth required by the architect while using nonprestressed methods became one of the key challenges for the structural design.

The team plucked the "low-hanging fruit" first. The landscape architect was able to locate and specify a lightweight landscaping soil to be used in lieu of standard planting soils. This reduced the soil weight by approximately 50%. Next, the bridge designers developed a voided deck system consisting of foam cavities cast into the deck. Approximately thirty-five 36 ft by 4 ft by 13 in. rigid foam panels were custom-fitted and secured between the transverse deck crossbeams (horizontally) and between the bottom and top deck sections (vertically).

Furthermore, the bridge designers created detailed 3-D finite element computer models of the continuous, curved structure to optimize the structural elements. The upturned edge girders were analyzed and detailed for complex flexure and shear effects in combination with significant torsional loads generated by the bridge's unusual geometry. By accurately modeling these complex effects, the designers were able to detail the most economical reinforcing layout and minimize the members' depths. Significant deck detailing, especially in high torsion and negative moment regions was used to keep the members as small and light as possible.

The longitudinal concrete edge girders were "upturned" in order to help increase the clearance above the highway and to serve the added function of retaining the 3-ft to 4-ft depth of landscaping soils placed along the sides of the pathway across the bridge. Turning the girders upward also helped enhance the visual and acoustic separation from the traffic below.

Girders and Abutments Perform Dual Functions

The bridge's curved plan and nonparallel approaches created unique loading conditions at the support piers. Computer models including soil springs were developed to evaluate the structure's complex behavior under both gravity and seismic loads. Understanding how changes to the design affected torsion loads, lateral earth pressures, and bridge deflections were key to successfully optimizing the bridge's design and construction, as well as providing a durable structure with decreased long-term maintenance costs.

Special decorative formliner finishes were cast into certain concrete surfaces to convey the site's Native American heritage to motorists passing beneath. Intricate basket weave patterns were formed into the abutments and bridge soffit.

Curved Retaining Walls

The curvature of the path demanded special attention to achieve the desired effect. The team designed over 15 separate

Environmental Considerations

The bridge was designed to capture all rainwater runoff. A slight cross slope in the pavement surface directs excess storm water into thin channels along the edges of the pathway. On one side of the bridge, the channel leads to a rain garden and a dry well to infiltrate slowly into the ground. On the other side, the water collects in a manmade creek and inlet that lead to an underground storage pipe, which stores the water to irrigate the bridge's landscaping. A shallow groundwater well fed by the Columbia River aquifer will supplement the irrigation system during dry periods until the plants become established. The use of indigenous plants for the landscaping also reduces the need for irrigation.

In addition to incorporating innovative sustainable water quality measures into the design, the team included water meters to quantify the amount of storm water reuse compared with well-water use, and to measure their effectiveness. These meters will provide invaluable data on the performance of different types of sustainable water treatment and reuse measures.

Basket-weave pattern on bridge soffit.

retaining walls reaching up to 25 ft tall in order to satisfy architectural requirements and enable constructability within the limited available space. Each horizontally and vertically curving wall followed its own unique alignment while still needing to tie into its neighboring wall. This required multi-dimensional thinking and extensive detailing.

To maximize landscape space within the constricted project area, the design team made creative use of stepped structural mechanically stabilized earth (MSE) retaining walls with concrete formliner facings. The architect wanted to minimize the joints in the exposed walls' faces, therefore the team decided against conventional, segmented precast concrete MSE wall panels. Instead, a cast-in-place concrete facing was used on the front side of the MSE walls and the contractor successfully cast the full height of the wall facings in a single placement with no horizontal joints. Full-height precast concrete wall panels were also considered. However, they proved to be less practical and more expensive for the higher walls. The project also incorporated a series of curved cast-in-place concrete cantilever and soil-nail retaining walls, all designed to blend and integrate together.

The Vancouver Land Bridge leaves a new legacy, one that links the visitor with the Native American cultural history of the site, commemorates the bicentennial of Lewis and Clark's journey West, and restores a community connection between Fort Vancouver and the Columbia River.

Tim Shell is an associate and Stephen Whittington is a structural engineer at KPFF Consulting Engineers in Portland, Ore. Shell was project manager and Whittington was structural engineer on the Vancouver Land Bridge.

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

AESTHETICS COMMENTARY

by Frederick Gottemoeller

The Vancouver Land Bridge is a too-rare example of a crossing that is conceived as an integrated extension of a larger landscape. The bridge and the approach ramps follow a single sweeping curve. The wing walls peel away from of the main curve to follow the contours of the approach embankment. The embankment in turn blends into the natural slopes of the site. The landscape itself crosses the bridge in the edge planters. There are no obvious dividing lines between bridge and ramp or between ramp and site. The site and crossing are a single piece. It is the same quality that Frank Lloyd Wright aimed for in his "organic" architecture.

The users' experience reflects that. As they approach the crossing, they are attracted onto a ramp that appears to be a natural extension of the landscape. They cross the highway with landscape planting buffering them on both sides, then descend again into the landscape. The patterns on the walls and paving engage users interest and at the same time educate them about the site. The covered overlooks and benches recognize the common human desire to pause and enjoy the view, to rest a moment and absorb what has been seen. The experience is as seamless as the crossing itself.