CUSTOM ARCHES

by James N. Bollman,
OBEC Consulting Engineers

The NW Maple Avenue Bridge in Redmond, Ore., features three continuous cast-in-place 210-ft-long arch spans, each of which is different to conform to the contours of Dry Canyon below.

Three cast-in-place arches with different shapes conform to Oregon canyon, adding beauty and functionality

The twin arches support bent and spandrel columns and the double-tee deck.

The NW Maple Avenue Bridge provides an east-west link for the city of Redmond, Ore., across Dry Canyon, which bisects the city. The canyon is a scenic natural feature, providing open space and recreation to local citizens. The designers and the construction team were challenged to design and build a bridge that could blend with its natural surroundings while satisfying current and future needs.

City officials desired a bridge that was affordable, functional, aesthetically pleasing, and capable of being efficiently widened in the future as needs required. To meet these needs, the designers created a cast-in-place structure featuring three continuous 210-ft-long arch spans and two 75-ft-long post-tensioned approach spans. Each arch has a distinct contour so the arches together conform perfectly to the sloping topography of the canyon floor.

A very wide range of crossing configurations was considered, from a sag-vertical curve on fill to a single-span arch. The fill was deemed inappropriate and inconsistent with the goals of the canyon, but city officials asked that the design be given at least a cursory investigation to determine a baseline cost.

Design Options

Bridge options that made the final cut for consideration were a five-span bulb-tee girder, a single-span arch bridge with half-arch approaches at each end, and the three-span arch that was selected. It offered the best combination of aesthetics, economy, and scale for the site. City officials were particularly interested in the potential to achieve a "landmark" bridge appearance if they could obtain it for only a modest cost premium.

In terms of materials, steel was considered but was ruled out because it was not competitive from a life-cycle perspective. Precast concrete was determined not to offer the best solution because there would not be many repetitive structural elements.

profile

MAPLE AVENUE BRIDGE / REDMOND, ORE.

ENGINEER: OBEC Consulting Engineers in conjunction with Jiri Strasky, Consulting Engineer, Eugene, Ore.

PRIME CONTRACTOR: Cascade Bridge LLC, Vancouver, Wash.

CONCRETE SUPPLIER: Central Oregon Redi-Mix LLC, Redmond, Ore.

***AWARDS:** 2008 Portland Cement Association Bridge Award*

Only the arch ribs were identical across the bridge, although they vary from span to span along the ribs. This lack of repetition meant that the production efficiencies offered by precast concrete would not be utilized well.

The columns support a double-tee deck section, with the tee stems matching the spacing of the arch ribs.

Substructure

The arch consists of two side-by-side ribs. Each rib is fixed to the footings at the ends of the three-span series, while pinned to and continuous across the intermediate footings. This arrangement allows the ribs to appear to touch lightly on the canyon floor. All substructure elements are slender in the dimension most visible in an elevation of the bridge.

Bent columns are located at each arch rib support, with spandrel columns placed midway between the arch supports and the composite crown segments. The columns are monolithic with the superstructure tee-beams and arch ribs or footings. The columns were designed as slender members in the direction along the bridge and wide members transverse to the bridge, creating unbraced, rigid transverse frames.

Spandrel columns and bent columns are architecturally similar, with the slender dimensions relative to height nearly constant for both types. At the bents, each column pair appears as one column architecturally but functions as two columns, with one of the pairs located on each side of the transverse deck joint. The twin columns provide little longitudinal restraint as they deflect elastically in response to the thermal length changes of each span.

Superstructure

The columns support a longitudinal cast-in-place double-tee deck section, with the tee stems matching the spacing of the arch ribs. The typical deck section for the arch spans continues across the approaches, where the longer spans of the shallow beams necessitated post-tensioning.

The arch ribs are monolithic with the tee-beams for a 50-ft length at each arch midspan. Seismicity at the site is low, so the transverse frames and composite crowns provide the necessary transverse resistance. Deck expansion joints were placed at each interior bent and at the abutments, where the beams are supported on bearings. Intermediate deck diaphragms, transverse beams, and transverse arch braces were not used, contributing to the structure's openness and clean lines.

At the bents, each column pair appears as one column architecturally but operates as two columns functionally, with one of the pairs located on each side of the transverse deck joint. All photos: OBEC Consulting Engineers.

Construction

Preparing the site for work consisted primarily of scaling loose basalt blocks from the canyon walls and relocating utilities along the bridge corridor. The site presented no particular environmental challenges, alleviating the contractors of those concerns. A staging area in a treeless region next to the bridge was used. Access to the canyon was gained via an existing cut into the canyon's wall face approximately one mile from the bridge site. The staging area was accessed via a temporary road along the canyon floor from the cut.

Stage dead-load sequencing was checked using a finite-element analysis. No temporary ties or longitudinal bracing were necessary to resist transient load conditions from stage loading, other than those for conventional falsework. All transient load conditions were accommodated by construction sequences that cost little in construction efficiency.

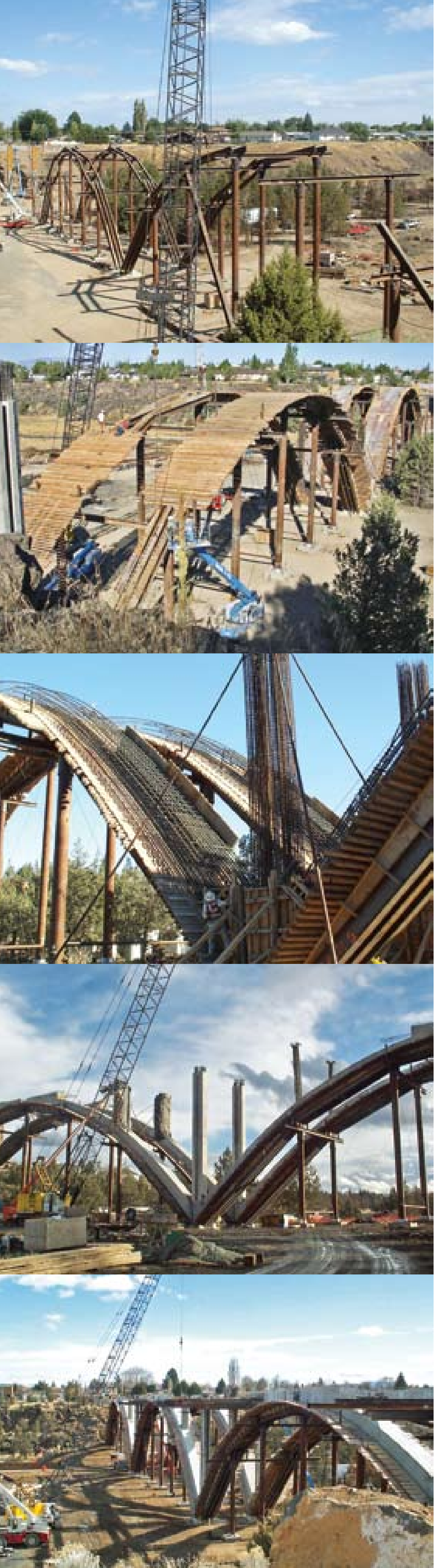
The construction used fairly typical falsework and forming, with the obvious exception that unequal concrete levels in the rib halves cast from the base toward the crown of each span introduced unbalanced lateral load into the falsework system.

Transverse temporary x-bracing between the two rib lines was required to reduce the unbraced length for the out-of-plane buckling until the deck was cast and cured. This bracing was planned and detailed in the bid documents, but subsequent superstructure falsework design was not completely coordinated with the bracing design. The bracing was then modified slightly to accommodate the falsework.

THREE-SPAN, CAST-IN-PLACE ARCH BRIDGE / CITY OF REDMOND, OWNER

BRIDGE DESCRIPTION: 780-ft-long cast-in-place bridge featuring three continuous 210-ft-long deck arch spans of different shapes

BRIDGE CONSTRUCTION COST: Superstructure \$76/ft²; Substructure \$78/ft²



The series of photos illustrates the construction sequence including arch falsework, arch forms, arch columns, and deck falsework.

The ribs were precompressed with hydraulic jacks placed in jacking frames at openings at the rib crowns. This compensated for the second-order load effects in the arch ribs and longitudinal beams from displacements in the foundations during development of the foundation resistance. Jacking occurred at an optimum step in the construction sequence, with the jacking frames cast into a closure placement at the crowns.

The bridge incorporates several pedestrian-scale features designed for compatibility with the recreational use of the canyon area. Overlooks are located at each abutment, allowing pedestrians to step off the sidewalk to enjoy the canyon's scenery. Similar areas are provided at the interior bents of the arch spans.

Raised cantilever sidewalks on each side have tubular steel rails. The rails meet the strength requirements for both vehicles and pedestrians while allowing freedom of view for all bridge users. Recessed step-lights concealed within the rail bottom tube provide low-level sidewalk lighting.

The open rail also facilitates an accurate perception of the superstructure depth when the bridge is viewed from the side, adding to the slender and graceful appearance. The design offers a majestic presence both from a distance, with its sleek, flowing arches, and from close up, where visitors can admire the canyon and the careful way that the new Maple Avenue Bridge fits into its surroundings.

James N. Bollman is senior bridge engineer, OBEC Consulting Engineers, Eugene, Ore.

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

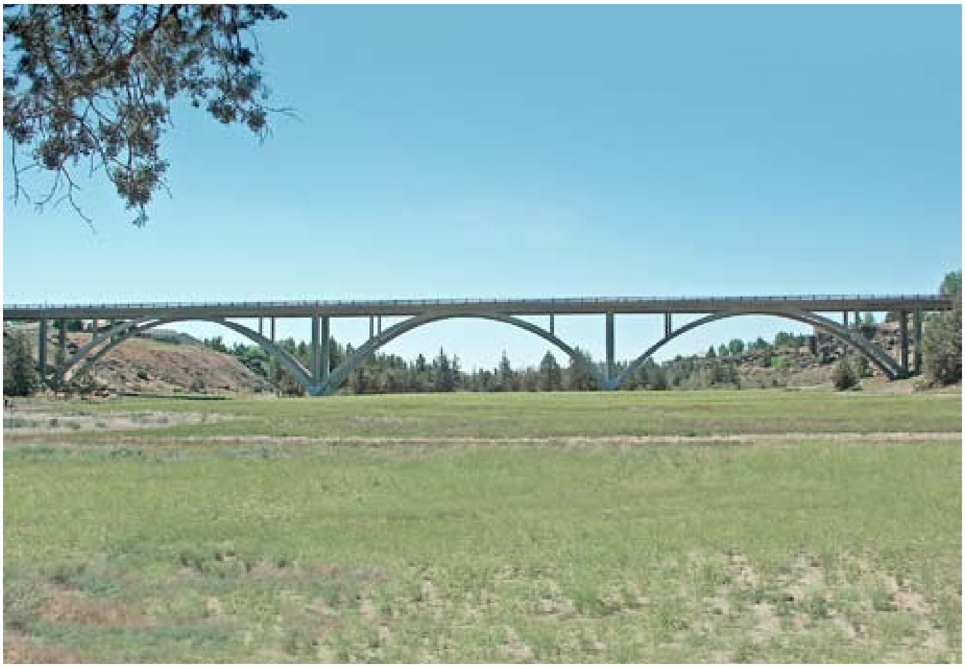
AESTHETICS **COMMENTARY**

by Frederick Gottemoeller

In the last issue, I quoted the renowned twentieth century architect Mies van der Rohe's famous dictum, "Less is More." This time I'd like to quote another of his famous sayings, "God is in the Details." On the Maple Avenue Bridge, one has only to look at the proportions of the joint where the arch ribs, bent column, and bearing come together to see what van der Rohe was driving at. The arch ribs appear to narrow to almost a single point as they reach the bearing. The bridge seems to barely touch the ground. That feature alone gives the whole structure an incredible lightness of being.

However, the same kind of attention is applied to the spandrel columns, the bracing, the railings, and all of the other features of the bridge. Each part has an elegant slenderness and simplicity. Each is smoothly and logically connected to the others. Every element appears competent to do its job without wasted effort or materials, giving the whole structure a sense of calm transparency. This bridge really does deserve that often-stated praise: it lies lightly on the land.

Achieving this result required a lot of sophisticated engineering. It is good to see such engineering being done in the service of visual goals, not just cost reduction. Calling the bridge a "signature bridge" creates the impression that only the rare structure deserves this attention to detail and to visual goals. Actually, all bridges deserve that attention. It ought to be a standard part of bridge engineering. Then we wouldn't have to identify "signature bridges," because they would all be signature bridges.



NW Full Elevation.

Under Deck.

Maple Avenue Bridge
Deck 1.

Jack System.