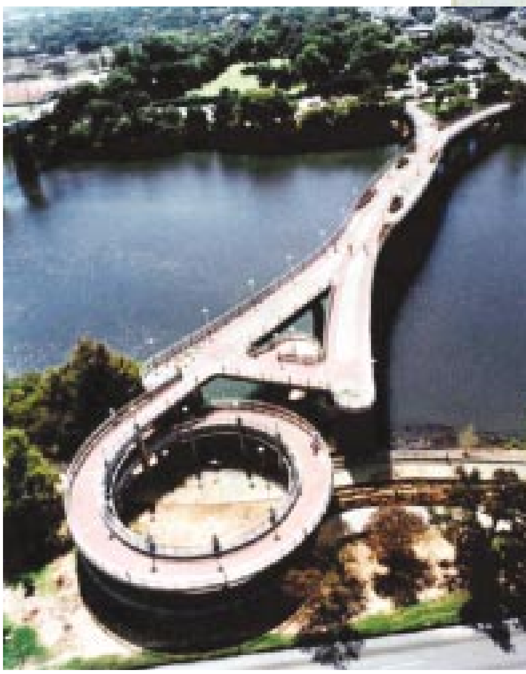


Photo courtesy White Photographic Services.

Cool Curves

Domenic Coletti, P.E., Jeff Curren, P.E. and Kalpana Sutaria, AIA

Crossing Town Lake in Austin, TX, the Pfluger Bridge's graceful curves are supported by plate girders fabricated from weathering steel.

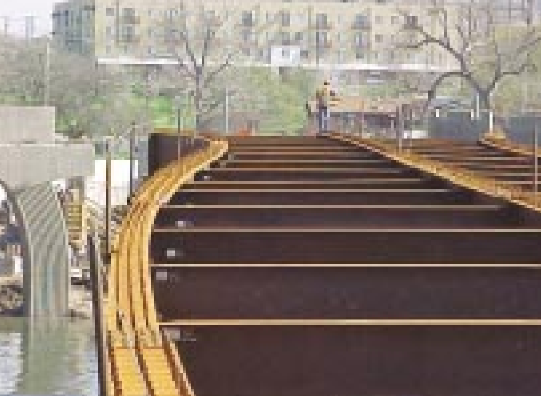
With its population soaring nearly 40% in the last 10 years, the City of Austin, Texas, needed an improved facility for crossing popular Town Lake and providing the city's many walkers, runners and bicyclists with a structure to meet their needs.

The existing Lamar Boulevard Bridge, a six-span concrete deck arch bridge built in 1940, features elegant Art Deco detailing and is historically significant to the area. The bridge's drawbacks were its 10-foot traffic lanes and narrow sidewalks. The City of Austin opted to design and build a new, stand-alone crossing of Town Lake adjacent to the existing bridge.

One of the most innovative and intriguing concepts proposed in a May 1998 public design idea workshop was the "Double Curve" concept, developed by a group of five workshop participants. The concept featured two curved alignments crossing over each other at Town Lake, and the curved theme was echoed in the design of the structure itself.

CHOOSING STEEL

Several structural systems—including cast-in-place, post-tensioned concrete box girders; precast segmental concrete box girders; and solid or voided cast-in-place, post-tensioned slab structures—were initially considered for the superstructure. However, the need for quick, simple design—combined with the overriding criteria of ease of constructability over the lake, ability to easily conform to geometric complexities and low construction cost—quickly led the engineering team



The unique reverse curvature of the exterior girders on the main river crossing unit resulted from the implementation of the "Double Curve Alignment" concept, which gives this bridge its unusual hourglass shape.

to select steel plate girders as the best possible choice for the superstructure system. The architect requested use of weathering steel to provide an "organic" or "natural" appearance to fit with the wooded shorelines of Town Lake and to minimize future maintenance costs.

The relatively tight construction budget led to the basic theme for the engineering design of the bridge: conventional materials and techniques used in unconventional manners. The engineering team set out to produce a set of plans closely resembling those for a major steel plate girder highway bridge. The scale of this structure and the selection of steel plate girders as the main structural system made it clear that only heavy highway bridge contractors would be bidding on this project. In order to obtain competitive bids, the engineering team had to produce plans that would look familiar to these contractors to give them confidence in their understanding of the project for bidding.

FRAMING PLAN

The double curve alignment resulted in an unusual plan for the bridge. At the south end, two ramp structures curve toward each other. The southwest ramp is a two-span continuous unit (Unit A, 86′-120′), while the southeast ramp consists of two single-span units (Units B and C, 48′ and 111′, respectively). Units A and C each utilize three concentric, horizontally curved composite plate girders. Unit B utilizes three concentric, horizontally curved composite rolled beams. Unit B has a relatively short span, allowing the use of rolled beams to achieve a shallow superstructure depth, required to maintain adequate vertical clearance over the hike and bike trail below. Units A, B and C are relatively narrow (for this structure), with a total out-to-out width of 23′.

Units A and C meet at Interior Bent 3 and the bridge continues out over Town Lake on Unit D, a three-span continuous steel plate girder unit (114′-114′-114′). Unit D has variable width (minimum width of 31′-3″; maximum width of 42′) and utilizes a very unusual hourglass framing plan. Unit D ends at Interior Bent 6, where two ramps split off to the northeast and the northwest.

Unit E is a triangular unit consisting of Span 6W (104′ span; 21′ width), a single span unit curving from Interior Bent 6 to Interior Bent 7W to the northwest; Span 6E (109′ span; 26′ width), a single span unit curving from Interior Bent 6 to Interior Bent 7E to the northeast; and Span 6X (49′ span; 18′ width), a single span unit spanning between support brackets on the exterior girders of Spans 6W and 6E. Spans 6W and 6E each utilize three concentric, horizontally curved composite plate girders, while Span 6X utilizes three tangent composite rolled beams. The use of relatively shallow rolled beams in Span 6X was possible due to the comparatively short span length.

Provisions were made at Interior Bent 7E for a future ramp running to the northeast toward the existing Seaholm power plant, which is planned to have a future public facility. Interior Bent 7E also serves to support a short-span, conventionally-reinforced concrete slab and beam span that links Span 6E to the Helix Ramp, a conventionally-reinforced helical ramp structure.

Units A, B, C and E utilize framing plans and design and construction techniques indistinguishable from those used in typical highway bridge construction. Beyond their unique pedestrian live load criteria, these bridges are identical to their highway bridge brethren.

The unique framing plan of Unit D – with a tangent center girder and two exterior girders with both reverse and opposing horizontal curvature – derives from its unusual hourglass plan. At first glance, the exterior girders might appear extremely difficult to analyze, but actually the symmetry of the framing plan negates most of the global overturning usually associated with curved girders and they can be analyzed as tangent girders with additional lateral flange bending stresses added in by hand using the simple lateral flange bending moment equation of the V-Load method. This is exactly what the engineering team did for the preliminary design of the Unit D exterior girders. This approach proved quite successful, and these preliminary designs exhibited excellent correlation with the results of a later, detailed 3D finite element analysis performed using the proprietary BSDI 3D System computer modeling service.

DIAPHRAGM DESIGN

Given the variable girder spacing in Unit D, the detailing of diaphragms warranted special attention during the design process. The engineering team initially examined several options, including plate diaphragms, rolled beam diaphragms, X-frames, W-frames and K-frames.

Frame diaphragms, the most typically used in highway bridge design, would have been cumbersome because of the variable girder spacing – a 12′-4″ minimum to a 17′-9″ maximum – in Unit D. With such wide girder spacings, the diagonals of X-frames or K-frames would have inefficiently shallow angles from horizontal. Similarly, W-frames would either have shallow diagonals or require multiple W's to span between the girders. Combined with these inefficiencies, there would have been virtually no identical diaphragms anywhere in Unit D (because of the 15 degree skew, half of the commonality due to symmetry was also lost).

As a result, the engineering team selected rolled beam diaphragms. In addition to eliminating problems with inefficient diagonal angles in the frame options, rolled beam diaphragms also offered substantial advantages in fabrication. Instead of developing jigs for many different frame diaphragms, the fabricator simply cut rolled sections to the lengths needed for the variable girder spacing. To reduce weight and keep the diaphragm stiffnesses reasonable, shallow rolled beams were selected for the diaphragms. The difference between the diaphragm depth and the depth of the girders was made up using a simple curved gusset detail at the ends of the diaphragms.

Conventional curved steel plate girders were assembled in unique configurations to create a striking appearance using cost-effective conventional components.

BIDDING AND CONSTRUCTION

Groundbreaking occurred on May 15, 2000, and the bridge was completed ahead of schedule on June 16, 2001. The smooth construction procedure was a testament to the philosophy followed in preparing the bridge plans.

Kalpana Sutaria, A.I.A., was the City of Austin's Project Manager for the Pfluger Bridge project. Jeff Curren, P.E. and Domenic Coletti, P.E., both of HDR Engineering, were the lead bridge engineer and a bridge project engineer for this project, respectively.

OWNER
City of Austin, TX

ARCHITECT
Kinney & Associates/Carter Design Associates, Austin, TX

STRUCTURAL ENGINEERS
Main Bridge
HDR (project management, Austin, TX office; bridge design, Dallas lead office with support from Omaha, NE and Tampa, FL offices)

Helix Ramp
Jose I. Guerra, Inc. Austin, TX

STEEL FABRICATOR
Hirschfeld Steel, San Angelo, TX (AISC member)

ENGINEERING SOFTWARE
BSDI 3D System, LARSA

DETAILING SOFTWARE
AutoCAD plus in-house software