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Bridges

Steel Pipe Trusses

Innovative Bridge in Arizona to Carry Light Rail

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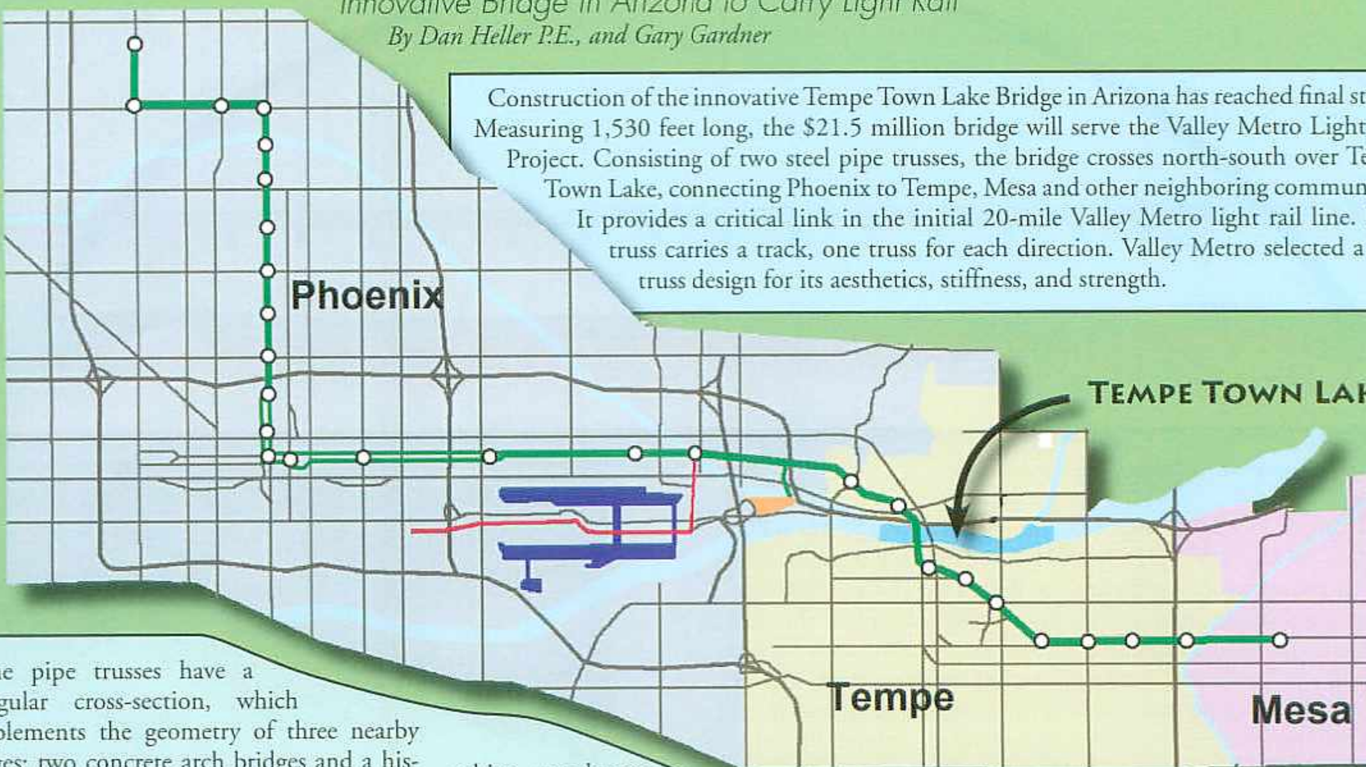

Construction of the innovative Tempe Town Lake Bridge in Arizona has reached final stages. Measuring 1,530 feet long, the $21.5 million bridge will serve the Valley Metro Light Rail Project. Consisting of two steel pipe trusses, the bridge crosses north-south over Tempe Town Lake, connecting Phoenix to Tempe, Mesa and other neighboring communities. It provides a critical link in the initial 20-mile Valley Metro light rail line. Each truss carries a track, one truss for each direction. Valley Metro selected a pipe truss design for its aesthetics, stiffness, and strength.

The pipe trusses have a triangular cross-section, which complements the geometry of three nearby bridges: two concrete arch bridges and a historical railroad bridge of rectangular cross section built in 1912. The new light rail bridge resides just 50 feet from the railroad bridge, which belongs to the Union Pacific Railroad.

Innovative Design

The general engineering consultant (GEC) and Valley Metro Rail originally presented three designs for the bridge, based on community discussions, for public review. The State Historic Preservation Office rejected the first design selected. The design firm TY Lin, along with Seattle artist Buster Simpson, subsequently developed a new final design concept — an innovative, continuous, 11-span triangular steel pipe truss for each track direction. All parties enthusiastically endorsed this novel design.

Detailed design for the bridge then commenced, finishing a year later in July of 2004. The bridge follows AASHTO Load Factor Design guidelines, using 50+ ksi yield strength steel pipe. The resulting shallow, stiff superstructure fits well with the existing bridge structures and provides an aesthetic gateway to the City of Tempe. A computerized system controls light emitting diodes that run down the center of each truss. A white, translucent (steel mesh) scrim that covers the sides of the truss will reflect and transmit colored light, which will chase the train as it passes across the bridge.

Figure 1 shows the basic geometry of the bridge in cross section. A 24-inch diameter steel pipe with a 1-inch wall thickness forms the bottom apex of each triangular truss. Two 18-inch diameter steel pipes about 5 feet apart lie at the top vertices of each truss, directly under a track rail. Wall thicknesses of these pipes vary, depending on whether the truss is in a positive or negative loading configuration. A series of four 10-inch diameter steel pipe braces, 880 in number, run diagonally upward from a steel saddle on the bottom pipe to saddles on the two pipes above, creating the truss. Spacing of the bottom saddles ranges from about 10 to 15 feet between longitudinal centers. Truss segments between piers range from about 75 to 160 feet long.

Horizontal 8-inch pipes, positioned directly above the bottom pipe saddles, connect the two upper pipe chords. The lighting system hangs from these pipes. Tubular cross-diaphragms, located at both abutments and at the nine piers, interconnect the parallel trusses. Disc bearings, two on each abutment and two atop each pier, control bridge movement.

The cylindrical piers look like they've been "wood chopped" at top center, forming a "Y". The bottom pipe of each truss rests on an arm of the Y (*Figure 2*). All the piers accommodate expansion except pier five in the center. Total movement for expansion at each abutment is about five inches. A 46,000 sq-ft continuous concrete deck poured within stay-in-place decking forms the tops of the two trusses, providing a 30-foot width for the two tracks and emergency walkways. Depth of the truss is 9.25 feet and the overall depth is 11 feet

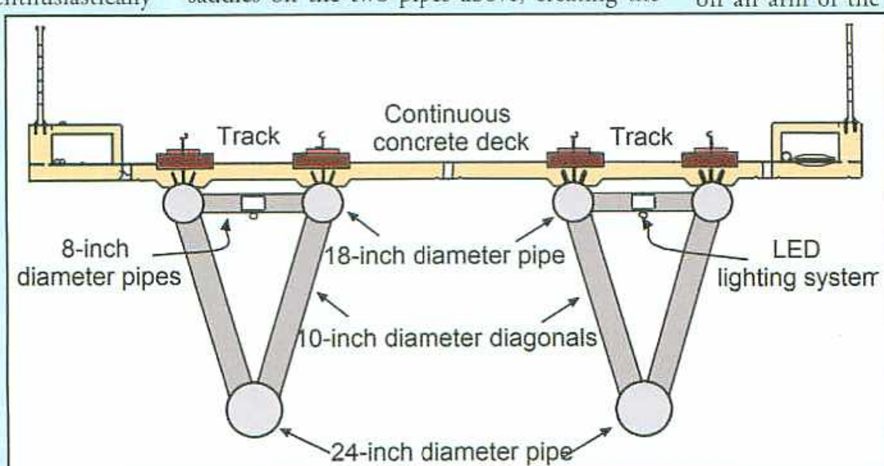

Figure 1: Triangular pipe truss design topped with continuous concrete deck over the two trusses

Figure 2: Bottom pipe of each truss rests on arm of "wood-chopped" Y-shaped pier. Tubular diaphragm connects the two trusses at each pier

to the top of the rail. TY Lin contracted with a local fabricator to create a full-size mockup of a truss section, including lighting, which is shown in *Figure 3*.

Truss Fabrication

Stinger Welding, Inc. (Coolidge, AZ) fabricated the trusses. Design engineers for the project offered fabricators the opportunity to make comments and recommendations about welding processes, filler metals, joint configurations, and inspection before the plans and specifications were written, and before the project was let to bid. Stinger Welding's engineering and quality assurance groups contributed significant information that resulted in a more reliable structure that was easier to fabricate.

Stinger assigned 50 welders, tested and certified per AWS/AISC specifications, to this project. The firm completed fabrication within the required six months, including time awaiting delivery of material.

The pipe connections, all of which are full penetration welds with inspection by visual and ultrasonic non-destructive testing, numbered in the thousands. The diagonal truss members (*Figure 4*) required 1,760 welds. Cross members connecting the two 18-inch pipes required another 880 welds. Flanges welded to pipe (200) at the ends for splicing truss sections further increased the weld count. Each weld is highly documented. Every piece of pipe is associated with a heat trace number and a cut program.

Specifications initially called for ASTM A618 pipe, which turned out to be unavailable in the required time frame. Bidders requested options for American Petroleum Institute pipe rated at 52 ksi yield strength. Despite the applicability of Buy America laws (the bridge includes federal funds), two pipe size and wall thickness combinations were not available from domestic sources. So these two sizes of steel pipe ultimately came from the U.K. and India (with FTA approval).

Cutting the diagonals within 1/16 inch accuracy proved to be a geometric nightmare. The centerlines of the diagonal pipes are offset from the centerlines of the top and bottom pipes. Of the 880 diagonal pipes, 722 were different. Because of the complexity of the diagonal pipe cuts, Stinger integrated specialized Tekla CAD software, a firmware interface, and Vernon CNC thermal cutting equipment for this project.

Figure 4: A certified inspector checks out full penetration welds of diagonals on bottom-pipe saddle while the welder looks on

This system (*Figure 5*) simultaneously cut and rotationally aligned the asymmetric "fish mouth," at each end of a diagonal within 0.5 degree; beveled the included welding angle; and, cut each to length with the allowance for tool openings with 0.05 inch clearance tolerance. Fabricating this structure within the timeframe and budget would not have been possible without such a system.

Stinger performed extensive tests on the steel pipe. Impact testing is not commonly required in Arizona because of its mild temperatures, but over water, the steel can radiate heat and can reach relatively low temperatures. Since Stinger was using uncommon weld fillers and fluxes, the firm checked the steel for Charpy impact down to 0 degrees F for verification of safety, and as a form of inexpensive insurance.

Since the maximum material yield strength requirement for all members in the structure was 52 ksi, both carbon steel and low-alloy filler metals having 58 ksi minimum yields were acceptable. Although preheating requirements were minimal, Stinger selected low-hydrogen materials for their consistently high-quality welds. These materials become economical when considering the resulting reduced inspection and rework as well as improved reliability and safety.

Figure 3: Fabricated full-size mock-up of design with lighting system

continued on next page

Figure 5: Computer-controlled system cuts the diagonal pipe "fish mouths"

Workers hand blasted the truss sections prior to painting. The trusses contain many angles and brackets plus studs for the concrete deck and for hanging the mesh scrim. The initial coat consisted of a minimum two mils DFT epoxy-based zinc-rich primer. Originally, the firm was to apply a primer and topcoats, but the trusses became marked up during shipment and handling. At that point, the contractor decided to apply the white top coats in the field.

Constructing the Bridge

Inflatable dams create Tempe Town Lake, which ranges from 10 to 15 feet deep. Drilled shafts for the piers run through another 10 to 15 feet of clay beyond the lake bed, and into about 10 feet of rock.

The town did not permit draining the lake, so PCL brought in barges with cranes and tugboats to implement pier construction. Pumpers "leapfrogged" concrete from barge to barge to the pier sites. The contractor used metal forms to create the arms of the pier. The color of the piers matches that of the nearby railroad bridge.

Figure 7: Each splice of two truss segments required 94 bolts

Truss sections from the fabricator that arrived at the site ranged in length from about 75 to 160 feet long. Workers added stay-in-place forms to the top of the truss section in the field. For erection over the lake, the contractor bolted multiple sections together on the barges before lifting the spliced sections into place.

During erection, a truss section already in position overhung the pier. Two barge cranes lifted the succeeding section, resting one end on the next pier while workers bolted the other end to the truss already in position. They bolted the three main pipe flanges plus the flanges at the midpoint of the diagonal pipes, using 94 high-strength bolts per splice tensioned to slip critical requirements. Next the contractor bolted the adjacent parallel truss into position and installed tubular diaphragms between the two trusses at the piers. Workers added the scrim, lighting system, and final paint coats later. Caps on the truss ends at the abutments prevent someone from climbing up and walking through the truss.

Valley Metro plans to open the entire 20 mile starter segment of the light rail project by December 2008.▪

Figure 8: Aerial view looking north as cranes on barges proceed with bridge construction

OWNER:
Valley Metro Rail
www.valleymetro.org/rail/

CONTRACTOR:
PCL Civil Constructors, Inc.
www.pcl.com

DESIGN ENGINEERING:
T Y LIN
www.tylin.com

FABRICATOR:
Stinger Welding, Inc.
www.deckjoint.com

ARTIST:
Buster Simpson
www.bustersimpson.net

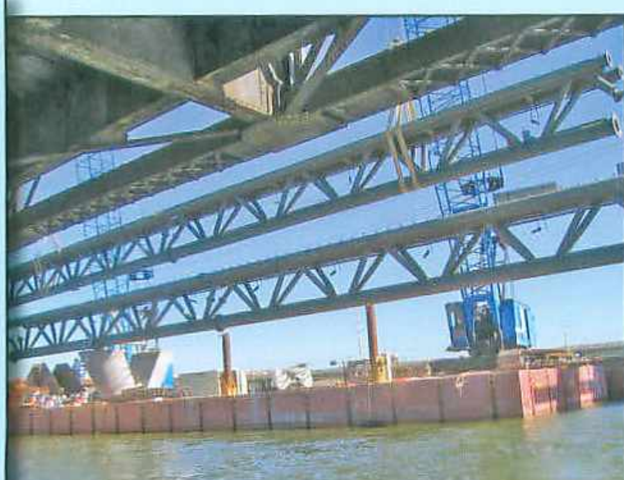

Figure 6: Two cranes on barges lift spliced truss segment into place on pier

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