Phoenix Sky Harbor
TRANSIT GUIDEWAY BRIDGE

by David A. Burrows, Gannett Fleming

The evolution of the PHX Sky Train's crossing of Taxiway "Romeo"

At one of the 10 busiest airports in the United States, cast-in-place, post-tensioned concrete was used to provide superior value, meet an aggressive construction schedule, squeeze into a tight construction corridor, and accomplish the world's first transit crossing of an active aircraft taxiway.

Taxiway "R" looking north showing removal of end span falsework. Photo Rights: Hensel Phelps Construction Co.; Photo Credit: Visions in Photography.

The Phoenix Sky Harbor International Airport is constructing the PHX Sky Train™, a 5-mile-long automated transit system that will run through and connect key existing and future airport facilities with strategically located stations at terminals, parking areas, ground transportation centers, Metro Light Rail, and the Rental Car Center. The development of this system requires several very unique design features. The lead designers and the Aviation Department developed a predominantly elevated train alignment that offered the most economical facilities and the best level of service for station connections to airport facilities.

The construction of the PHX Sky Train will be implemented in two stages to spread the overall capital costs. Stage 1 is currently under construction with a planned opening in early 2013. Stage 2 is still in conceptual design development and is scheduled for opening in 2020. Stage 1 consists of three stations and 12,000 linear ft of guideway, of which 9000 ft will be elevated. One of the biggest challenges to Stage 1 was the crossing of Taxiway Romeo (Taxiway "R"), the first time in the world that a transit system would cross over an active taxiway. In fact, the taxiway itself crosses over Sky Harbor Boulevard, thereby putting planes, trains, and automobiles all within close proximity.

Design Constraints

The main span of the bridge is 340 ft long and 75 ft above the taxiway in order to provide the clearance required for Group V Aircraft. Additionally, to stay below the ceiling established by the Federal Aviation Administration for safe aircraft operations, the height of the bridge was limited. Thus, a narrow vertical band approximately 40 ft deep remained within which the bridge could be built. Equally daunting to the geometric constraints was the task of constructing the bridge above an active taxiway, which could only be shut down for a short period of 2 months.

In 2007, a selection process was begun to determine the structure type that would best meet project objectives, while minimizing impacts to airport operations, facilities, and security and meeting or exceeding established design criteria. Because of advantages in constructability, maintenance, serviceability, inspection, and total life-cycle cost, a precast concrete segmental box girder was recommended. Evident from a drive on metro-Phoenix's freeway system, concrete box girders are a popular choice. They require little maintenance and only routine inspection and thus have a reduced life-cycle cost. Aesthetically, the box girder was the most streamlined and least obtrusive choice, fitting nicely with surrounding concrete structures and adjacent guideway.

Cast-in-Place Box Girder Selected

After preliminary design of the precast concrete segmental box girder was completed, the contract for construction manager at risk was awarded. Then began an investigation into reducing the projected $10.5 million construction

profile

TAXIWAY "R" BRIDGE/ PHOENIX SKY HARBOR INTERNATIONAL AIRPORT, PHOENIX, ARIZONA

BRIDGE DESIGN ENGINEER: Gannett Fleming, Phoenix, Ariz.

CONSTRUCTION MANAGER AT RISK: Hensel Phelps Construction Company, Phoenix, Ariz.

SUBCONTRACTOR, PIERS AND SUPERSTRUCTURE: Austin Bridge & Road, Phoenix, Ariz.

SUBCONTRACTOR, DRILLED SHAFTS: Case Foundation Company, Tempe, Ariz.

CONCRETE SUPPLIER: CEMEX, Phoenix, Ariz.

The world's first transit crossing of an active aircraft taxiway.

cost. The initial restriction to a taxiway shutdown period longer than 2 months was extended to 6 months based on the Aviation Department's ability to divert traffic to two parallel taxiways crossing Sky Harbor Boulevard. The shutdown timing was an additional factor to be managed. Due to seasonal traffic volumes, closure had to occur between Spring Break and Thanksgiving. If this window was missed, it would delay the construction of the bridge thus delaying the entire project.

Once the longer closure time appeared possible, several other advantages for a cast-in-place concrete option became apparent: the cost and difficulty of transporting precast segments would be eliminated, or a large staging area near the taxiway to cast segments on-site would not be needed, end spans could be constructed without cast-in-place closure placements, and significantly more experience within the local construction community building cast-in-place concrete box girders would result in more competitive bids. All of these issues led to the decision by the city to adopt cast-in-place concrete in lieu of precast concrete segmental construction.

Construction contracts were awarded in September 2009. With the demand for construction impacted by the recession, the contractor had access to an abundant supply of falsework material and proposed supporting all three spans simultaneously until post-tensioning was complete.

Bridge Details

With the design adjusted to take advantage of the simultaneous falsework configuration, the following dimensions and reinforcement resulted:

- Three-span continuous cast-in-place concrete box-girder bridge with 200-ft-long end spans and a 340-ft main span
- A deck width of 27 ft to accommodate dual train tracks
- A trapezoidal three-cell box-girder section with depth varying from 8 ft 9 in. to 17 ft 6 in.
- Box girder cross section with an 8-in.-thick top slab; 12-in.-thick webs; and a bottom slab that varies from 12 in. to 24 in. thick
- Specified concrete compressive strengths of 6000 psi and 4000 psi for the superstructure and the substructure, respectively
- Post-tensioning consisting of four tendons in each of the four webs. Each tendon contains twenty-seven 0.6-in.-diameter strands
- 5900 yd^3 of concrete and 1.2 million lb of uncoated, nonprestressed reinforcement

The erection of falsework for the center span showing the proximity of Sky Harbor Boulevard crossing under Taxiway "R." Photo: Gannett Fleming Inc.

Taxiway "R" looking west showing deck and curb east of bridge complete. Photo Rights: Hensel Phelps Construction Co.; Photo Credit: Visions in Photography.

THREE-SPAN, CAST-IN-PLACE CONCRETE, POST-TENSIONED BOX GIRDER TRANSIT BRIDGE / CITY OF PHOENIX, ARIZONA, OWNER

POST-TENSIONING CONTRACTOR: DYWIDAG-Systems International USA Inc., Long Beach, Calif.

BRIDGE DESCRIPTION: Three span, 740-ft-long (200-ft end spans, 340-ft main span) cast-in-place concrete, post-tensioned box-girder transit bridge, 75 ft above an airport active taxiway

STRUCTURAL COMPONENTS: Three-cell box girder, 27-ft 0-in.-wide deck with depth varying from 8 ft 9 in. to 17 ft 6 in., 13-ft-diameter integral main piers and 8-ft-diameter end piers founded on 8-ft-diameter drilled shafts

BRIDGE CONSTRUCTION COST: $6.7 million ($335/ft^2)

Above: Taxiway "R" re-opening event on October 10, 2010, with a Southwest Airlines 737, the first plane to taxi under the completed bridge. Photo: City of Phoenix Aviation Department.

Below: Taxiway "R" looking north, showing shoring under 340-ft-long main span and floor and webs complete. Photo Rights: Hensel Phelps Construction Co.; Photo Credit: Visions in Photography.

While the taxiway remained open, construction began with pier foundations. The foundations included a group of four 8-ft-diameter drilled shafts 90 ft deep with a 10-ft-thick cap for the main piers and one 8-ft-diameter drilled shaft 75 ft deep for each end pier. Pier construction included 8-ft-diameter end piers first, followed by 13-ft-diameter main piers. The main piers required a limitation on the size of aircraft accessing the taxiway during their construction. Falsework towers and formwork for the end spans took approximately 2 months to build. Once the floor and webs of the girders for the end spans were constructed, the taxiway was shut down in April 2010 to begin the construction of the main span. A milestone was celebrated at the construction site when the floor and webs of the bridge were completed on July 2, 2010. The deck was placed continuously over all three spans, and post-tensioning of the bridge occurred in early September 2010.

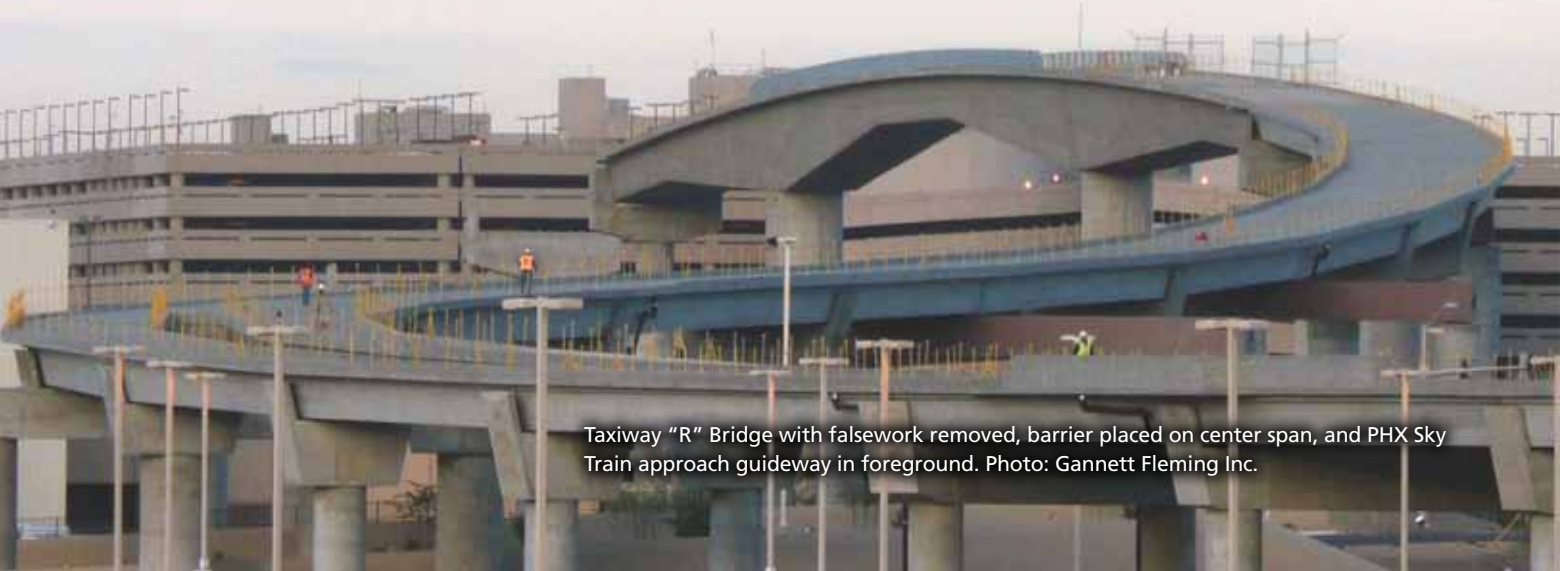
Taxiway Reopening

A celebration to mark the re-opening of the taxiway was held by the city on Oct. 10, 2010, with members of the city's Aviation Department, designers, contractors and media watching as the first two planes taxied under the new bridge. Although the bridge itself is complete, the running surface and propulsion systems for the train have yet to be installed. Installation of these systems will occur through 2011, with rigorous testing of the train system occurring in 2012 and opening of the first stage of the Sky Train to the public slated for early 2013. Final accounting indicates a total bridge cost of approximately $6.7 million, an impressive 36% savings from the preliminary estimate.

Thanks to the successful use of post-tensioned concrete, future passengers that cross over the taxiway will enjoy expansive views of Sky Harbor International Airport, the city, and surrounding desert landscape, as well as the experience of riding a train over planes and crossing above automobiles.

David A. Burrows is structural engineer with Gannett Fleming in Phoenix, Ariz.

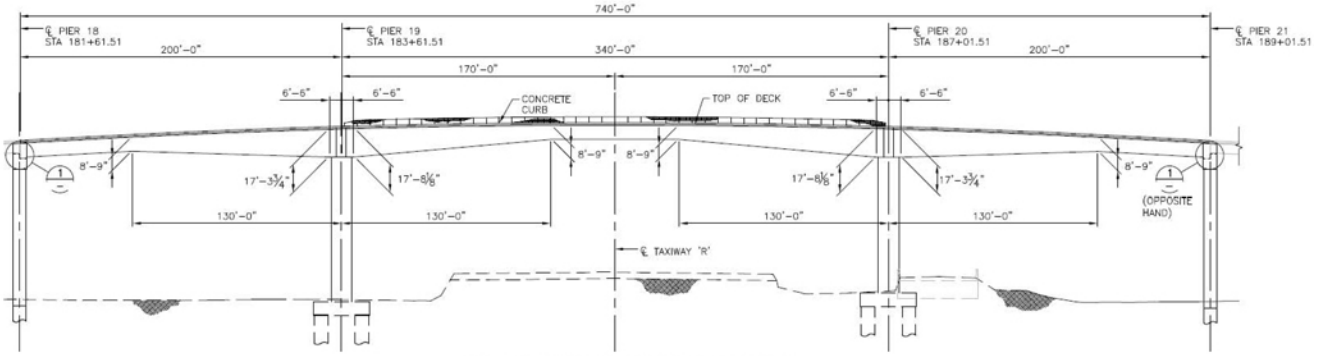
For additional photographs or information on this or other projects, visit www.aspirebridge.org and open Current Issue.



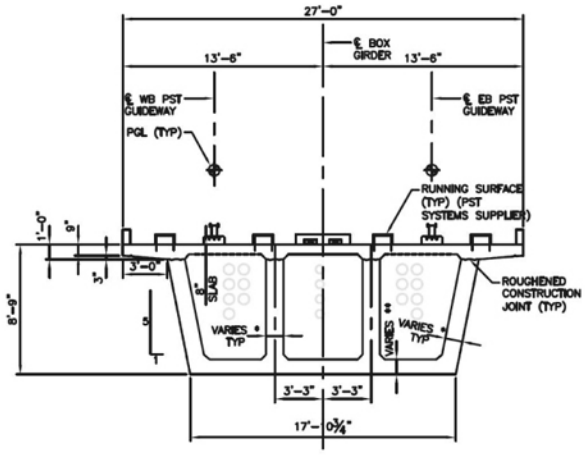
Taxiway "R" Bridge with falsework removed, barrier placed on center span, and PHX Sky Train approach guideway in foreground. Photo: Gannett Fleming Inc.

Taxiway "R" looking north with falsework removed and barrier placed on center span. Photo Rights: Hensel Phelps Construction Co.; Photo Credit: Visions in Photography.

Aerial view of Taxiway "R" with box girder floor and webs complete and the deck being formed. Photo Rights: Hensel Phelps Construction Co.; Photo Credit: Visions in Photography.



A TAXIWAY 'R' BRIDGE GIRDER GEOMETRY
SCALE: NOT TO SCALE



A TYPICAL MINIMUM DEPTH SECTION
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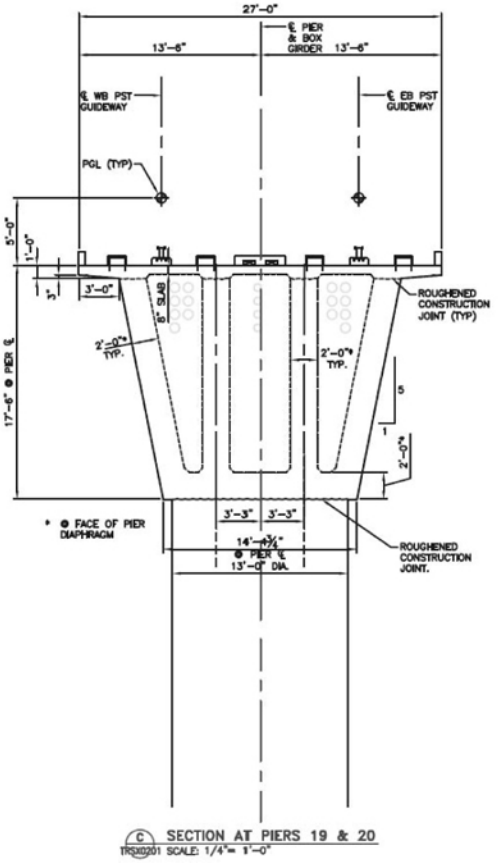

C SECTION AT PIERS 19 & 20
TRSX0201 SCALE: 1/4"= 1'-0"

PROJECT / TAXIWAY "R" BRIDGE