Aircraft Bridges Take Off

by Ted Bush, Kent Bormann, and Rob Turton, HDR Inc.

profile

TAXIWAY SIERRA UNDERPASS / SKY HARBOR AIRPORT, PHOENIX, ARIZONA

ENGINEER: HDR Inc.

CIVIL ENGINEER: Dibble Engineering, Phoenix, Ariz.

PRIME CONTRACTOR: Kiewit Western Co., Phoenix, Ariz.

AWARDS: 2007 American Public Works Association Project of the Year (Arizona); 2007 Southwest Contractor Project of the Year; 2007 Associated General Contractors Project of the Year (Arizona)

A five-span, cast-in-place, post-tensioned box girder bridge carried the taxiway across Sky Harbor Boulevard at the Sky Harbor International Airport. Photos: Richard Strange.

Taxiway at Sky Harbor International Airport in Phoenix shows how concrete designs can meet the growing need

Airport administrators are commissioning more bridges than ever before to handle airplane traffic, and this trend will continue. Airport bridge design requirements differ from highway and railroad designs due to their applications, geometries, and rules set out by the Federal Aviation Administration. But they also must meet the same goals as any bridge in providing a safe, long-lasting, and low-maintenance structure.

Site constraints are forcing airports to build runways at greater distances from terminals, and to shuttle planes over runway and taxiway bridges to access them. These same constraints also create challenges for bridge designs. Their geometry must accommodate the largest airplane type envisioned to use the structure, as defined by wingspan and tail height. A "safety area" that increases the width requirement is also desirable.

These designs are also governed by function. For example, impact loads are significantly higher for runways and taxiways than highways, and aircraft braking exerts substantial forces, which typically control lateral load for substructure design. Other non-gravity loads include the usual wind, thermal, and seismic considerations that are applied in accordance with AASHTO specifications.

Structural components have unique design considerations. For example, the deck design is more apt to be controlled by punching shear than flexure due to the heavy wheel loads. Additional considerations include provisions for edge curbs, to prevent aircraft from sliding off the bridge during icy or windy conditions, and fencing to prevent vehicles or pedestrians from gaining access.

Sky Harbor Reconstruction

An example of how these considerations are addressed in the field can be seen in the $35-million Taxiway Sierra Underpass reconstruction at Sky Harbor International Airport in Phoenix, Arizona. Airport administrators wanted to reconstruct the existing taxiway, including replacing the pavement and two single-span, reinforced concrete, rigid-frame structures.

Working with the City of Phoenix Aviation Department, designers established three key goals:

1. **Minimize interruptions to operations during construction.** Shutting down the existing taxiway would increase congestion on the other airside routes, and drilling operations for foundation construction and the erection of falsework would complicate landside access to the terminals.
2. **Create a design that was aesthetically compatible, cost-effective, and low-maintenance.** The nearby Taxiway Tango Underpass served as a standard, having been constructed with cast-in-place, post-tensioned concrete box girders. The bridge had experienced minimal service issues during the past 15 years.
3. **Eliminate the potential for conflict with future facilities.** Parking was

CAST-IN-PLACE, POST-TENSIONED CONCRETE BOX GIRDER / CITY OF PHOENIX AVIATION DEPARTMENT, OWNER

POST-TENSIONING AND REBAR INSTALLER: Paradise Rebar, Phoenix, Ariz.

POST-TENSIONING AND REBAR SUPPLIER: Consolidated Rebar Inc., Phoenix, Ariz.

CONCRETE SUPPLIERS: AZ Portland Cement, Phoenix, Ariz.; Salt River Materials Group, Phoenix, Ariz.; and Rinker Materials, Phoenix, Ariz.

BRIDGE DESCRIPTION: Five-span, cast-in-place, post-tensioned concrete box girder

STRUCTURAL COMPONENTS: Cast-in-place, five-span superstructure, pier bents, columns, drilled shaft foundations, and cantilevered abutments

BRIDGE CONSTRUCTION COST: $13 million

The structure was designed to support a gross aircraft weight of 1.5 million lb, plus a 30 percent impact factor. Photo: HDR Inc.

available beneath the Taxiway Tango Underpass, and the owners wanted the same revenue-generating option available for the Sierra project.

Three superstructure types were considered: a cast-in-place, post-tensioned concrete box girder to replicate the Taxiway Tango Underpass design; precast, prestressed concrete I-girders; and precast, prestressed concrete box girders. Steel girders were not considered due to the relatively high cost of steel in the area and the incompatibility with nearby concrete bridges and buildings.

Each option provided advantages, and they were all factored into the evaluation including cost, closure times, under-deck potential, constructibility, aesthetics, and serviceability. Ultimately, replicating the Taxiway Tango Underpass design was selected for the structure, which spans Sky Harbor Boulevard and provides three interior spans for future under-deck use.

The 406-ft-long, design-build project features five continuous spans of post-tensioned concrete box girders. The bridge was designed to be 214 ft wide to meet the safety area requirement for Group V aircraft and to support a gross aircraft weight of 1.5 million lb using the wheel configurations for a Boeing 747-400. A vertical force equal to 30 percent of the design aircraft's weight was added to the live load to account for impact, while a longitudinal braking force equal to 75 percent of the design aircraft weight was applied.

Conventional design techniques were used to distribute live loading across the bridge deck, and the 15-in.-thick deck slab was sized for punching shear and flexural requirements. Transverse flexural reinforcement in the girder was determined using various possible aircraft landing gear configurations. Drop beams were added at taxiway-lighting locations to effectively transfer loads to the adjacent girders.

3-D Modeling Verifies Design

The girder design was accomplished using traditional techniques accounting for the number of girder webs within the footprint of the landing gear. This distribution factor was verified by three-dimensional, finite-element modeling. The design aircraft was positioned transversely across the full bridge width to determine the extreme live-loading effects. A girder web spacing of 5 ft 11 in. and a total post-tensioning jacking force of 87,800 kips was required to support the bridge weight and design aircraft.

The substructure features four piers and two abutments, supported on deep-foundation cast-in-place drilled shafts. The columns at the outside pier lines are much wider than the interior pier lines to accommodate braking forces.

Nonintegral abutments were chosen due to the bridge's length. A 5-ft-thick stemwall and two rows of drilled shafts were used to accommodate the live-load surcharge from the approaching aircraft. Fortunately, as Phoenix is in a low-seismic region, seismic loads were not a significant consideration.

The approach slab at each end of the bridge required a thickness of 20 in. to meet flexural demands from aircraft loads. Anchor slabs also were provided between the taxiway pavement and the approach slabs.

Longitudinal and transverse construction joints were an important consideration, due to the continuous nature of the structural system and the sheer expanse of the girder. Considerable time was spent detailing the location of construction joints in the construction of the continuous structure. All bridge expansion and contraction movements were accommodated at expansion joints at the abutments. Expansion joints, with a 3-in. width, were also provided between the anchor slabs and approach slabs, and doweled construction joints between the anchor slabs and taxiway pavement accommodate any taxiway pavement movement.

Several additional constructibility issues were addressed during design. Heavy reinforcement requirements at the pier caps to column connections and abutment anchorages required special detailing to avoid congestion and ensure adequate concrete consolidation. Other

Cast-in-place drilled shafts, columns, and abutments were used for the substructure. Photo: HDR Inc.

construction considerations included airside and landside staging/phasing requirements, foundation construction, and requirements for sequencing, falsework construction, and post-tensioning operations.

Sequencing Was Critical

Removal of the existing bridge also had to be addressed. The same detour that was created to facilitate demolition was also used during falsework construction. Construction sequencing of the new bridge was planned to minimize obstacles for users and reduce detour time. In the first phase of work, drilled shafts for the deep foundations were constructed, after which all substructure elements, including abutments, abutment walls, and pier columns, were built.

Falsework was erected for the construction of girder soffit and web stems, with transverse joints provided to aid sequencing of the work. Crews first erected falsework for the two end spans of the bridge, which required openings for maintenance of traffic on Sky Harbor Boulevard. This was accomplished by diverting traffic with a temporary detour through the infield. Upon completion, traffic was reverted to allow erection of falsework for the interior spans.

Deck concrete placement was carefully sequenced longitudinally and transversely. Photo: HDR Inc.

Deck concrete was placed in a patchwork sequence both longitudinally and transversely to maximize construction efficiency and account for staged construction efforts with respect to stress and camber.

The design of the Taxiway Sierra Underpass shows some of the unique considerations required for aircraft bridges, compared to those designed for highways and railroads. Factors that must be addressed include unusual design specifications, requirements for airside and landside geometry, and designing structural components to transfer large aircraft loads. These projects are becoming more commonplace, creating more opportunities for designers who understand the unique conditions they represent.

Early discussions with the owner and local officials so that all considerations are understood can ensure the proper type, size, and location for the bridge. Working as a team with the owner, contractor, and key suppliers will save time and cost while leading to a successful project.

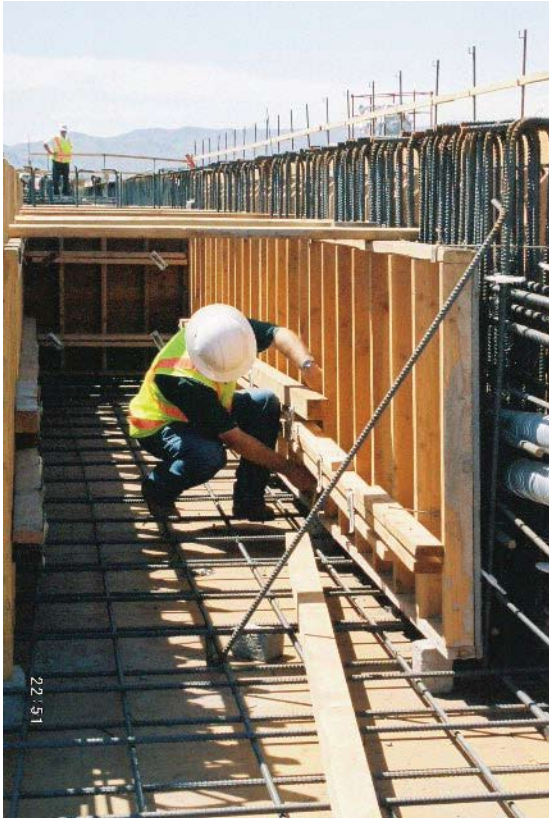
Ted Bush, Structural Engineer; Kent Bormann, Senior Bridge Engineer; and Rob Turton, Vice President and National Technical Director for Bridges are all with HDR Inc.

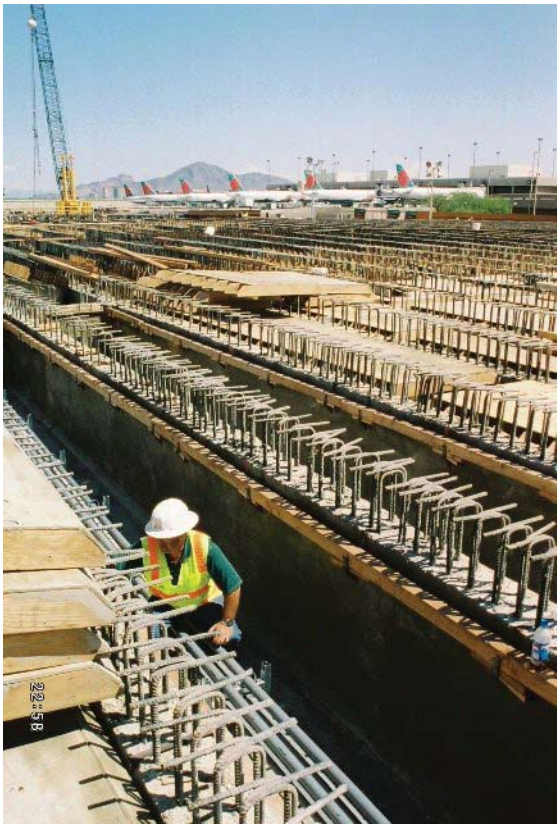
For more information on this or other projects, visit www.aspirebridge.org.

Northeast view of rebar cage set in cassion pier.

Photos: HDR Inc.

Worker with deck reebar.





Inspector checking rebar placement for abutment 1.

Photos: HDR Inc.

Eastern view of completed pier 2 and 3 colums. Photo: HDR Inc.