SUPERSTITION FREEWAY PEDESTRIAN BRIDGES: DESIGN AND ERECTION OF SPLICED PRECAST-PRESTRESSED TRAPEZOIDAL BOX GIRDERS

Randy Simpson, PE, URS Corporation, Phoenix, Arizona

ABSTRACT

A frequent challenge in the design and construction of urban freeway bridges is the need to minimize the duration of construction activities and the accompanying adverse impacts to traffic flow. Six two-span pedestrian bridges were recently constructed over US 60 Superstition Freeway in Tempe and Mesa, Arizona utilizing structural concepts and a construction approach designed specifically to address this challenge. The bridge superstructures consisted of five segments of precast-prestressed trapezoidal box girders designed for erection with minimal temporary falsework. The segments were post-tensioned after erection both for continuity and to create fixity with the intermediate pier. The structural concepts and construction approach enabled erection of each superstructure within a single weekend freeway closure.

Keywords: Rapid Construction, Pedestrian Bridges, Spliced Girders

OVERVIEW

In January of 2000 URS was hired by the Arizona Department of Transportation to design the widening of five urban arterial streets crossing the US 60 freeway in Tempe and Mesa, Arizona. At four locations, the widening was accomplished by converting the sidewalk areas of the existing underpass bridges to traffic lanes. Each of the sidewalks removed in this manner was replaced with a new stand-alone pedestrian bridge.

The new pedestrian bridges consisted of two-span precast-prestressed trapezoidal box girders. The superstructures were fabricated and transported in five segments. The segments were erected individually and post-tensioned in place to form continuous structures.

This paper describes the physical constraints imposed by the site, the details of the new superstructures and the approach used to erect the new bridges.

PROJECT PURPOSE AND DESIGN CONCEPT

The traffic interchanges improved in this project were constructed in 1975 through 1977 at the same time as the US 60 freeway. The freeway in this area is depressed below the elevation of natural grade and new bridges were constructed to carry the arterial traffic over the mainline roadway. The superstructures were continuous 2-span cast-in-place and post-tensioned box girders supported by “Y” type piers in the freeway median and integral abutments located at the top of the 3:1 depressed freeway cut slopes.

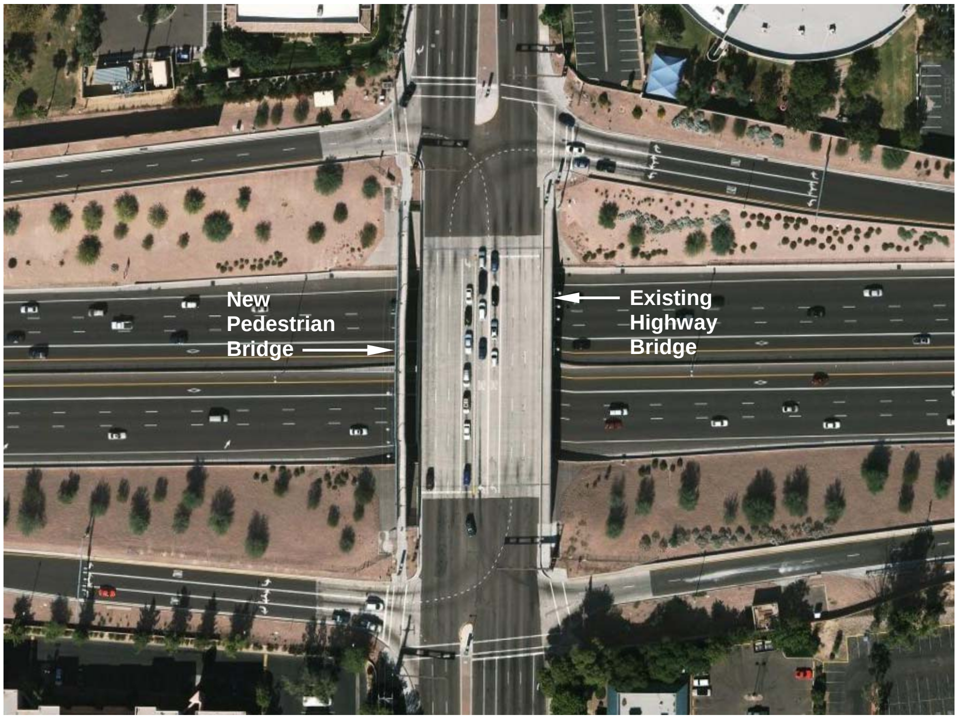


Figure 1: Site Plan (typical of 4 Locations)

The purpose of this project was to increase the capacity of the traffic interchanges by adding through-lanes and/or left turn lanes to the existing bridges. ADOT conducted a study of various alternatives, including widening the existing bridges, and concluded that the best approach would be to eliminate the sidewalks on the existing bridges and convert the sidewalk areas to traffic lanes. New stand-alone pedestrian bridges would be constructed to replace the sidewalks (see Figure 2).

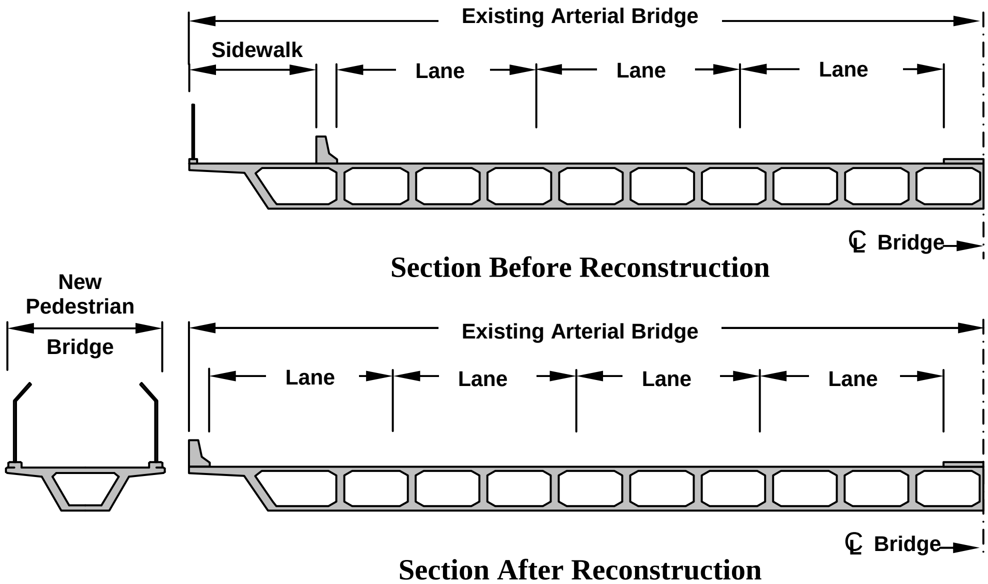


Figure 2: Design Concept

DESIGN CONSTRAINTS

Several constraints influenced the development of structure concepts for the new pedestrian bridges:

1. The new bridges needed to span 120 feet each side of the US 60 centerline and provide a minimum of 17 feet of vertical clearance. The overall structure depth was limited to a maximum of 4’-0”.

2. The bridges needed to be constructible while maintaining traffic on the freeway below. US 60 is one of the busiest freeways in the Phoenix metropolitan area with traffic volumes of approximately 185,000 vehicles per day (2000 data). Partial closures of the eastbound and westbound lanes were limited to the early morning hours between midnight and 5:00 am. Full closures, with temporary detours, were limited to the weekends between midnight Friday and 5:00 am Monday morning.

3. The maximum weight that can be carried by conventional girder-hauling equipment in the Phoenix area is 160,000 Lbs.

4. The cities of Tempe and Mesa consider theses bridges to be gateways to their cities. A good aesthetic appearance was essential.

5. SUPERSTRUCTURE

A two-span layout was selected in order to accommodate the overall structure length of 240 feet with a maximum structure depth of 4'-0". The following structure type alternatives were evaluated in a Bridge Selection Report:

- Steel Truss
- Precast-Prestressed I-Girders (decked and through-girder)
- Rectangular Precast-Prestressed Box Girder
- Trapezoidal Precast-Prestressed Box Girder

The trapezoidal precast-prestressed box girder alternative was selected for the following reasons:

1. The entire cross-section could be precast off-site. Major concrete pours after erection would not be necessary.
2. The proposed section was well adapted to pre-tensioning off-site, erecting in segments and splicing in place with post tensioning.
3. The efficiency of the trapezoidal box section made a shallow depth to span ratio feasible.
4. The proposed section was well adapted to haunching at the pier and abutments. This enhanced structural efficiency as well as the finished appearance of the bridges.
5. Since there were a total of six bridges in this project, the relatively high cost of constructing unique steel forms was economically feasible.
6. The trapezoidal section was selected over the rectangular section due to superior aesthetics for essentially the same cost.

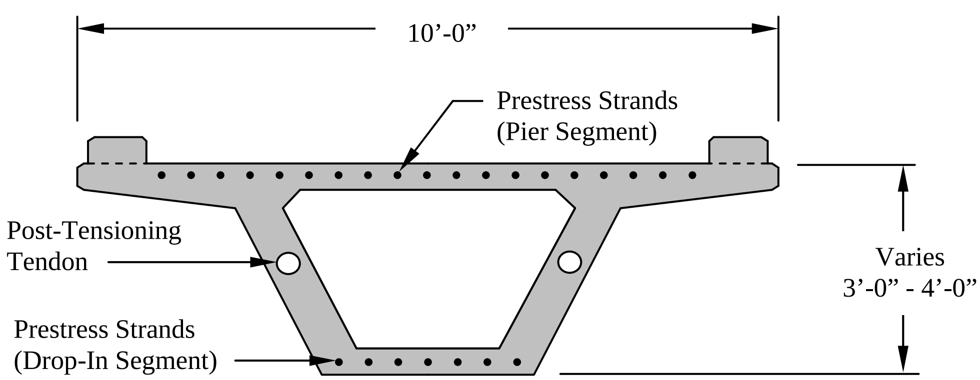


Figure 3: Typical Section of Selected Alternative

The superstructures were precast, transported and erected in five segments. The individual segments were designed to weigh less than the capacity of conventional girder hauling equipment and to facilitate erection of the superstructures with minimum disruptions to US 60 traffic. The segments are briefly described in the following paragraphs and shown in Figures 4 through 7.

End Segments: The abutment ends of the 2-span superstructures consisted of haunched precast segments approximately 22 feet long and varying in depth between 4'-0" at the abutment end and 3'-0" at the interface with the adjacent span segment. The variable depth was not necessary from a structure design perspective but was incorporated for the purpose of mirroring the haunch of the pier segment and improving the aesthetic appearance. These segments had only conventional reinforcing prior to erection, but included post-tensioning ducts in each web. The total precast weight was 44 kips.

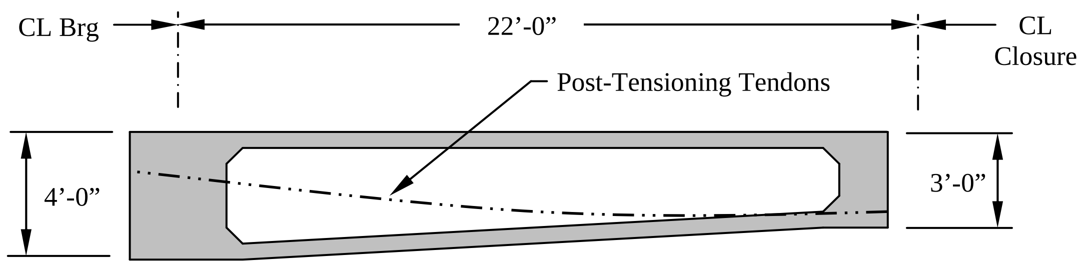


Figure 4: End Segment Elevation (2 Required)
(Opposite Hand Similar)

Pier Segment: The portion of the superstructure over the pier was cast as a single 44-foot long segment varying in depth between 4'-0" at the pier centerline and 3'-0" at the ends. The ends were cast with integral lower hinges to provide support for one end of "drop-in" segments and avoid the need for temporary falsework.

Pier segments were pre-tensioned in the precasting yard with 32 straight ½" diameter low-relaxation strands in the top slab providing an effective prestress force of 781 kips after all losses. The total precast weight was 81 kips.

Pier segments were post-tensioned to the pier column immediately after erection. Post-tensioning reinforcing consisted of eight 1-3/4" diameter x 16'-0" long high-strength bars embedded 12'-6" into the top of the pier column. The post-tensioning was designed to prevent differential rotation between the pier segment and column under the unbalanced condition during erection wherein the pier segment would support a drop-in segment on one side only. The post-tensioning also served to create fixity at the pier under live loads and minimize the amount of longitudinal post-tensioning of the superstructure.

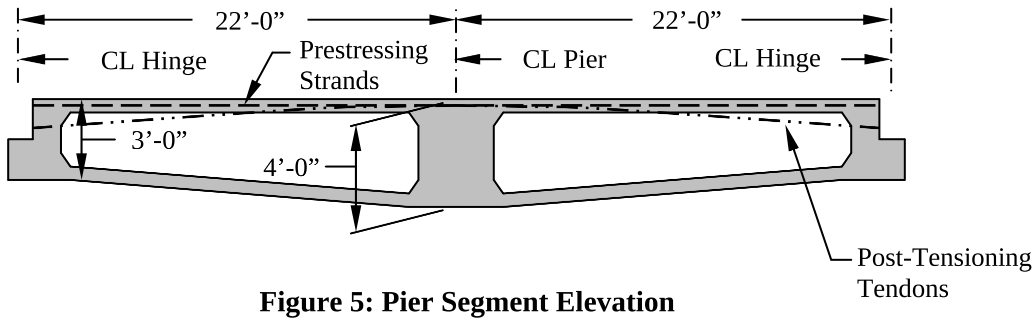


Figure 5: Pier Segment Elevation

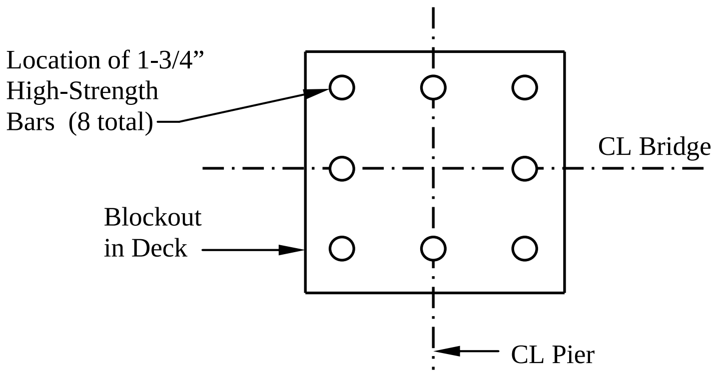


Figure 6: Plan of Post-Tensioned Pier Connection

Drop-in Segments: Drop-in segments consisted of 76-foot long prismatic sections with integral upper hinges on the pier ends only. The depth was 3'-0" throughout.

Drop-in segments were pre-tensioned in the precasting yard with 22 straight ½" diameter low-relaxation strands, providing an effective prestress force of 530 kips after all losses. The total precast weight was 127 kips.

Post tensioning consisted of two 18-strand tendons constructed on a parabolic profile. The tendon ducts were spliced at each gap between segments prior to placing grout in the gaps. The effective post-tensioning force was 1,582 kips after all losses.

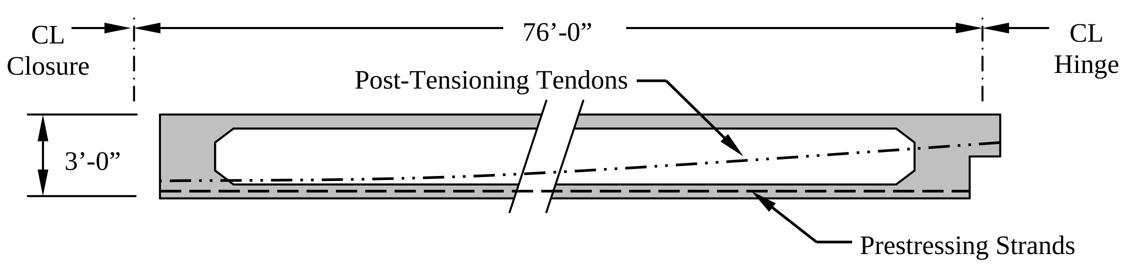


Figure 7: Drop-in Segment Elevation (2 Required)

(Opposite Hand Similar)

SUBSTRUCTURE

The cast-in-place concrete bridge abutments were each supported on a single 48” drilled shaft foundation. Wingwalls were constructed integrally with the abutments and spanned horizontally.

Abutment bearings were expansion-type and consisted of a single 3-1/2” thick x 12” long x 34” wide steel-reinforced elastomeric bearing pad. The bearing thickness was selected to provide sufficient movement capacity without need for a sliding surface.

The intermediate piers were supported by a single 78” drilled shaft foundation. The cast-in-place concrete pier columns tapered in the transverse dimension from 5’-0” at the base to 3’-0” at the soffit of the superstructure. The longitudinal dimension was a constant 4’-0” from top to bottom.

Eight high-strength bars were embedded 12’-6” into the tops of each pier to allow post-tensioning of the superstructure to the pier. A 3” thick steel plate was embedded in the top of each pier to provide a flat and level mating surface with a similar embedment in the girder soffit. The top 12” of the column was placed with a secondary closure pour to allow for precise leveling of the plate prior to completing the column.

GIRDER FABRICATION

The precast superstructure segments were fabricated and erected by Royden Construction Company of Phoenix. Because there were six bridges to be constructed in this project, it was economically feasible to construct unique fixed steel forms for each of the segments. The use of steel for all form surfaces had a secondary benefit of providing an excellent concrete surface finish.

The forms were constructed on concrete foundations incorporating prestressing bulkheads. Voids were formed with shaped polystyrene topped with plywood and were held down with steel rods extending through the form soffit.

Figure 8: End Segment Form

The completed decks supported 8’-0” high fences for pedestrian safety. The embedments for the fence posts, consisting of 1-3/8” x 2-3/8” solid steel bars, were included in the precasting operation to enable rapid erection of the fencing after erection of the superstructures.

SUPERSTRUCTURE ERECTION

Each of the new superstructures was erected with a full closure of US 60 starting at midnight Friday and ending before the morning rush at 5:00 am Monday. During this closure, freeway traffic was routed to the "upstream" exit ramp, over the crossroad, and to the "downstream" entrance ramp. This allowed the entire area of the freeway mainline between ramp gores to be used for staging and erection activities. Due to the weekend timing, no significant freeway traffic delays were experienced.

Each of the superstructures was erected within a single weekend closure, including grouting of the gaps between segments. The superstructures were post-tensioned within one week of erection without an additional freeway closure. Subsequent partial closures of the freeway were required to strip the forming for gap grouting, erect fencing, place signs, and paint the girders.

The superstructures were erected in stages as follows:

1) *Erect the end segments*. The end segments were supported by the abutment on one end and temporary falsework on the other. The temporary falsework was located outside the freeway cross-section in order to avoid any disruptions to traffic. Work in this stage was accomplished without restricting freeway traffic.

Figure 9: Falsework at End Segment

2) *Erect the pier segment and post-tension it to the pier.* A transit located on one abutment was used to align the centerline of the pier segment with the bridge axis prior to post-tensioning. No leveling was required due to the embedded steel mating surfaces in the pier top and girder soffit and the tolerances on levelness

specified for the pier construction. Work in this stage required a full closure of freeway traffic. Post-tensioning proceeded one bar at a time in an “inside out” sequence to ensure full surface contact.

Figure 10: Erecting the Pier Segment

3) *Erect the drop-in segments.* Each drop-in segment was supported by the lower hinge of the pier segment on one end and temporary falsework on the other. Immediately after erection, the post-tensioning ducts were spliced and mild reinforcing was placed in each gap between segments. The segment gaps were generally formed and grouted within hours of placing the drop-in segment.

Figure 11: Setting the Drop-In Segment

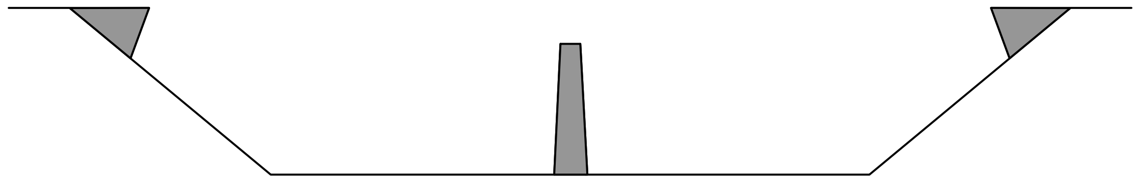
4) *Splice post-tensioning ducts and cast closures.* Post-tensioning ducts were spliced with threaded duct segments prior to forming and casting the closures. The specified compression strength of the closure pour concrete was 6,000 psi within 7 days. The contractor elected to use neat grout for casting closures for the purpose of improving consolidation and achieving strength quickly.

Figure 12: Preparing the Closure for Grouting

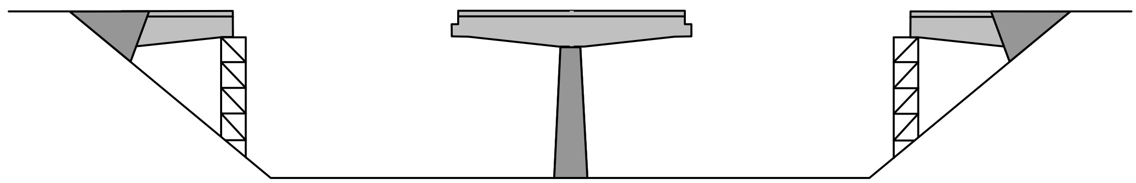
At the completion of Step 4, the structure spanned each direction of the freeway without falsework within the traveled way. The freeway was re-opened to traffic while the grout in the closures gained strength and prior to post-tensioning.

5) *Post-tension the superstructure.* The specifications required the contractor to post-tension the superstructure within 7 days of casting the closures for the purpose of avoiding cracks in the closures due to creep shortening and end rotations of superstructure segments. Tendons were pulled in one operation using multi-strand jacks. The superstructures were jacked from one end only.

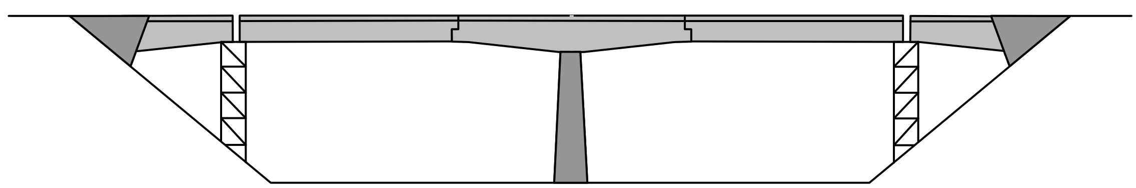
Figure 13: Abutment Segment Prior to Post-Tensioning



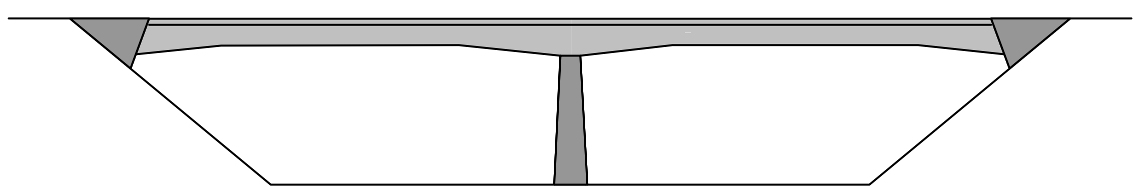
Stage 1: Construct Pier and Abutments



Stage 2: Erect End Segments and Pier Segment



Stage 3: Erect Drop-In Spans



Stages 4&5: Cast Closures and Post-Tension

Figure 14: Construction Sequence

Figure 15: Completed Bridge at Rural Road

CONCLUSION

Spliced precast-prestressed trapezoidal box girders were found to be a practical, economical and constructible structure type for the US 60 pedestrian bridges. The structure details and erection approach minimized the need for temporary falsework and enabled construction of the bridges with minimal disruption of US 60 mainline traffic.

The superstructure concepts used in this project were used again in a subsequent project involving two pedestrian bridges. Those bridges were modified to provide a clear deck width of 10’-0” in contrast to the clear width of 8’-0” for the bridges in this project. The steel forms fabricated for this project were modified to provide the additional width and currently will accommodate either an 8’-0” or 10’-0” clear deck width.