

The Cotton Lane Bridge over the Gila River in Goodyear, Ariz., was created with a unique public/private partnership that involved the city, county, and two developers.

Exterior girders had textural decorations reflecting the desert environment cast into them with the use of formliners.

# PUBLIC/PRIVATE PARTNERSHIP SUCCEEDS

by David Lawson, Michael Baker Jr. Inc.

## Combination of local government and developers produces decorative, cost-efficient bridge design

Bridge designs often must meet the concerns of a variety of participants, and finding innovative ways to ensure all needs are met becomes even more acute as more private organizations join with public entities to fund bridge designs. That proved to be the case for the Cotton Lane Bridge over the Gila River in Goodyear, Ariz., where the Maricopa County Department of Transportation (MCDOT), as the lead agency, joined forces with the City of Goodyear (COGY) and two local developers. The resulting precast concrete design met everyone's needs and produced a strikingly attractive structure that met a reasonable budget and was produced on schedule.

As the city experienced strong growth, COGY and MCDOT officials recognized the need to alleviate traffic congestion in a region that was expanding with housing developments. They also wanted to provide an additional bridge crossing over the Gila River to improve the regional transportation system.

In achieving these goals, the various stakeholders had specific priorities. MCDOT, which transferred ownership to COGY upon completion, wanted to ensure the project was constructed quickly to support the local development and to improve the regional transportation network, setting a one-year construction schedule. The two contributing developers (Sonterra Partners and Estrella Mountain Ranch) emphasized the need for an attractive design to draw potential buyers to the development while remaining within budget. Meanwhile, the Flood Control District of Maricopa County (FCDMC) wanted to ensure the new crossing preserved the area's rich environmental resources and unique river wildlife.

Meeting these needs was complicated by the requirement that the structure optimize the modest construction budget. To achieve this, Michael Baker Jr., serving as the prime consultant, worked with COGY, MCDOT, FCDMC, and the developers through a

## profile

### **COTTON LANE BRIDGE / GOODYEAR, ARIZONA**

**LEAD AGENCY:** Maricopa County Department of Transportation

**ENGINEER:** Michael Baker Jr. Inc., Phoenix, Ariz.

**CONSTRUCTION MANAGER:** Tristar Engineering & Management Inc., Chandler, Ariz.

**GEOTECHNICAL INVESTIGATION:** Ricker Atkinson McBee Mormann & Associates, Tempe, Ariz.

**AWARDS:** *Best Bridge With Spans Between 75 and 150 Feet, Co-Winner, Precast/Prestressed Concrete Institute's Design Awards 2008; Top 20 Project, Southwest Contractor magazine, 2008; 2008 Honor Award, Arizona chapter of the American Council of Engineering Companies.*

Construction Management at Risk (CMAR) partnership.

COGY, MCDOT, and the developers were all financial participants in the bridge and corresponding roadway's cost. Kiewit Western Co. was selected early in the design process to serve as the construction manager and advisor during design. It also served as general contractor. The CMAR format allowed Baker and the entire design team to evaluate alternatives quickly during design with more accurate estimation of construction cost, constructability, and construction time.

The final design consisted of a 17-span bridge using 12 lines of AASHTO Type VI-modified girders per span. Each span is approximately 121 ft 6 in., resulting in a 2067-ft-long bridge. All interior girders are modified to a 6-in.-thick web as a result of moving the side forms closer together. This



The substructure consisted of cast-in-place drilled shafts, piers, and bent caps.



The precaster, who was brought onto the project early due to the use of a Construction Management at Risk contracting method, supplied 204 Type VI-modified AASHTO girders in 17 spans, each approximately 122 ft long, to create the 2067-ft-long bridge.



provides a 26-in.-wide bottom flange and 40-in.-wide top flange. Interior girders are spaced at 9 ft 5 in. centers.

The fascia girders were modified to accommodate an aesthetic formliner that imparted textures that are overlain by two-dimensional illustrations of geckos. This pattern has a maximum  $\frac{3}{4}$  in. relief, 3 ft 6 in. tall by the full length of the girder. To achieve the flat face to apply the pattern, both top and bottom flanges on the exterior face of the girder were blocked off during casting, creating a "C" or channel shaped girder. In addition, the web was increased to 14 in. thick by adding 6 in. to the outside face. The resulting top flange is 2 ft 7 in.



Alcoves with benches were created along the bridge's length to invite pedestrians to linger and enjoy the scenery, while two bat lodgings were created beneath the bridge to accommodate up to 8000 bats. The alcoves along the bridge are each supported by two precast concrete corbels, which served as falsework during construction, reducing project cost and construction time.

### Stakeholder Input and Environmental Assessment

In addition to the four funding groups, many other stakeholders were involved in the design and construction of the project. These stakeholders included local schools, a number of city, county, state, and federal governmental agencies, irrigation districts, railroad, utilities, local residents, and business owners.

With these inputs, designers analyzed several bridge-design alternatives relative to hydraulics, on-site and off-site hydrology, sediment transport, cost, environmental options, and drainage-infrastructure impacts to the Gila River corridor and floodplain.

Drainage design included a review of the Gila River hydraulic and sediment-transport modeling report, and the design and modeling of various alternatives in compliance with the requirements. The alternatives consisted of a longer bridge without floodplain impact and a shorter bridge with improvements to the floodplain. The selected alternative was the shorter bridge with corresponding improvements to the floodplain.

Permitting presented several challenges, since the Gila River is among the jurisdictional waters of the United States, requiring various permits. This effort led to the largest Section 404 permit in Arizona's history.

## 17-SPAN PRECAST, PRESTRESSED CONCRETE AASHTO I-GIRDER BRIDGE / CITY OF GOODYEAR, OWNER

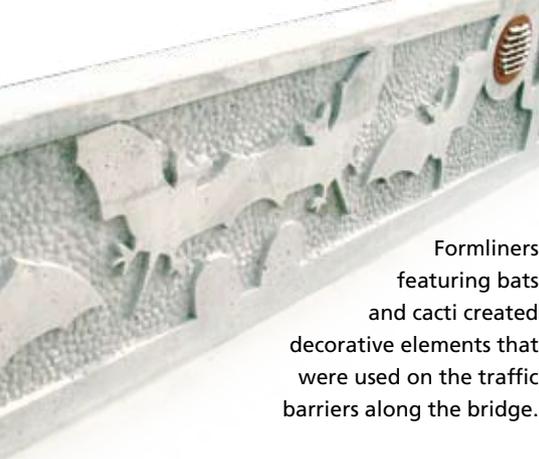
**LANDSCAPE ARCHITECT:** Corral Dybas Group Inc., Phoenix, Ariz.

**PRIME CONTRACTOR:** Kiewit Western Company, Phoenix, Ariz.

**PRECASTER:** Tpac—A Division of Kiewit Western Co., Phoenix, Ariz., a PCI-certified producer

**BRIDGE DESCRIPTION:** 2067-ft-long bridge featuring 17 spans of AASHTO Type VI-modified precast, prestressed concrete girders, including exterior girders with decorative designs created with form liners; precast concrete corbels supporting circular pedestrian alcoves; and cast-in-place substructure and deck

**BRIDGE CONSTRUCTION COST:** \$27 million



Formliners featuring bats and cacti created decorative elements that were used on the traffic barriers along the bridge.

wide and the bottom flange is 2 ft 0 in. wide. This modified edge girder contains fifty-three 0.6-in.-diameter strands—41 straight and 12 harped. The specified concrete strength was 6500 psi at 28 days and 5200 psi at release. More details of design of the horizontally asymmetric exterior girders may be found in a paper by the author.<sup>1</sup>

The 8-in.-thick deck has an out-to-out width of 114 ft 9½ in. with a 16-ft-wide striped median and provides, in each direction, a 6-ft-wide outside sidewalk protected by a traffic barrier to the inside and pedestrian railing to the outside, a 5-ft 5-in.-wide bicycle lane, and three 12-ft-wide traffic lanes (two striped now and one in the future). Beneath the deck, the bridge carries a 24-in.-diameter reclaimed water line, two 30-in.-diameter water lines, and a large utility bank (12 conduit lines).

Thirty-two circular pedestrian alcoves, placed on both sides of the bridge at each pier

location, invite pedestrians to linger and enjoy the scenery. Each alcove is supported by two precast concrete corbels, which were designed to serve as the falsework during construction, reducing project cost and construction time.

In an effort to achieve cost savings without compromising any of the stakeholders' interests, the team utilized creative cost saving strategies. Precast concrete was used where possible to minimize construction time, cost, and adverse impact to the environment. Additionally, a static drilled shaft load test utilizing the Osterberg load cell was performed during early design. Due to the higher reliability of the soil response obtained through the use of this load test, a reduced safety factor, as permitted by the AASHTO LRFD specifications was permitted in design. Savings in the foundation cost far outweighed the cost of the load test and resulted in net savings of more than \$1 million to the project.

The bridge's substructure, including columns and bent caps, is cast-in-place concrete. Each column is founded on a single, 72-in.-diameter drilled shaft approximately 105 ft deep.

The Cotton Lane Bridge was a project of firsts and extremes, but the innovative design approach chosen and solutions incorporated into the project exceeded the needs of the owner and client. The

design exemplifies environmentally responsive and responsible engineering achieved through continual collaboration of all project stakeholders. The versatility of precast concrete produced a cost-efficient and aesthetically unique bridge that pleased everyone involved.

From forging a creative public/private funding partnership to using unique aesthetics and the CMAR process, the solutions created for this project can serve as a prototype for future bridge-engineering challenges in achieving the collective goals of context sensitivity, project streamlining, and cost efficiency.

## References

1. Lawson, David J., and G. P. Wollmann, 2007, "Advanced Aesthetic Embedment in Prestressed Girder," Proceedings of the PCI-FHWA National Bridge Conference, October 22-24, Phoenix, Ariz., 10 pp.
2. Lawson, David J., Ed Corral, and Larry N. Sullivan, 2007, "Cotton Lane Gila River Bridge—Integration of Environment and Infrastructure," Proceedings of the PCI-FHWA National Bridge Conference, October 22-24, Phoenix, Ariz., 11 pp.

*David Lawson is a structural engineer with Michael Baker Jr. Inc. in Phoenix, Ariz.*

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## Sustainability and Aesthetic Impact

The Construction Management at Risk (CMAR) process allowed local precasters to add their valuable input to the design process, contributing to the development of effective precast concrete alternatives. This ensured that critical construction elements were not overlooked and that the most efficient solutions to each challenge were discussed, refined, and implemented.

### Creating a Natural Design<sup>2</sup>

Recognizing that this bridge would forever change the natural environment of this portion of the Gila River, the Maricopa County Department of Transportation inspired the team to frame its conceptual design around the question, "How would nature build this?" The answer produced numerous design elements to support the natural environment and wildlife at the construction site while also meeting goals for incorporating sustainable design wherever possible.

The bridge features a low-profile vertical curve, allowing the minimized-arch shape to blend visually with the backdrop of the Estrella Mountains. Sustainability measures also were incorporated into the precast concrete components in a variety of ways. Precasting the components minimized construction waste, and concrete remaining after casting was recycled for use with other ongoing projects. The precast concrete components were

cast in nearby Phoenix, minimizing transportation costs. Precast products incorporated Type F fly ash in the concrete mixture, reducing the amount of Portland cement.

### Amenities Enhance Design

Inspired by the weathered desert surroundings, the design features exterior girders that used custom form liners to create textures that are overlain by two-dimensional illustrations of geckos. The columns used construction techniques to create fossil-like patterns of prehistoric creatures and plants on their sides. Incorporating the aesthetics directly onto the fascia girders decreased construction time by eliminating the need to hang aesthetic-patterned panels after girder placement. Bats and cacti also were cast onto the back of the traffic barrier to further enhance the desert-themed aesthetics and visual connection to the environment.

To support the wildlife of the river ecosystem, designers created enclosed lodgings to sustain the bat populations living near the river. Baker worked closely with the Arizona Game & Fish Department to incorporate two appropriate bat lodgings on the underside of the bridge, each of which can accommodate up to 4000 bats. Additionally, to minimize pollution caused by excess illumination and comply with the city's "dark sky" requirements, designers created shortened light poles with low-intensity lighting.



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## COTTON LANE BRIDGE / GOODYEAR, ARIZONA



Precast girders aided sustainability factors by reducing construction waste, minimizing transportation costs, and contained Type F fly ash..

**The CMAR process allowed local precasters to be involved in the design process.**

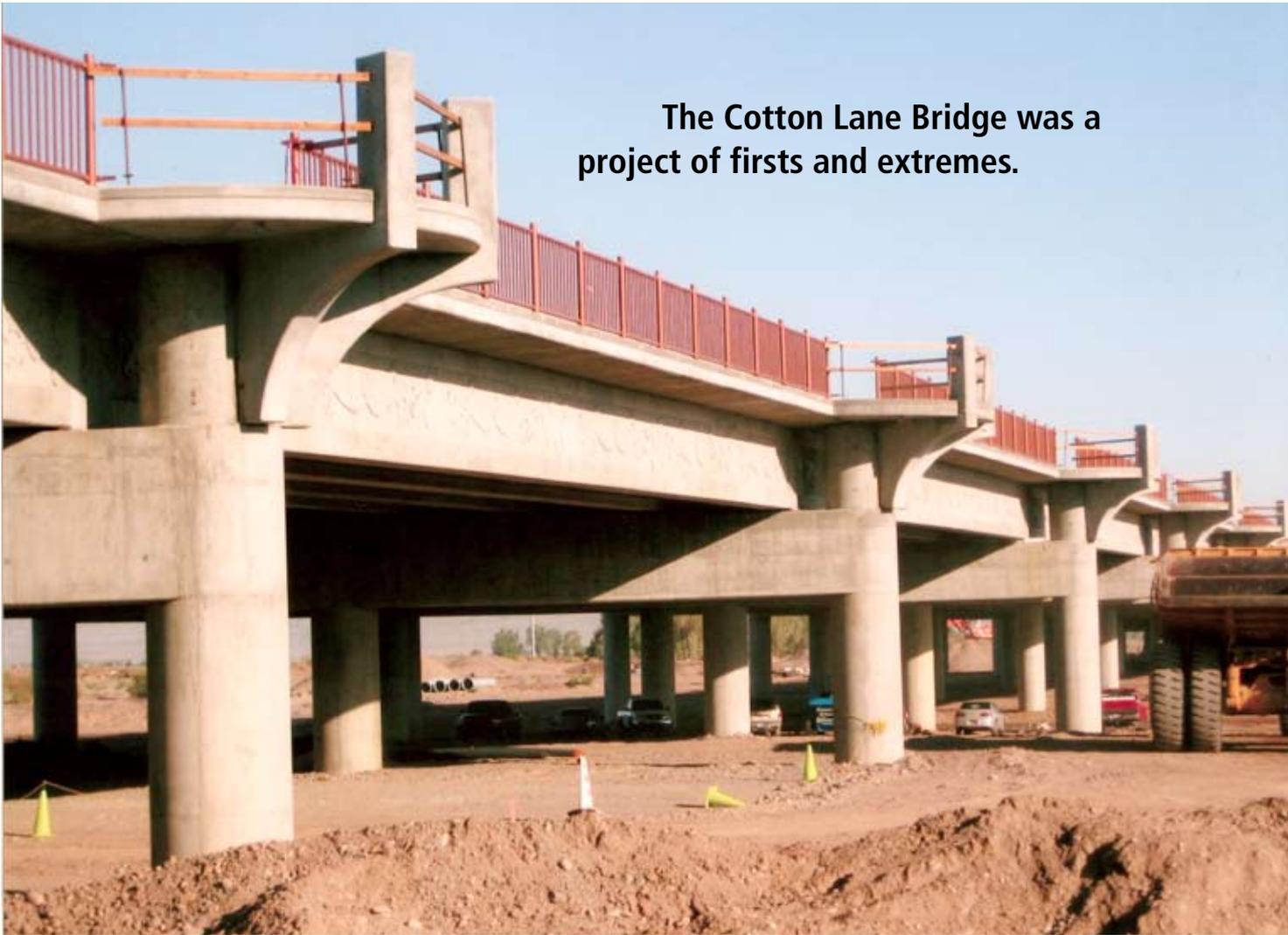


COTTON LANE BRIDGE / GOODYEAR, ARIZONA



**COTTON LANE BRIDGE / GOODYEAR, ARIZONA**

**The Cotton Lane Bridge was a project of firsts and extremes.**



## **COTTON LANE GILA RIVER BRIDGE – INTEGRATION OF ENVIRONMENT AND INFRASTRUCTURE**

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**Ed Corral, R.L.A.**, Corral Dybas Group, Phoenix, Arizona  
**Larry N. Sullivan, JD, MLA**, Corral Dybas Group, Phoenix, Arizona

### **ABSTRACT**

*It is often difficult to blend the design of highway bridges with the surrounding environment. The recently constructed Cotton Lane Bridge over the Gila River at Goodyear, Arizona features a unique design that not only uses the site's natural surroundings for inspiration, but incorporates them without large scale land transformation. Primary goals for the design aesthetic included visual access to the mountain horizon and the riverine environment, as well as support for native geomorphic and biotic processes with materials, colors, and patterns. On vertical concrete surfaces, unpainted sandblast and simulated sandblast textures reveal both prehistoric and familiar desert life. The outboard face of the exterior precast, prestressed girders uses form-liners to create gecko and cactus imprints. The bridge's pier columns also feature artistic impressions of Goodyear's ecosystem, with ancient life forms such as water scorpions and dragonflies exposed by sandblasting. Patterns in the safety barrier reveal saguaro cactus, the bats that pollinate them, and a moon form. All pier columns were stained copper oxide color up to the 100 year flood elevation to suggest the wet-dry desert riparian cycle and to connect with the copper mining history of the region.*

### **Keywords:**

Aesthetics, Environment, Bridge

## INTRODUCTION

Increased traffic volumes and congestion, dynamic suburban residential development, and a river habitat enhancement initiative worked together to create the need for a unique bridge across the Gila River in Maricopa county. The City of Goodyear has experienced rapid residential development in recent years. Major parts of the community were separated by the Gila River. City officials wanted to connect these areas and consolidate development on the north side of the river with a major north-south arterial that would cross the river at the foot of the Estrella Mountain formation. Maricopa County transportation officials, along with several private developers, wanted a bridge that could be constructed quickly and cost-effectively. Both the developers and the sponsors of a river habitat enhancement effort wanted to make sure that bridge styling and appearance fit with outspoken local preferences for a rustic and natural appearance. Further, the City of Goodyear was concerned about how the bridge would impact their “dark sky” requirements. A unique partnership of county, city, and private developers was forged to address the varying interests and needs of each stakeholder. Using a construction management at risk (CMAR) contracting method, engineers, landscape architects, contractors, and project partners addressed these needs through unique design and construction solutions for the Cotton Lane Bridge over the Gila River.

## OVERVIEW

In combination with a proposed river habitat enhancement program, hydraulic analysis indicated that a 2,100 foot long bridge was necessary to span the Gila River and properly connect with planned freeway alignments. A traffic analysis recommended an ultimate capacity of three travel lanes in each direction on the bridge. The City of Goodyear and the developers required a six-foot wide sidewalk on each side of the bridge to encourage pedestrian traffic across the river. A bridge type study revealed that traffic and hydraulic needs could be satisfied with a structure consisting of 17 spans of about 122 feet each, utilizing AASHTO Type VI modified prestressed girders. County and river improvement officials insisted that the designers use a context sensitive approach. The designers recommended that conceptual design be driven by an intensive collaboration between project sponsors, engineers, landscape architects, and contractors.

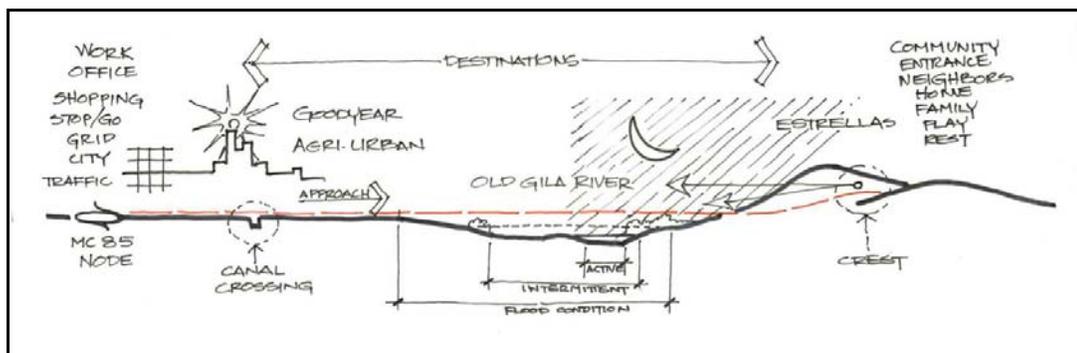


Figure 1: Context Section

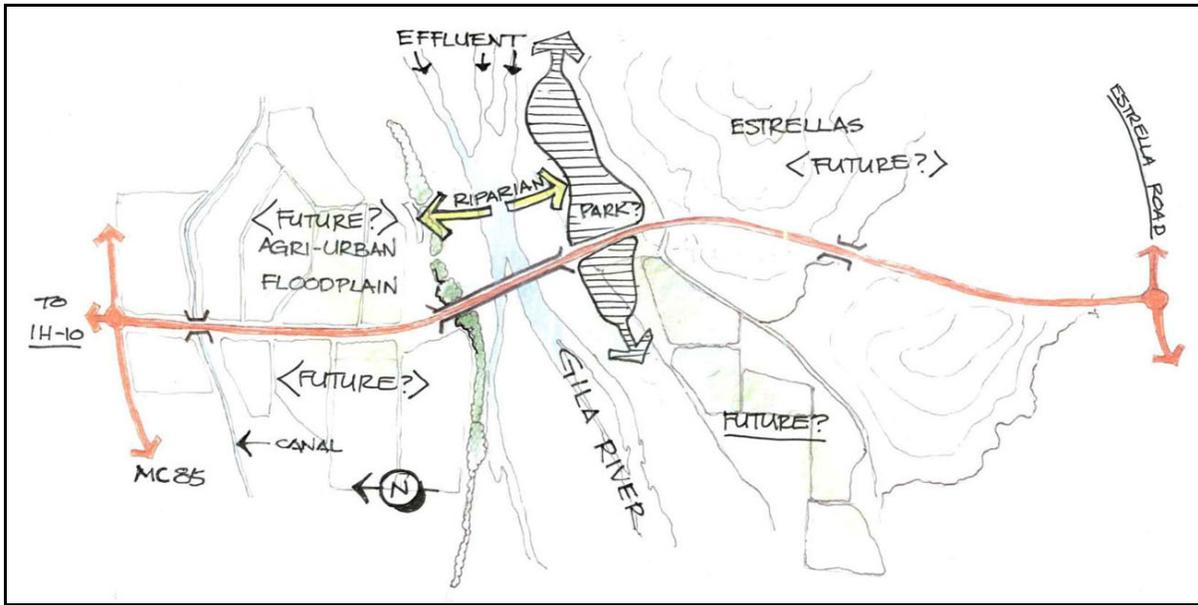


Figure 2: Context Elevation

Designers began the charrette process by conducting a graphical site analysis, which observed the various visual, geographical, cultural, and social contexts associated with the use and siting of the bridge, as can be seen in Figures 1 and 2. Fueling the conceptual design process was the idea that motorists’ experience of the mountains, river, and flood plain environment in Goodyear would be shaped, in part, by the physical attributes of the bridge. The design charrettes used the highly interactive process shown in Figure 3, which included high levels of participant involvement. The participants explored the various aesthetic options and conceptual themes associated with different bridge types in order to effectively blend appearance with functionality in the design. A “Rapid-viz” visualization process was used, whereby the charrette facilitator conducted on-the-spot sketching in order to receive immediate feedback and alternatives from the participants.

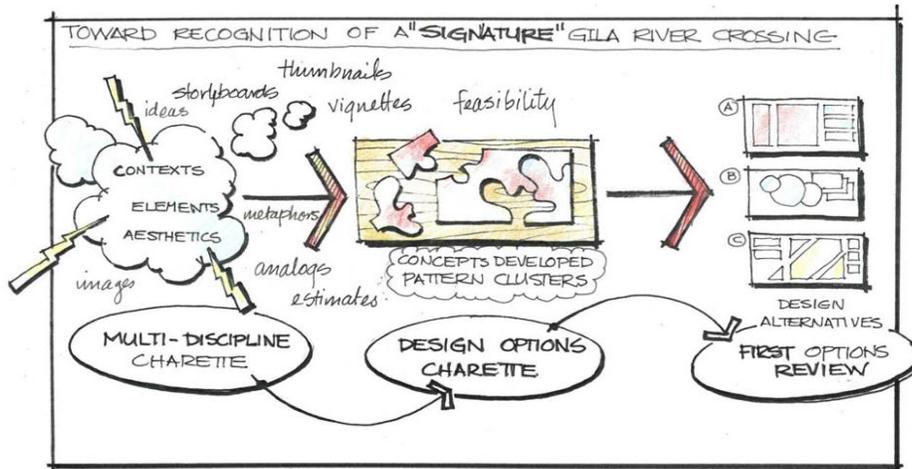


Figure 3: Concept Development Process

The Rapid-viz technique (Ref. 1) is similar to drawing short hand, using symbolic images to represent verbal ideas. It not only eliminated the designers' need for an elaborate sequence of presentation boards, but also allowed them to expedite the process of generating, assessing and refining concepts for basic structural forms and styling. It can be geared to encourage real time participations in a workshop context. Or it can be used to reduce studies and time devoted to polishing formal alternatives panels. Comments from specialists in different disciplines can be incorporated into design development instantaneously. Figures 1, 2, and 3 illustrate some of the ways that Rapid-viz was used in this project.

Since the scope and goals of the project were broad and somewhat unrestricted, the project used a CMAR contracting method, which allowed the contractor to contribute to the design process. Participation from the contractor helped to ensure that the costs, schedule and constructability were reasonable and acceptable to the project stakeholders and that design goals were feasible to construct. The CMAR process also provided greater access to the local precasters in order to determine most effective solutions.

The project was funded through a unique public/private agreement. Maricopa County Department of Transportation, the City of Goodyear, and two private developers representing the neighboring housing developments participated in financing the bridge's construction cost. Because each contributor was allowed a role in the development of design aesthetics, conflicting concerns about cost, schedule, and aesthetics arose. The design charettes allowed involvement and contribution from all participating parties, resolving many differences early in the design process.



Figure 4: Drilled Shaft Load Test per Osterberg Cell Method

In an effort to achieve cost savings without compromising any of the stakeholders' interests, the team utilized creative cost saving strategies. Precast concrete was used where possible to

minimize construction time, cost, and adverse impact to the environment. Additionally, a static dilled shaft load test utilizing the Osterberg Load Cell was performed during early design as shown in Figure 4. Due to the higher reliability of the soil response obtained thru use of this load test, a reduced safety factor, as permitted by the AASHTO LRFD code (Ref. 2), was correspondingly permitted in design. Savings in the foundation far outweighed the cost of the load test and resulted in net savings of more than \$1M to the project.

Through a Clean Water Act Section 404 Individual Permit (IP), which is regulated by the U.S. Corps of Army Engineers, the bridge construction project now contains 859 acres of habitat enhancement mitigation measures to off-set construction impacts to the Gila River. This IP authorized the largest amount of construction related impacts in Arizona to date. The bridge project is also linked to the Flood Control District's Rio Salado Project, a habitat enhancement and flood control project. This project will enhance over 18 miles of riparian habitat along the Gila River Corridor while providing flood protection to the Town of Buckeye. The project will also decongest the river by removing not-native plants and restoring the Gila River to its natural state.

## CONTEXT SENSITIVE DESIGN

The County Transportation Engineer admonished the Design Team that what is done at this bridge crossing project would forever change the environment. He insisted that concept development be sensitive to the physical environment and biotic communities.

The design team introduced concepts of environmental and local landscape preservation early in design discussions. Dialog often centered around two questions: "How would nature build this?" and "How would nature help to achieve a desirable aesthetic result?" The charette process produced several ideas that shaped structural and aesthetic treatments. One element of the design aesthetic was inspired by the nature's own process of erosion. Stencil and sand blast techniques were used to reveal fossil-like patterns of prehistoric creatures and plants on columns. The same process was used for reveling contemporary life forms on the back of the traffic barrier, as shown in Figure 6. To achieve this weathered and eroded appearance on specially designed precast girders, designers used custom made form liners in girder production molds to reveal gecko patterns like the one shown in Figure 5. Since local aggregate was used for the cast-in-place concrete, the only paint used on the project simulated a stain that might be left on bridge piers after a major flood event originating in the upstream copper mining district.

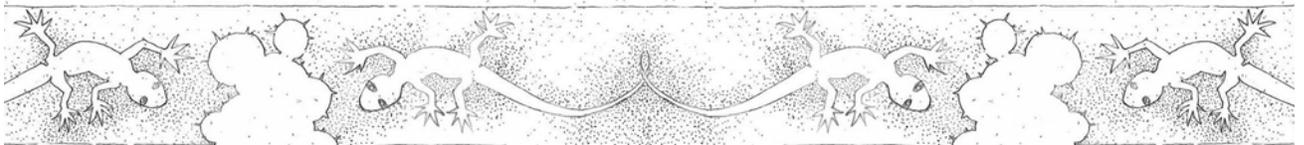


Figure 5: Preliminary Sketch of Life Forms to be Integrated within Girders

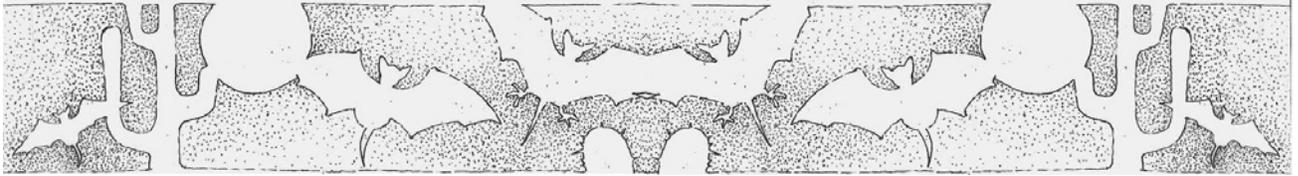


Figure 6: Preliminary Sketch of Life Forms to be Integrated within Traffic Barrier

Arizona's history is deeply connected with that of the copper mining industry in the United States. The region surrounding the Gila River, in particular, remains rich with copper today. As a means of incorporating copper into the design, a pale green shade, resembling oxidized copper, was used as an accent in many of the bridge's stains, including the railing (Figure 7) as well as the pavers off the bridge that comprise the median flatwork.

Desert storms produce sudden, often turbulent floods that can act as abrasive forces on bridges. Bridge piers were extended above the Gila's riverbed, and coated with a water-borne stain. The stain was the same pale green, oxidized copper shade as the other stained areas of the bridge.



Figure 7: Preliminary Sketch of Alcove with Copper Accents in Railing

In an effort to preserve motorists' view of the Estrella Mountains, the bridge was designed to have only a slight vertical curve, with no pier structures or light poles breaking the horizon. The addition of the minimized arch required less fill than that of a flat profile, and therefore, less harmful impact to the Gila River. Shortened light poles with low-intensity lighting were used to comply with the City's light pollution and "dark sky" ordinances, providing the effect shown in Figure 8.



Figure 8: Preliminary Sketch of Bridge at Night – “Dark Sky” Requirement

The bridge’s design was also driven by an awareness of the Gila’s River environment. Driving at 60 mph, drivers would have almost 30 seconds of viewing time on the bridge. Designers wanted barriers that would allow motorists and pedestrians to look at the riverbed. Design of the bridge included a series of alcoves and benches, as shown in Figure 9, inviting pedestrians to gaze at the river and enjoy the natural surroundings. The versatility of precast concrete made the addition of the alcoves feasible, with the alcoves’ concrete corbels serving as the false work system for the alcove slabs during construction. Pedestrian walkways were further enhanced with a design of native bats and cacti on the back face of the traffic safety barriers.

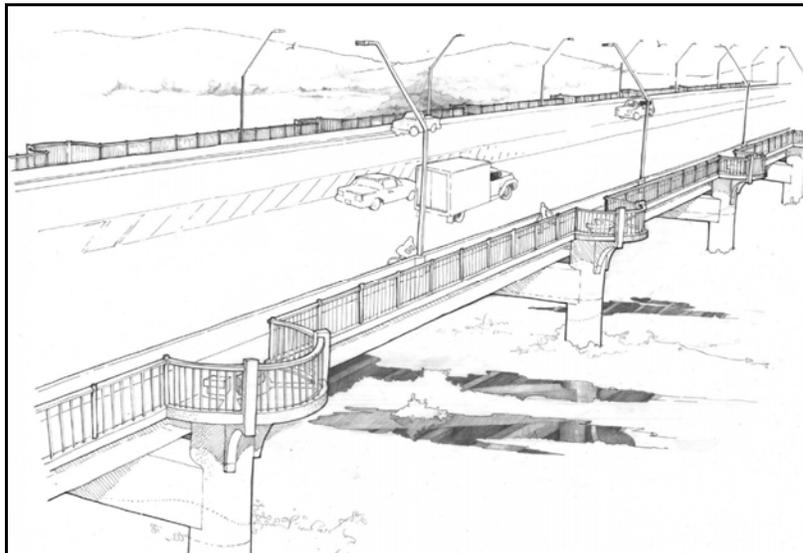


Figure 9: Preliminary Sketch of Bridge with Pedestrian Alcoves

## APPLICATIONS

A relief pattern was applied to the outboard faces of the exterior precast prestressed girders in order to reveal the gecko patterns shown in Figures 10 and 11. This resulted in unsymmetrical girder section, which required special design and detailing. During design of these girders, the design team worked with the contractor and local girder precasters to determine the most cost effective way to incorporate the form-liner into the girder prior to prestressing.



Figure 10: Exterior Girder with Embedded Gecko & Cacti Pattern



Figure 11: Construction prior to Deck Pour

Pier lines on both sides of the bridge feature half circle pedestrian alcoves supported by two precast curved corbels as shown in Figure 12. These alcoves are 9'-9" in radius and feature precast park benches. Eventually, the alcoves will also feature the work of local artists or informational plaques on the local history and environment. Inviting pedestrians to rest and view the natural surroundings, the alcoves allow the bridge to act as more than simply a conveyance over the Gila River.



Figure 12: Pedestrian Alcove with Precast Corbels

The alcove slab and adjacent sidewalk area feature exposed aggregate with stain. The exposed aggregate finish was achieved by sandblasting around the patterns after concrete placement. Further enhancing each alcove is a bat and cacti pattern, like the one in Figure 13, that is displayed on the back face of the F-barrier.



Figure 13: Relief Pattern on Back Face of Barrier

The pier columns received a treatment of stain and sand-blasted patterns, as Figure 14 shows. The stain on each column extends up to the 100-year storm elevation in order to suggest the abrasive and eroding capability of the floods over time.

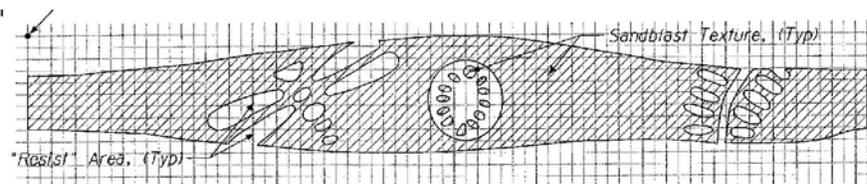


Figure 14: Stain and Pattern on Columns (Constructed Photo not available yet)

## CONCLUSIONS

From charrettes to construction, design of the Cotton Lane Bridge over the Gila River in Goodyear, Arizona, balanced the stakeholders' need for an attractive, functional, and pedestrian-friendly bridge with their concerns about environmental context and sensitivity. The collaborative nature of the conceptual design expedited the design process. Such concern for preservation of the local landscape influenced designers to use specific colors, materials, and textures, while the awareness of the Gila's River environment and inhabitants shaped the bridge's form. Above all, the versatility of precast concrete, from the modified exterior girders to the curved corbels at the alcoves, enabled and provided for a more cost efficient, environmentally friendly, quickly constructed and unique bridge.

## **REFERENCES**

1. Hanks, Kurt, "Rapid Viz, Third Edition, A New Method for the Rapid Visualization of Ideas", William Kaufmann Inc., 2006.
2. AASHTO 2004 LRFD Bridge Design Specifications, Customary U.S. Units, 3rd Edition, American Association of State Highway and Transportation Officials, Washington, D.C.

**ADVANCED AESTHETIC EMBEDMENT IN PRESTRESSED GIRDER**

**David J. Lawson, P.E.**, Michael Baker Jr., Inc., Phoenix, Arizona  
**Gregor P. Wollmann, Ph.D., P.E.**, Michael Baker Jr., Inc., Charleston, West Virginia

**ABSTRACT**

*For the recently completed Cotton Lane Bridge over the Gila River in Goodyear, Arizona, architectural form liners were embedded into the outboard face of the exterior modified AASHTO Type VI girders. The girders were modified by increasing the web thickness and by curtailing the top flange on one side to create a C-shaped section. The resulting deep outboard girder face received a relief pattern of lizards and cacti. The asymmetric girder cross section required a modified prestressing strand pattern. Due to the non-symmetry additional torsional shear stresses and weak axis bending were introduced. Increased torsional rigidity of the modified girder compared to the non-modified interior girders influences the live load and composite dead load distribution. Eccentricity between centroid of prestressing strands and centroid of section caused horizontal bowing. The unsymmetrical girder needed to be adequately braced during concrete deck placement to minimize both additional torsional stresses and non-uniform pressure on the bearing pads. The paper discusses these and other design issues as well as the construction of the Cotton Lane Bridge in detail.*

**Keywords**

Aesthetics, Concrete, Unsymmetrical, Prestressing, Precast

## INTRODUCTION

Design of the new Cotton Lane Bridge was driven by Goodyear, Arizona's rapid growth and suburbanization, and the resulting need to span the Gila River with an attractive, cost-efficient structure. In order to create a visually interesting structure, architectural relief patterns were cast directly into the prestressed concrete bridge girders. Each panel was embedded with a Southwestern-themed lizard and cacti pattern, eliminating the need to hang patterned panels after girder placement, and thereby decreasing construction time. This approach enhanced aesthetics without sacrificing economy. However, incorporating this pattern into prestressed girder sections increased the complexity of both the design and construction, as will be shown in this paper.

Recently constructed, the Cotton Lane Bridge over the Gila River is a 17 span, 2,067-foot long bridge with a bridge deck that is 114-feet wide. Each span measures approximately 122-feet from pier to pier, and consists of 12 girder lines spaced at 9'-5" centers. The cast-in-place deck is eight inches thick. Each pier was made from cast-in-place concrete and consists of a 5-foot wide pier cap, supported on four columns, each 5-foot in diameter which transition directly into drilled caissons that are 6-foot diameter. The outside face of all 34 exterior girders received a relief pattern of lizards and cacti, totaling approximately 4,080 linear feet. The ten interior girder lines consist of typical AASHTO Type VI modified prestressed girders. Figure 1 shows the modified exterior girder at the precast yard. Figures 2 and 3 are in-construction pictures taken at the job site.

The bridge owner is Maricopa County Department of Transportation and the general contractor is Peter Kiewit & Sons. The girder precaster is T-PAC.



Fig. 1 Exterior Girder at Precast Yard (After Stripping)



Fig. 2 Girder Placement at Job Site (Before Deck Pour)



Fig. 3 Exterior Girder at Job Site (After Deck Pour)

## DESIGN CONSIDERATIONS

This section examines the unique design considerations that are associated with using embedded form liners within prestressed bridge girders. The architectural pattern is 3'-6"

deep with  $\frac{3}{4}$  in. maximum relief depth. The inboard face of the girder has the same profile and dimensions as the AASHTO Type VI section. Web thickness was increased to 14-inch, which resulted in a 24-inch wide bottom flange and a 31-inch wide top flange. These modifications resulted in the C-shaped asymmetric section shown in Figure 4.

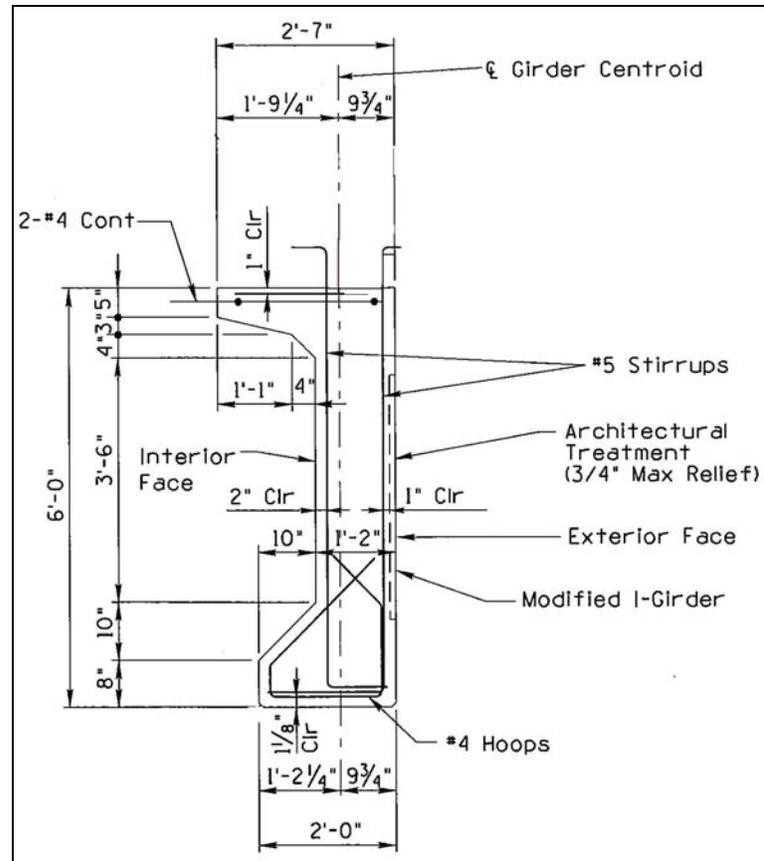


Fig. 4 Typical Cross Section

Due to the asymmetry, the principal axes do not coincide with the vertical and horizontal directions. The deviation is very small (less than 1.3 degrees) so that principal section properties do not differ much from the properties about the original axes. However, it is important that the applied moments are properly decomposed into principal axes components. Moments about the horizontal axes due to prestressing and dead load are large and thus cause appreciable moments about the weak principal axis which cannot be ignored for stress and deflection calculations. An additional complication is that the shear center is about 6-inch horizontally eccentric with respect to the centroid, which creates additional torsional stresses.

Figure 5 is the strand pattern that was used for these modified exterior girders. The girder is prestressed using 53 - 0.6-inch diameter 270-ksi low relaxation strands stressed to 202.5-ksi. Forty-one of these strands are straight, while the remaining twelve strands are harped with hold-down points located at a distance of 12-feet on either side of the midpoint of the girder.

Because of the draped pattern, debonding of strands to control stresses near the girder ends was not necessary. The specified 28-day concrete strength was 6,500-psi.

This asymmetric section required a modified prestressing strand pattern. The modified strand pattern shown in Figure 5 was chosen, in part, to minimize the horizontal eccentricity between centroid of section and center of gravity of prestressing. The final eccentricity was only 1/4 inch. However, even with such a small eccentricity the effects on girder stresses and deflections need to be accounted for in design due to the small stiffness of the girder about its weak axis.

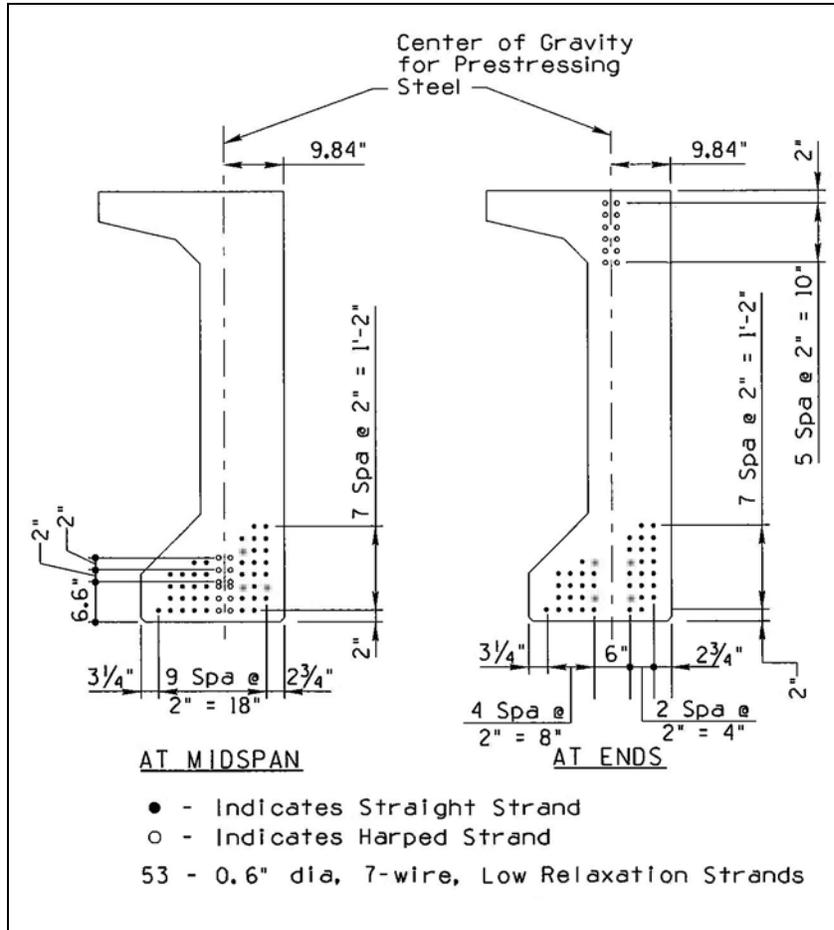


Fig. 5 Prestressing Strand Pattern

At various locations along the girder, additional tensile and compressive stresses reaching up to 300 psi resulted from the weak axis bending under prestressing and non-composite dead loads. These additional stresses, either tensile or compressive, were appropriately combined with the traditional stresses to ensure the code limits were not exceeded. For loads on the composite system the stiffness of deck and diaphragms prevents horizontal girder displacements, which justifies the common assumption that vertical and horizontal axes are principal directions of the composite edge girder.

Due to weak axis bending and principal axes rotation, horizontal bowing at transfer is much larger than for conventional, symmetric girders. For the Cotton Lane Bridge the calculated horizontal displacement at midspan under self weight and prestress was 1.70 in. on 119'-8" girder length. Because horizontal bowing can impact deck forming operations as well as intermediate diaphragm forming operations, the contractors needs to be informed of and plan for the anticipated horizontal bowing. This is best done by indicating the anticipated bowing at release on the contract drawings. The precaster is typically limited to a sweep tolerance of 1/8 inch per 10-feet of girder length (Ref. 1). If horizontal bowing is anticipated, then the tolerance limit should only be applied to the deformation difference from the anticipated value. Similarly to camber growth, horizontal bowing will grow with time due to creep until diaphragms in the completed structure restrain further growth.

Increasing the torsional rigidity of the modified exterior girder influenced both the live load and composite dead load distribution to the girder. The modified load distribution needs to be investigated and determined before the girder can be properly designed. Performing a grid analysis provides a more realistic estimate of how the live loads and composite dead loads will distribute to the girder lines.



Fig. 6 Girder Elevation with diaphragms

Per Reference 2 torsional rigidity does not significantly influence live load distribution as long as the moment of inertia is at least ten times greater than the torsional stiffness. For the Cotton Lane Bridge this requirement was just satisfied. However, in order to better understand the likely distribution of loads between the girder lines a grid line analysis was performed and compared to the AASHTO LRFD distribution factors. The grid analysis results were found to be within 10% of the AASHTO values and the AASHTO values were used for design.

Self weight and initial prestressing force introduced torsional shear stresses up to a maximum of about 90-psi, due to the approximately 6-in. eccentricity of the shear center with respect to the centroid of the section. Concrete diaphragms were installed prior to placement of the deck concrete in order to minimize the introduction of additional torsional stresses due to superimposed dead loads. The intermediate diaphragms were located at the third points between all girder lines and the end-bracing diaphragms were located five feet from the girder ends between exterior and first interior girders only (Figure 6). The location of the end-bracing diaphragms was selected to not interfere with the pier diaphragms, which were placed concurrently with the concrete for the deck.

These end-bracing diaphragms provided an added benefit in that they prevented rotation at the girder ends. By preventing this rotation, the non-uniform pressure on the elastomeric bearing pads was limited to that caused by the weight of the girders themselves.

### CONSTRUCTION CONSIDERATIONS

This section presents several of the unusual construction considerations that arose from the use of the C-shaped edge girders with embedded form liners and the on-going dialogue between the designer and the precaster from early design to construction.



Fig. 7 Unloading Girder at Job Site

In early design, the local precasters were contacted in order to discuss various aesthetic modifications to standard girder sections and to understand their constraints and limitations. For special projects such as this, a good relationship must be established between the designer and the precaster. Before deciding on the use of the C-shaped edge girders with embedded form liners, several other aesthetic enhancements were considered. Precast

patterned panels hung on traditional exterior girders were considered and dismissed because of the lesser aesthetic qualities (vertical joints between the panels) and long-term maintenance needs. Trapezoidal tub girders in lieu of AASHTO girders were considered and dismissed because of the high cost of purchasing the necessary steel forms.

One consideration associated with the C-shaped sections is that the modified girder was heavier due to the increased web thickness. Therefore, local precasters were contacted to determine the maximum efficient girder shipping weight. If a girder is too heavy, special transportation vehicles and hauling permits may be required, which will impact cost and time. Additionally, lifting devices need to be checked for adequacy. During the Cotton Lane Bridge project, the local precaster was able to accommodate and ship the 80 ton girders to the job site. Figure 7 shows the exterior girder being unloaded at the job site. Figure 8 shows the custom form created for the outboard face.

Once stripping is complete, the precaster must evaluate which way the girders will face while being stored in the yard prior to shipping. Girders should be oriented in such a way that bowing caused by environmental temperature changes are minimized. Further, the direction the girder is bowing due to the eccentricity between the prestressing and the section centroid should also be considered. The Cotton Lane Bridge spans primarily North-South which means the exterior girders on one side face East and face West on the other side. Once the girders were placed at the job site and prior to placing diaphragms and deck, the East facing exterior girders experienced additional bowing due to temperature differences. At night, the girders all cooled down. At sunrise, the outboard face of the East facing girders rapidly heated up while their inboard faces remained cooler causing the temperature difference and additional on-site bowing. Since the West facing girders did not experience direct sunlight exposure until the afternoon, there was not a large temperature difference between the inboard and outboard faces.

Any horizontal bowing will impact deck forming operations. The contractor needs to be informed of the anticipated horizontal bowing caused by the asymmetric exterior girders. By indicating the anticipated horizontal bowing on the plans, the contractor can properly account for it with respect to their deck forming operations.

The precaster and contractor should carefully evaluate and accommodate the requirements for lateral stability (Ref. 4) in combination with horizontal bowing with respect to girder shipping, picking, placing, and temporary stability before deck & diaphragm placement.



Fig. 8 Precaster's Custom Form for Outboard Face

## CONCLUSIONS

The recently constructed Cotton Lane Bridge over the Gila River in Goodyear, Arizona utilized artistic form liners embedded in the outboard face of the prestressed exterior girders. Even with the complexities resulting from using an asymmetric section, this architectural enhancement still proved economically reasonable.

Design needs to account for the rotation of the principal axes relative to the vertical and horizontal axes. Prestress and self weight induce significant moments about the principal weak axis which causes bowing and additional stresses. Additional torsional and thus principal stresses arise from the offset of the shear center relative to the centroid of the section. Finally, the C-section has greater torsional rigidity due to its thicker web which influences live load and composite dead load distribution.

The use of end-braces and intermediate braces (diaphragms) will limit torsional stress to that caused only by self weight and prestressing. End-bracing diaphragms placed prior to the pouring of the deck concrete provide the added benefit of preventing end rotation, which will, in turn, minimize non-uniform pressure on the bearing pads under the fascia girders.

The asymmetric section required a modified prestressing strand pattern. Any horizontal eccentricity between prestressing center of gravity of prestressing and section centroid will cause horizontal camber and additional flexural stresses through weak axis bending.

Major construction considerations on the Cotton Lane project included increased horizontal bowing due to temperature differences, transporting & lifting the heavier section and using due diligence with respect to lateral stability.

The tremendous versatility offered by precast and prestressed concrete makes the creation of an asymmetric section with embedded form liner quite feasible and practical from both a design and construction perspective. While hanging aesthetic precast panels on standard exterior girders is also quite feasible & practical, embedding the aesthetics into the exterior girder section prior to prestressing has the added benefits of increased aesthetics (no vertical joints between the panels) and elimination of long-term maintenance on the panels.

## REFERENCES

1. "Tolerance Manual for Precast and Prestressed Concrete Construction," MNL 135-00, Precast/Prestressed Concrete Institute, Chicago, IL, 2000.
2. Hambly, E.C., "Bridge Deck Behavior", John Wiley and Sons, Inc., New York, NY, 2<sup>nd</sup> Edition, 1991.
3. AASHTO 2004 LRFD Bridge Design Specifications, Customary U.S. Units, 3rd Edition, American Association of State Highway and Transportation Officials, Washington, D.C.
4. Mast, Robert F., "Lateral Stability of Long Prestressed Concrete Beams – Parts 1 & 2", PCI JOURNAL, V. 38, No. 1, January – February 1993