



ASBI



2015
"ASBI Bridge Award of Excellence"



“ASBI Bridge Award of Excellence”

2015

In recognition of the owners of bridges which exemplify concrete segmental bridge design and construction excellence.

In the eighth biennial American Segmental Bridge Institute (ASBI) Bridge Award of Excellence competition, six projects were selected as outstanding examples of segmental concrete bridge construction. Judging for the 2015 program was conducted via webinar at the ASBI office and hosted by Gregg Freeby, Bridge Division Director, Texas Department of Transportation.

All concrete segmental or cable-supported bridges located within the 50 United States and completed between January 1, 2013 and August 1, 2015 were eligible for the 2015 awards competition. The jury also considered international projects involving ASBI members. Entrants in the competition were judged on the basis of the following criteria:

- **Innovation of Design and/or Construction**
- **Rapid Construction**
- **Aesthetics and/or Harmony with Environment**
- **Cost Competitiveness**
- **Minimization of Construction Impact on the Traveling Public (When Applicable)**

Bridge Awards Jury



John Corven
Corven Engineering, Inc.



Gregg Freeby
TxDOT



Reggie Holt
FHWA, Office of Bridge
Technology

BRIDGE AWARD OF EXCELLENCE WINNERS:

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Awards are presented to bridge owners' representatives during the 2015 ASBI Convention Awards Luncheon, Monday, November 2 at the Omni Dallas Hotel in Dallas, Texas. Following are jury comments, project details, and participant credits for the winning entries (ASBI Members are noted in bold).

I-4/Selmon Expressway Connector

Innovation of Design and/or Construction

Innovations used in the design were:

- External post-tensioning which allowed reductions in the web thickness, principal stresses in the web, required shear reinforcement, and overall cost of the cantilever construction.
- Segmental concrete construction that significantly decreased the construction schedule.
- Erection of highly curved flyovers with horizontal radii of 570 feet over I-4 using the balanced cantilever method with segment lifters instead of large ground-mounted crawler cranes.
- Precast segmental construction method on highly skewed piers in the I-4 median to minimize cast-in-place construction.

Numerous innovative methods were used during construction to maximize efficiencies in safety, quality, and production, including:

- Top down erection equipment with custom segment lifters (self-propelled beam and winches) built specifically for this project were used where there was insufficient space for traditional ground based erection cranes, resulting in reduced lane closures and detours.
- Custom compact out-of-balance pier falsework towers combined with outboard stability prop towers were implemented to solve bridge construction challenges where existing features (structures, roads, railroads) were in close proximity of new bridge piers.
- Temporary PT bar stressing blocks were implemented throughout the segmental superstructure to increase construction efficiencies, resulting in time and cost savings when demolishing cast-in-place blocks that required removal.
- Bottom up concrete placement for construction of bridge piers using a high slump concrete and specialized formwork with valves spaced vertically along the column formwork.

Rapid Construction

Due to unexpected available funding, the consultants were asked to shorten Florida Department of Transportation's (FDOT) original design schedule. The consultants added design resources, allowing the completion of all design work three months ahead of FDOT's new schedule.

The original anticipated construction schedule was 1,065 days, which was 753 days ahead of the maximum 1,818 days in FDOT's Request for Proposals. The project team accomplished this by using eight casting machines to accelerate the fabrication of the bridge components. As many as six drilled shaft crews and multiple substructure crews were implemented to expedite the construction of the foundation and substructure elements. For segment erection, five balanced cantilever erection crews working day and night shifts and one span-by-span erection crew were used to reduce the overall project schedule. These crews, combined with state-of-the-art erection equipment, including mobile segment lifters for top-down erection, greatly exceeded production cycles originally anticipated. In addition, top-down erection equipment was used to minimize the number of lane closures and detours, which resulted in reduced impacts to the traveling public.

Photo Courtesy of PCL Constructors, Inc.

The \$426 million I-4/Selmon Expressway Connector provides a connection between Interstate 4 (I-4) and the Selmon Expressway in Tampa, Florida. This facility, which includes dedicated truck lanes, services approximately 10,000 trucks a day, reducing traffic on local city streets and improving safety. The Connector also provides additional route options for the traveling public, including convenient access to the Selmon Expressway from I-4, the Tampa cruise terminal, local beaches, Tampa International Airport, and flexibility for hurricane evacuation.



Photo Courtesy of PCL Constructors, Inc.

Jury Comments

The project demonstrated how segmental construction can provide obstruction free, fast and flexible bridge erection in a highly congested urban/environment. The Florida DOT should be commended for allowing the designers and contracting team to take every advantage that segmental construction affords to orchestrate the building of this very complex urban interchange within budget and schedule.



Aesthetics and/or Harmony with Environment

Nearly all of the required 75 right-of-way parcels involved remediation for contamination. Contamination cleanup, including remediation of dewatering operations, transpired concurrently with construction. The cleanup effort greatly enhanced the quality of the environment in and around Ybor City.

The project also included addressing impacts to McKay Bay Park, a valued Section 4(f) resource and environmentally-sensitive habitat for migratory shorebirds. A two-year coordination process with the City of Tampa and the Federal Highway Administration was required to obtain approval. The result was a reduction in pollutants discharging into the preserve. Stormwater management facilities were established to enhance untreated waters prior to entering McKay Bay and areas of Tampa Bay surrounding Port Tampa Bay.

The project team worked diligently with community agencies and business leaders to develop context sensitive and harmonizing architectural aesthetics which incorporated the brick and color patterns well established within the fabric of the Ybor City community, Palmetto Beach Historic Districts and Tampa's McKay Bay Park. This includes the historically-themed exterior treatment the 7th and 4th Avenues Gateway underpass facades, the toll plaza gantry and supporting structural members, and the retaining wall panel facades throughout the project.

Cost Competitiveness

The estimated construction cost was originally \$446 million. Through the alternative bid package process, the project was completed at a construction cost of \$429 million, resulting in a net savings of \$17 million.

Minimization of Construction Impact on the Traveling Public

The design teams preserved one bridge in the median of I-4 that was slated for demolition during a prior construction project. This bridge was used as construction access and also as a median diversion during construction of the bridges overhead, resulting in a reduced construction impact to the traveling public.

During construction, top-down span-by-span and balanced cantilever segment erection equipment and methods were implemented to minimize impact to the traveling public, the railroad, and to environmentally-sensitive areas of the project.

Overall, the community was extremely supportive of the project. FDOT received minimal complaints from the traveling public, nearby residents, or other parties during project construction.

CREDITS

Owner: **Florida Department of Transportation**

Designer: **Atkins, FIGG Bridge Engineers, Inc., and Parsons Brinckerhoff, Inc.**

Contractor: **PCL / Archer Western, a Joint Venture (PCLAW)**

Construction Engineering Services: **Corven Engineering, Inc. and McNary Bergeron & Associates**

Construction Engineering Inspection: **Cardno TBE, Johnson-Adams & Associates, LLC, and FIGG Bridge Inspection, Inc.**

Precast Producer: **PCL / Archer Western, a Joint Venture (PCLAW)**

Formwork for Precast Segments: **EFCO Corp.**

Erection Equipment: **Deal and Beijing Wowjoint Machinery Co.**

Post-Tensioning: **VStructural, LLC (VSL)**

Bearings: **COSMEC, Inc.**

Expansion Joints: **Watson Bowman Acme Corp.**

Epoxy Supplier: **Pilgrim Permocoat, Inc.**

Prepackaged Grout: **Euclid Chemical, Inc.**



Photo Courtesy of Aerial Innovations, Inc



San Francisco-Oakland Bay Bridge New East Span Skyway

Innovation of Design and/or Construction

The East Span comprises four interconnected structures: the 2,047-foot-long Self-Anchored Suspension Span (SAS); the 6,900-foot-long segmental concrete box girder Skyway viaducts (Skyway) that sweep up from the Oakland shoreline to connect with the SAS; the 4,229-foot-long Oakland Touchdown, which links the Skyway to California's Interstate 80; and the 1,542-foot-long Yerba Buena Island (YBI) Transition Structure that connects the SAS to the YBI tunnel.

The Skyway portion of the East Span is the bridge's longest component. The parallel eastbound and westbound viaducts carry 10 lanes of traffic in each direction, with 10-foot-wide shoulders to maintain traffic flow and a new bicycle-pedestrian path that enables users to enjoy panoramic views of the region.

The viaducts of the Skyway are three-cell, variable-depth, precast segmental box girders, erected in balanced cantilever, with a typical span of 525 feet. The 452 concrete segments for the Skyway box girders were cast in a special precasting yard and are the largest of their kind ever cast, each weighing up to 750 tons.

After being match cast and stored up to six months to reduce the effects of creep and shrinkage, the segments were barged about 70 miles to the Skyway construction site. Once on site, Self-Launching Erection Devices (SLEDs) were used to lift the massive segments up to 135 feet above the water and into place on the cantilevers. The SLEDs were set up and anchored to the cast-in-place pier tables. The first precast segment was hoisted up from a float barge and a cast-in-place closure was made between the pier table and the first segment. Once the pier table and segments were post-tensioned together, the SLEDs advanced onto the leading segment and were re-anchored. The next pair of segments were then erected and post-tensioned together. The process repeated, with the SLEDs advancing outward from the pier table until all pairs of segments of a typical cantilever were erected.

The balanced-cantilever method of construction was used for the Skyway to compensate for the high cost of constructing seismically-resistant foundations in the soft bay mud. Using this method, the variable-depth segments were erected in both directions, working outward from the piers, and allowed longer span lengths. While this method increased the cost of the superstructure, it reduced the number of spans and lowered the cost of the foundations.

The Skyway superstructure is divided by expansion joints into four frames, three with four piers and one with two piers. The frames are typically connected at midspan by a large hinge pipe beam measuring 6.5 feet in diameter and 60 feet long and are supported on circular bearings. The pipe beams are designed to not unseat during an earthquake, and are constrained against longitudinal movement in one cantilever and free to slide in the adjacent cantilever. This permits the bridge frame to expand and contract at the hinge locations. During an earthquake, the hinge pipe beams constrain the two parts of the structure to move together transversely and vertically, thereby limiting damage to the expansion joint above. In case of overstress, the midsection of the hinge pipe beam absorbs the strain, minimizing damage to the remaining length of the pipe beams.

Carrying 300,000 vehicles per day, the Skyway viaducts also required specially-designed expansion joints that could carry heavy traffic and reduce lane closures during repair procedures. While the expansion joints on the original bridge could only accommodate up to a few inches of movement during an earthquake, the expansion joints used on the new structure can handle up to several feet of movement.

After the 1989 Loma Prieta earthquake damaged the original East Span of the San Francisco-Oakland Bay Bridge, Caltrans determined that the safest, most cost-effective solution was a total bridge replacement. The new, 2.2-mile-long East Span of the San Francisco-Oakland Bay Bridge opened to traffic on September 2, 2013, and is one of the busiest toll bridges in the United States. The bridge is also a designated Lifeline Structure with a 150-year design life, and must be operational for emergency vehicles shortly after the strongest ground motions engineers can expect in a 1,500-year period.

Constructed using the balanced cantilever method, the Skyway incorporates the latest seismic-safety technologies. Each viaduct consists of four structural frames joined together by special hinges that can transfer shear and moment during seismic motion while allowing longitudinal movement. The Skyway decks are composed of precast concrete segments, the largest segments of their kind ever cast.

Jury Comments

Truly a landmark structure that is sleek, yet robust, and establishes a new gold standard in seismic performance for lifeline structures. With a 150 year design life it will impress generations to come. Massive precast segments, long spans, and durable post-tensioned concrete all within the most severe of seismic environments-absolutely impressive.



A battery of mock-ups was performed to verify constructability and circumvent challenges in the field, thereby maintaining and/or accelerating erection operations and reducing the risk of impacts to the schedule. While this method has been used to create secure foundations for offshore oil rigs, this is the first time the technology has been used for bridge construction of this scale.

Aesthetics and/or Harmony with Environment

The structure has a sleek aerodynamic form that minimizes its visual mass. The Skyway that ascends gracefully from the Oakland shoreline connects seamlessly with the parallel roadways of the SAS.

Aesthetic design flow can also be seen in the shape of the piers and the profile of the new bicycle-pedestrian path that “floats” alongside the eastbound Skyway structure. The 15.5-foot-wide path currently offers a scenic, 4-mile round-trip at steady 2 percent climb across the Skyway to the SAS, where the trail stops just west of the tower. The path also has benches at wider belvedere locations where users can enjoy panoramic views of the Bay Area without blocking traffic.

Because the San Francisco Bay is home to large, diverse communities of plant, fish and marine mammal life, the project team developed and implemented a comprehensive

program to safeguard the environment during construction activities. One innovation used during Skyway construction was the marine pile driver energy attenuator, which creates a dense shower of underwater bubbles. This “bubble curtain” protected fish and other marine life by enveloping the Skyway pilings and dissipating the shock waves produced by the energy from the pile-driving hammer. In addition, since certain bird species have roosted on the original bridge for decades, the team designed special nesting platforms under the Skyway, nicknamed “Cormorant Condos,” to provide nesting habitat in the same general area.

Minimization of Construction Impact on the Traveling Public

Although the East Span was a seismic engineering project, the structure also addresses local and regional transportation needs in several ways. From the onset, one of the most important project considerations was the need to keep traffic moving during construction. For this reason, the original bridge was kept operational until the new structure opened on Labor Day 2013. Major construction and demolition work was also scheduled during nights and weekends in order to minimize disruption to peak commute hours.

The design team also provided effective solutions for bridge repair after an earthquake. Not only does this save on costs, but it also minimizes disruptions to traffic on this vital infrastructure link. As a notable example, the hinge pipe beams in the Skyway decks, which protect the main structures from damage during an earthquake, also permit simpler, faster, and more economical repair procedures. After a seismic event, and if needed, any damaged beams can be removed and replaced, saving on repair costs and enabling the viaducts to remain operational during repair procedures.

All Photos Courtesy
of T.Y. Lin International

CREDITS

Owner: **California Department of Transportation (Caltrans)**

Owner’s Engineers: **Ade Akinsanya**

Designer: **T.Y. Lin International / Moffatt & Nichol, Joint Venture**

Contractor: **Kiewit / FCI / Manson, A Joint Venture**

Construction Engineering Services: **Parsons Transportation Group**

Constructability Review/ Estimating Services: **California Department of Transportation (Caltrans)**

Construction Engineering Inspection: **California Department of Transportation (Caltrans)**

Precast Producer: **Kiewit / FCI / Manson, A Joint Venture**

Formwork for Precast Segments: **Deal**

Form Travelers for Cast-in-Place Segments: **Schwager Davis, Inc.**

Erection Equipment: **Schwager Davis, Inc.**

Post-Tensioning: **Schwager Davis, Inc.**

Bearings: **D.S. Brown Company**

Expansion Joints: **D.S. Brown Company**

Epoxy Supplier: **Sika USA**

Prepackaged Grout: **Sika USA**



The reconstruction of Section 5 Palmetto SR 826/836 Interchange will create safer and less congested travel for 430,000 vehicles traveling through the interchange daily.

This \$559 million design-build-finance project involves the construction of an Interchange between SR 826 and SR 836, two limited access facilities, as well as the reconstruction of SR 826 at Flagler Street and SR 836 at NW 72nd Avenue interchanges. Capacity improvements include the reconstruction and widening along both SR 826 and SR 836, and the construction of 46 bridges. The project will provide new direct connector ramps for major improvements and collector-distributor ramps to eliminate existing geometric and operational deficiencies.

Four high-level precast segmental bridges traverse the core of the interchange and form the centerpiece of the intersection. These bridges are 46 feet wide and range in length from 31,100 feet to 2,450 feet. Total deck area is 360,718 square feet, with 7,764 linear feet for the segmental bridges. The longest span is 266 feet, the tallest pier is 81 feet and there are 783 total segments.

The curved segmental bridge ramps are the third level of the interchange with radii down to 590 feet and a proposed maximum superstructure deck height of 95 feet above ground. All of the bridges are supported on 24 inch pile foundations and reinforced concrete piers and caps.

Section 5 Palmetto SR826/836 Interchange (Bridges 9, 11, 15, and 19)

Innovation of Design and/or Construction

Design innovations reduced construction costs by nearly \$100 million dollars. The redesign reintroduced three points of access to the Expressway that would have been lost in the original design plan, a much-preferred option for the Florida Department of Transportation (FDOT) and the area's traveling public. **Three out of four Alternative Technical Concepts (ATCs) were accepted for segmental bridges:**

1. FIRST USE OF DIABOLOS IN THE STATE.

FDOT allowed diabolos for the first time based on the advanced design and demonstration of their successful application on segmental bridges in other states. Traditional bent steel pipes were eliminated, segment weight was reduced allowing for variable tendon geometry and continuous external tension ducts. External tendons will reduce future maintenance costs through improved future access for tendon replacement, as well as upgrading and stressing of any single strand inside the box.

2. HAUNCHED SEGMENTS. Increased in span lengths reduced the amount of temporary supports adjacent to the highway and simplified the design of the interchange. Expansion joints were eliminated. This also increased the efficiency of post-tensioning and provided the capacity to support the launching gantry.

3. POLYSTYRENE HOLLOW PIER COLUMNS.

Use of Polystyrene in the hollow pier columns cores (except for solid bases and caps) eliminated the need for interior formwork, thereby reducing the amount of concrete material and overall mass of the structure.

Other innovations:

• **PIER CAPS.** The pier caps were designed to support the balanced cantilever during construction, and include loop tendons through the caps to tie down the launching gantry and curved balanced cantilever superstructure. In addition to their vital functional role in the construction process, the pier caps contribute to the overall aesthetics, an important factor considering the prominent location of the interchange.

• **NON-TRADITIONAL SHAPED PIERS.** Using non-traditional shaped piers, adjusting the footing size to accommodate conditions, and increasing span lengths all helped improve maintenance of traffic sequencing, which was critical to accelerating the project schedule. Advance planning for building the foundation, for what would be the last segmental bridge, much earlier in the schedule was another critical aspect.



All Photos Courtesy of FDOT

Jury Comments

Great solution in a difficult urban environment. Proportioning piers caps to accept temporary jacks for cantilever stability during construction was an innovative way of eliminating temporary stability towers, reducing impacts to the motoring public. Rapid construction completed 4½ years ahead along with significant cost savings proves once again, segmental is a competitive structure type. First use of diabolos in Florida was proven successful.



Rapid Construction

The design-build team realized that the critical path depended on speed of construction of the high-level segmental bridges. Most notable and significant among these design solutions was the decision to build the four segmental bridges “from the top down.”

- Use of a 460-ft. self-launching overhead gantry to build the precast segmental bridges in balanced cantilever over the core of the interchange reduced the need for temporary supports on the ground and segments that were stabilized off the pier caps.
- The casting yard was located 8 miles away from the project and transportation time of the segments ranged from 30 to 90 minutes.
- Three casting machines were utilized, one for pier and expansion segments, and two for typical segments. There were no rejected segments.
- Equipment and construction had to move fast and Quality Control was a key to keeping the project on the critical path. The engineer of record for the high-level segmental bridges understood these challenges and built the design into the construction methodology.

Aesthetics and/or Harmony with Environment

The bridge design, which included haunched segments, met a major project goal - strong aesthetic requirements.

The segmental bridge design is highly-aesthetic and features mechanically stabilized earth (MSE) walls. Multi-color, Energy Star LED lighting that are mercury-free, long-lasting and economical will be added to the four high level segmental bridges to enhance the stunning architectural details at night.

Cost Competitiveness

- \$332.67 per square foot.
- Segmental bridge costs: \$120 million.
Total deck area: 360,718 sq. ft.

Minimization of Construction Impact on the Traveling Public

The design offered unique challenges integrating underlying roadways, canals and Maintenance of Traffic (MOT) requirements into the layout of these segmental bridge ramps. Nightly road closures were implemented to allow for erection of segments (11PM – 5AM).

This project was constructed in the Miami International Airport flight path and had FAA Requirements. The high level segmental flyovers are built over multiple roads that carry 430,000 vehicles per day and are the tightest elevation curves erected in the United States. The all overhead erection method eliminated the need for falsework and cranes, as well as 5 MOT phases that would have impacted traffic, while providing a safer work environment.

CREDITS

Owner: **Florida Department of Transportation**

Owner's Engineers: **AECOM Technical Services** and **EAC**

Designer: **BCC Engineering, Inc.** (Prime Design Consultant) and **Finley Engineering Group, Inc. (Segmental Bridge Design)**

Design-Build Team: **Community / Condotte America, Inc. / De Moya JV, BCC Engineering, Inc., and Finley Engineering Group, Inc.**

Contractor: **Community / Condotte America, Inc. / De Moya JV**

Construction Engineering Services: **Finley Engineering Group, Inc.**

Construction Engineering Inspection: **AIM Engineering & Surveying, Inc., and Eisman & Russo, Inc.**

Precast Producer: **Rizzani de Eccher**

Formwork for Precast Segments: **DEAL**

Erection Equipment: **DEAL**

Post-Tensioning Materials: **VStructural, LLC (VSL)**

Bearings: **D.S. Brown Company**

Expansion Joints: **D.S. Brown Company**

Epoxy Supplier: **Sika Corporation and Pilgrim**

Prepackaged Grout: **The Euclid Chemical Company**





Photos Courtesy of Tri-County Metropolitan Transportation District of Oregon

In December 2014, construction was substantially completed on Tilikum Crossing Transit Bridge, a new concrete cable-stay bridge crossing the Willamette River in Portland, Oregon. The first of its kind in the U.S., the cable-stayed transit-only bridge will carry light rail trains, buses, pedestrians, bicyclists, and future streetcars. Named Tilikum Crossing, "Bridge of the People," the landmark bridge is the feature component and vital element of the Portland-Milwaukie Light Rail Transit Project to reduce congestion and provide efficient travel along the 7.3-mile light rail corridor connecting downtown Portland, the South Waterfront, the City of Milwaukie, and North Clackamas County.

Tilikum Crossing Transit Bridge

Innovation of Design and/or Construction

Design and construction innovations were the key to success for this design-build project. The team designed tower foundations that retained the required aesthetic while reducing the footprint and number of deep shafts in the river, using a sophisticated testing program to prove shaft capacities well in excess of standard design values. The high seismic environment and liquefiable, contaminated soils were a particular challenge that gave the team a competitive edge: our integrated seismic design avoided removal and disposal of hazardous material and ground improvement by engaging the continuous superstructure to transfer seismic demands from the liquefiable banks to the stiff main piers.

The team drew upon their collective segmental experience to develop a cast-in-place erection system that used conventional form travelers and temporary stay cables for casting in half-segment lengths. The team also used stay cable technology to provide a replaceable tie-down required for the extreme train loading-induced uplift in the back spans. The slender tower design incorporated the first domestic application of contemporary saddle details for a transit bridge, requiring special erection controls for cantilever construction and staged stay installation. The team had a particular challenge with a stepped navigation clearance across the main span that led to an innovative split-edge girder stay anchor, recessing the entire anchorage within the soffit of the deck that added the necessary 2 ft. of clearance.

Rapid Construction

Construction of Tilikum Crossing defined the critical path for opening the client's entire light rail line. Parallel hazardous material remediation by the property owner on the west shore complicated access and scheduling at the outset of the project. The design-build team partnered with the client from notice-to-proceed, meeting on a weekly basis to advance schedule throughout the project. The team took advantage of the design-build format to advance construction of the main river piers while completing design of the superstructure. Cooperation and coordination between the contractor, designer, reviewers, and client were vital to success, in part by review of the foundation design innovations that led the project activities, and that had to be choreographed with the in-water work windows in the Willamette River. Form traveler-based construction was accelerated by casting on both towers in parallel. As a result, the project was finished six weeks ahead of schedule, allowing added time for the client to test systems and safely train operators.

Aesthetics and/or Harmony with Environment

The bridge is now the brightest star in the family of Portland bridges. With some celebrations past, there are more to come as the city boasts of its new icon. Images of the bridge with Mt. Hood in the background have already been the subject of architectural conference, and the bridge is featured in images of the city, occupying a key position in local literature. In addition to complying with the challenging environmental regulations related



Jury Comments

Great example of the competitiveness of segmental bridges in a design-build environment. Highly aesthetic cable-stayed structure with special attention given to pedestrian access. Showcases how a segmental solution can provide both strength and slenderness for long-span cable supported bridges. This bridge is outstanding in so many ways. The design-build team finessed every detail in producing a great technical achievement with iconic aesthetics. From the segmental industry's perspective, this project further demonstrates the applicability of segmental and cable-stayed bridge construction for a wide variety of transit projects.



to construction in a prime salmon river, the team's design innovations for reducing foundation size and eliminating handling of hazardous waste were a major enhancement to the project's environmental footprint. And certainly, the very purpose of the bridge as a public transit facility is heralded for reducing the carbon footprint of the transportation system in the Portland region.

Cost Competitiveness

The client placed great value on the high aesthetic content of the design, and used the design-build delivery format to get maximum value for the most competitive cost. The project was delivered under budget and within the original schedule requested by the client. A few unexpected challenges, such as extended third-party permit reviews and approvals and revisions to aesthetic guidelines, threatened to increase the budget and

schedule. However, for each occurrence, the team partnered with the client to re-sequence construction, add resources, or modify the design review schedule to keep the project on target.

Minimization of Construction Impact on the Traveling Public

Construction access for personnel and materials was in downtown Portland, requiring continuous coordination with numerous local stakeholders and downtown commuters. However, the major mitigations for travel impacts were associated with river traffic and the heavily used Springwater Corridor trail on the east shore. The team coordinated marine activities with operations of Portland Spirit River Cruises, whose adjacent dock had to remain operational throughout the project.



Photo Courtesy of Steve Shanow

CREDITS

Owner: Tri-County Metropolitan District of Oregon

Owner's Engineer: **HNTB Corporation**

Designer: **T.Y. Lin International**

Design-Build Team: **Kiewit Infrastructure West Co.**

Contractor: **Kiewit Infrastructure West Co.**

Construction Engineering Services: **T.Y. Lin International**

Construction Engineering Inspection: **Cooper Zietz**

Formwork for Precast Segments: **Kiewit Infrastructure West Co. (Supplier)** and Parkin Engineering (Inspection)

Form Travelers for Cast-in-Place Segments: **Kiewit Infrastructure West Co.**

Erection Equipment: **Kiewit Infrastructure West Co.**

Post-Tensioning Materials: **Schwager Davis, Inc. (Supplier)** and Liberty Steel (Installation)

Stay Cable Materials: **Freyssinet**

Bearings: **R.J. Watson, Inc.**

Expansion Joints: **Watson Bowman Acme Corp., STV Inc./Atlantic Track**

Prepackaged Grout: **Williams Form Engineering Corp.**

The new U.S. 281 Bridge over the Colorado River replaces a functionally obsolete steel truss bridge with a 958' long segmental bridge. The bridge design by the Texas Department of Transportation (TxDOT) along with design innovations from the Contractor-Engineer team created a highly aesthetic bridge with a minimal footprint in the water. The bridge was completed on October 9, 2014.

U.S. 281 is a major north-south highway from Wichita Falls to San Antonio and serves as an important evacuation route and emergency services access for the area. Factors leading to selecting a cast-in-place segmental design include:

- The nearest river crossing detour is located 30 miles north.
- Limited site access and right-of-way due to adjacent businesses and utilities restricting an alignment change.
- Active recreational lake traffic in the area that is reliant on tourists.
- High local regard for the look of the old truss bridge.

There are 24 concrete segments per cantilever, with 48 segments total per bridge. Each segment measures 14' to 16' long and 47' wide. The variable segments sport a unique tapered boat hull design in the bottom slab, an aesthetic treatment that matches the community's focus on recreational boat racing. The segments have a box depth that ranges from 23' at the interior piers to 9'5" at the end spans, with a variable superelevation up to 5.5%. Each segment weighs a maximum of 150 tons.

U.S. 281 Bridge Over Colorado River

Innovation of Design and/or Construction

- The major changes proposed by the Contractor-Engineer team included revising the pier table design, segment layout and post-tensioning specifications. The design modification called for an unbalanced design (22' x 14' from centerline of column). This required less falsework, and only two temporary supports during construction on a reduced schedule.
- Temporary shoring for the prop drilled shafts which were incorporated into the pier table falsework.
- The transverse and longitudinal post-tensioning was modified to utilize 4 strand tendons at 2'9-1/2" spacing. This modification saved on duct, heads, grout, caps and allowed for smaller stressing anchors in some areas.
- While reducing the length of each segment required more segments, the process of pouring each segment using the form travelers was optimized, and required less labor-intensive falsework to be built.
- Cofferdams could not be used due to hard limestone rock at the bottom of the lake, close proximity to the existing bridge, and the need to maintain an open water channel for boating traffic. The design modification called for drilling shafts into the rock riverbed and lowering an on-site precast concrete footing form to accommodate the forms and the work platform.



Rapid Construction

- The structures were built with two form travelers using balanced cantilever construction, with end segments constructed on falsework.
- The modified pier table length allowed for a significant reduction in falsework. The unbalanced design also eliminated the need for a stability prop on both sides of the pier. This reduced approximately 12 weeks off the construction schedule and maintained the horizontal clearance envelope throughout construction.
- Since it was desirable to limit the drilling in the water, the Contractor's Engineer developed an innovative approach for the pier table falsework and stability prop design. The prop also served as the support for the main pier table falsework beams.
- The Contractor's Engineer used Bridge Information Modeling (BriM) which made it possible to develop details quickly to meet the demanding schedule.

Jury Comments

Reused form travelers from another project resulted in cost and time savings. Highly aesthetic shape in an area with heavy recreational boat traffic. Innovative precast footing box allowed footings to be placed below the waterline without cofferdams. The perfect fit to meet this project's diverse demands of the traveling public, local environment, and surrounding community. The boat-shaped hull bottom slab, tapered piers, absence of visible foundations, and lighting have combined to produce a beautiful bridge day or night.



Aesthetics and/or Harmony with Environment

- The public was very sensitive to the aesthetics of this bridge since the lake is also used for recreation.
- The variable segments feature a unique tapered boat hull design in the bottom slab, an aesthetic treatment that matches the community's focus on recreational boat racing. A flared column design with a seamless transition between the pier and pier table required a custom built form poured in two pieces, with 6' of column base, 3' under the normal water level.
- To maintain a minimal footprint, traditional footing was not used. Pier table falsework was designed with bolted connections to ease installation and removal. Drilled shafts were designed to stop at the mud line. The props incorporated sand jacks to aid in removal by slowly relieving the 1000 kip per leg load.

Cost Competitiveness

The Contractor secured two form travelers that met the specifications for this project which resulted in cost savings of \$750,000 and several month's reduction to the schedule for design and fabrication of new travelers. These and other design modifications met all the goals of the project providing approximately \$2 million savings, 5% below the TxDOT estimate.

- Cost per square foot is \$206.74

Minimization of Construction Impact on the Traveling Public

Since the closest river crossing was over 30 miles away, this bridge crossing had to remain open continuously, requiring phased construction.

CREDITS

Owner: **Texas Department of Transportation**

Owner's Engineers: **Texas Department of Transportation Bridge Division**

Designer: **Texas Department of Transportation and Finley Engineering Group, Inc.**
(Alternative Superstructure Design and Construction Engineering)

Contractor: **Archer Western Contractors**

Construction Engineering Services: **Finley Engineering Group, Inc.**

Constructability Review/Estimating Services: **Archer Western Contractors**

Construction Engineering Inspection: **Texas Department of Transportation**

Formwork for Precast Segments: **Doka USA, Ltd.** (Cast-in-Place Segments)

Form Travelers for Cast-in-Place Segments: **VStructual, LLC (VSL)**

Post-Tensioning Materials: **VStructual, LLC (VSL)**

Bearings: *Dynamic Rubber*

Expansion Joints: **CMC Capital City Steel**

Prepackaged Grout: **Masterflow 1205**

Roadway and Hydraulic Design: **Jacobs Engineering, Inc.**

All Photos Courtesy of Archer Western Contractors





Caijia Bridge

Located close to the center of China, Chongqing is the largest of the country's four municipalities, with a population of approximately 32 million people. For the past three decades, China has been pursuing a policy of relocating close to 80% of its impoverished rural population to existing cities or new urban centers being constructed to accommodate them. Roughly 10 million people have been moved to urban areas to date, making extensive infrastructure projects an imperative. While numerous new roads and bridges have been built, the problems of traffic congestion, due in part to increased private vehicle ownership, and pollution persist. In response, Chongqing officials have been planning to construct an extensive mass transit network.

One of the highest metro line bridges in the world at close to 100 meters above water level, the Caijia Bridge is one of Chongqing's most recent rail-only bridges. Passengers can now make the expedited trip from Beibei to the Chongqing city center in about 40 minutes, a tremendous improvement considering that a bus or automobile trip could take hours in the past. Each six-car train can carry 1,410 passengers, reducing traffic congestion and lowering exhaust emissions generated by vehicular traffic. The Caijia Bridge has also become a much-admired city landmark, and has already contributed significantly to the development of the northwestern area of this fast-growing municipality.

Innovation of Design and/or Construction

The 1,240-meter-long Caijia Bridge was designed to have a 640-meter-long main section that consists of five spans. The main span is flanked by end sections: a southern end section comprising two 45-meter-long spans and a northern end section with six 60-meter spans and three 50-meter spans. Under a 100-year flood, the water level of the Jialing River can also rise to an elevation of 198.43 meters, or about 30 meters above the normal 168.87-meter level. As a result, the main-span girder is located 100 meters above the normal water level.

The majestic towers of the Caijia Bridge ascend 186 meters from the top of the pile cap, with 105 meters below the deck and 78 meters above it. The two legs of the lower portion of the towers are connected to form a box cross section that extends above the highest high-water level. This enables the lower portion of the tower to better withstand vessel impacts, using the impact of a 1,000-ton barge as the criterion.

The tower cross beam is prestressed to overcome the tensile force created by the horizontal components. The upper portions of the tower legs have cross-sectional dimensions of 2.80 meters (transverse) by 6.0 meters (longitudinal). The lower portions of the legs vary in dimensions from 2.0 by 6.0 meters at the deck level to 4.0 by 9.0 meters at the bottom. At the top of the pile cap, the tower is 12.24 meters wide in the transverse direction.

A double-plane arrangement for the cables was chosen to give the bridge a more robust appearance. The cables are spaced 8.0 meters apart at the deck. A transverse beam at each cable location brings the cable forces from the edge of the deck back to the girder box. These transverse beams are 0.5 meters thick and 1.5 meters deep at the centerline of the box. All are made of prestressed concrete.

The bridge girder has a single-cell box cross section and a constant depth of 3.5 meters over the entire five-span main section. The deck is 15 meters wide, including two 4.7-meter-wide tracks, two 1.3-meter-wide maintenance paths, and two 1.5-meter-wide cable anchorage zones.

The bottom of the box is 8.0 meters wide. In a typical section, the webs are 0.50 meters thick and the bottom slab is 0.3 meters thick, a haunch on each side tapering to 0.5 meters at the inner face of the web. At the north approach spans, the deck widens from 15 meters to 18.09 meters to accommodate the curvature of the tracks.

Rapid Construction

The bridge girder has a single-cell box cross section and a constant depth of 3.5 meters over the entire five-span main section. The deck is 15 meters wide, including two 4.7-meter-wide tracks, two 1.3-meter-wide maintenance paths, and two 1.5-meter-wide cable anchorage zones. The box girder in the cable-stayed portion was constructed segmentally using form travelers to expedite construction. The segment length was 8.0 meters to match cable spacing. After each segment was completed, a cable pair was installed, one cable on each side of the deck. The box girder was prestressed longitudinally and transversely, and the slab atop the girder was prestressed transversely. The construction cycle for each segment averaged 12 days.

The side and approach spans were constructed using a self-advancing underslung truss. To facilitate the advance of the truss, the middle portion of each pier top was hollowed out and the box girder was cast on top of the truss. After each span was placed and prestressed, the truss was advanced to the next span. Construction of each span took approximately 25 days on average.

The towers were constructed using jump forms, with C50 concrete (cube compressive strength of 50 MPa,

Jury Comments

Challenging design requirements for limited live load deflections were met by combining segmental with cable-stayed technology demonstrating how a segmental bridge solution addressed the unique demands for a heavy rail bridge structure. In addition to outstanding aesthetics, the engineering team should be commended for the rigor required to analyze and design this cable stayed bridge built using cast-in-place balanced cantilever construction. Special studies of this light rail transit bridge with direct fixation track included rail-structure interaction, dynamic response of the bridge for the moving transit loads, and wind studies that included the rolling stock.



CREDITS

Owner: **Chongqing Rail Transit Group Co., Ltd.**

Owner's Engineers: **T.Y. Lin International**

Designer: **T.Y. Lin International**

Contractor: **China First Highway Engineering Co., Ltd.**

Construction Engineering Services: **T.Y. Lin International**

Construction Engineering Inspection: **Chongqing Construction Science Research Institute**

Form Travelers for Cast-in-Place Segments: **China First Highway Engineering Co., Ltd.**

Erection Equipment: **China First Highway Engineering Co., Ltd.**

Post-Tensioning: **Liu Zhou OVM Machinery Co., Ltd.**

Stay Cable Materials: **Liu Zhou OVM Machinery Co., Ltd.**

Bearings: **Chengdu Xinzhu Road & Bridge Machinery Co., Ltd.**

Expansion Joints: **Chengdu Xinzhu Road & Bridge Machinery Co., Ltd.**

Epoxy Supplier: **Liu Zhou OVM Machinery Co., Ltd.**

equivalent to a cylinder compressive strength of about 39 MPa) mixed at the jobsite. A temporary work bridge was built to pump material from the shore to the tower location and for constructing the bridge girder.

Anchored in the box section of the tower legs are the upper ends of the 112 cables used on the Caijia Bridge. Installation began with the external pipe. Strands were then pulled, one at a time, from the lower end to the upper end and stressed individually. A lead strand was installed first, and the force in this strand was monitored by a gauge. Each subsequent strand was then stressed to the force indicated by the first strand. After installation of all strands, the force in the entire cable was adjusted to the specified force with a single hydraulic jack.

The cables comprise 15.2-millimeter-diameter, seven-wire strands with a breaking strength of 1,860 MPa. Each cable strand is encased in its own high-density polyethylene pipe to enable individual replacement and ensure that the cable force in each can be adjusted in the future without interrupting traffic. Individual strands are further protected by an outer pipe of high-density polyethylene.

Aesthetics and/or Harmony with Environment

The Caijia Bridge is located at the northeastern part of Chongqing, a region slated for development as a new business center. This region is also one of the municipality's most scenic, featuring hot springs, recreational facilities, and a beautiful, rolling landscape that attracts hikers. Because of this, bridge design aesthetics were considered of significant importance.

The cable-stayed design incorporating segmental construction offers the advantages of both a visually appealing profile and the appropriate deflection control. The cable forces can also be adjusted anytime in the future, if required, making it possible to adjust the elevation of the girder.

Cost Competitiveness

The construction cost of the entire bridge was 251 million yuan (roughly \$38 million). This amounts to an average of \$189 per square foot of deck area.

All Photos Courtesy of T.Y. Lin International



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