THE DAVID KREITZER LAKE HODGES BICYCLE PEDESTRIAN BRIDGE

by Tony Sanchez, T.Y. Lin International

The Lake Hodges Stress Ribbon Bridge. All Photos: T.Y. Lin International.

On May 15, 2009, the world's longest stress ribbon bridge opened in San Diego, California. The David Kreitzer Bicycle Pedestrian Bridge uses high-strength cables embedded in an ultra-slender concrete deck to span nearly 1000 ft across Lake Hodges, and it does so with grace and respect for the site and sensitive lake habitat.

Unique Design

The stress ribbon bridge type is unique regionally as there are only six examples in North America and only about 50 worldwide. At Lake Hodges, it has proven to be the perfect bridge for the site. Prior to Lake Hodges, a stress ribbon bridge of this length had never before been constructed.

At Lake Hodges, the stress ribbon enabled the long spans required for a three-span design. With spans of 330 ft, it gracefully stretches 990 ft between abutments with only two piers in the lake. And it does this with a deck that is only 16 in. thick. The result is a thin ribbon of concrete with an amazing depth-to-span ratio of 1:248.

Asset to the Community

The bridge provides a crossing for hikers, cyclists, joggers, and bird watchers and allows access to the extensive trail system on the north and south shores of the lake. It provides a significant enhancement to the region by adding both a transportation and recreational resource. By eliminating a 9-mile detour in the system and improving public access to surrounding trails and recreational facilities, the bridge has become a vital link in the 55-mile-long Coast to Crest Trail within the San Dieguito River Valley Open Space Park.

The bridge also provides a safe crossing for bicycles. Prior to the bridge, bicycle commuters had to cross Lake Hodges on the shoulder of the busy I-15 freeway, which posed a safety concern. Now these commuters use the new bridge to safely cross the lake on a dedicated path away from vehicular traffic.

Design Complexities

Although the bridge is simple in appearance, its analysis and design were very complex. Since the bridge behaves as a cable, it is geometrically non-linear. This made linear-elastic analysis—the standard for most bridges—inappropriate. Since the bridge was constructed segmentally, a stage construction analysis was required to track the stresses that were locked in during construction. Further, since the bridge is made of concrete that is post-tensioned and has no expansion joints, the bridge accommodates expansion and contraction by a rise or fall of each span. Thus, the effects of concrete creep and shrinkage and thermal loading were critical. These effects were accounted for by performing a time-dependent creep and shrinkage analysis that included thermal loading.

The bridge was modeled stage by stage to represent the construction sequence, and then live load, temperature, and wind loads were applied. Next the analysis stepped through 50 years of creep and shrinkage and the loading process was repeated. In the end, the critical load case was 50 years of creep and shrinkage plus live load on all three spans and a temperature drop of 35 °F.

A dynamic analysis was performed to evaluate the bridge under wind, seismic, and vibrational loads. A detailed wind study was performed, which included wind tunnel testing. Critical in the wind study was the torsional response of the bridge, which can be excited through buffeting as strong winds pass transversely over the deck. The results showed the bridge would be stable at the maximum wind speed of 85 mph predicted for the site.

The results of the seismic analysis showed the bridge would stay elastic under the maximum credible earthquake. This is surprising for a bridge in California, but somewhat intuitive for the stress ribbon design. With a 16-in.-thick deck, this bridge has relatively low mass, and is restrained laterally by 12 large cables. In essence, the structure is one large seismic cable restrainer.

profile

DAVID KREITZER, LAKE HODGES BICYCLE PEDESTRAIN BRIDGE / SAN DIEGO, CALIFORNIA

BRIDGE DESIGN AND CONSTRUCTION ENGINEER: T.Y. Lin International, San Francisco, Calif.

INDEPENDENT CHECK ENGINEER: Jiri Strasky, Greenbrae, Calif.

ARCHITECT: Safdie Rabines Architects, San Diego, Calif.

PRIME CONTRACTOR: Flatiron, Longmont, Colo.

CONCRETE SUPPLIER: Palomar Transit Mix, Escondido, Calif.

PRECASTER: U.S. Concrete, San Diego, Calif.

The Lake Hodges Bridge is located just 1000 ft west of the I-15 Freeway in San Diego.

For the vibration analysis, a simplified approach from the British and Canadian bridge codes was used. The results showed the accelerations from pedestrians walking, running, or even jumping up and down on the bridge would be well within acceptable limits.

Construction

The construction was divided into three phases to meet funding and environmental constraints. The south abutment was constructed in the first phase, from September 2006 to March 2007. The contractor then moved off site in accordance with the environmental requirements related to the breeding season of endangered birds.

In the second phase, from September 2007 to March 2008, a construction trestle was built to gain access to the piers. Sheet pile cofferdams were constructed and steel piles were driven for the pier foundations. Next, concrete seals were placed and the coffer dams were dewatered to facilitate the balance of the pier construction.

The north abutment was also constructed in this second phase by excavating down to sound rock and placing a concrete leveling course. A reinforced concrete structural abutment was placed on top of the leveling course. Next, 15 anchors were drilled through the leveling course and into rock. Each anchor was tensioned to 1100 kips. After completing the piers and north abutment, the contractor once again moved off site.

The bridge deck was constructed from September 2008 to May 2009, in the third and final phase. The contractor utilized the trestle as a work platform for placing the cables and panels. First the bearing cables were installed from abutment to abutment and over the steel saddles at the piers. Each of the six bearing cables comprised nineteen 0.6-in.-diameter, 270 ksi prestressing strands. The six tendons were tensioned to a total force of 4300 kips.

Next, the deck panels were suspended from the bearing cables using high-strength bars near the corners of each panel. A total of 87 panels, each 10 ft long, 14 ft wide and 16 in. thick, were used. The design compressive strength of the concrete was 6000 psi. Longitudinal troughs were built into the panels to provide a place for the bearing and post-tensioning cables.

Once the panels were in place, the post-tensioning ducts and tendons were installed in the longitudinal troughs above the suspension cables. Again six tendons were used, this time with twenty-seven 0.6-in.-diameter strands each. Formwork was then constructed for the final 20 ft of each span. Concrete

One of 87 precast concrete panels is shown during the typical erection procedure.

Concrete is placed in the longitudinal trough that was cast in the panels.

THREE-SPAN, STRESS RIBBON BRIDGE / SAN DIEGUITO RIVER VALLEY OPEN SPACE PARK JOINT POWERS AUTHORITY, OWNER

POST-TENSIONING CONTRACTOR: Dywidag-Systems International, Long Beach, Calif.

BRIDGE DESCRIPTION: 990-ft-long, three-span stress ribbon bridge, 14 ft wide and 16 in. deep

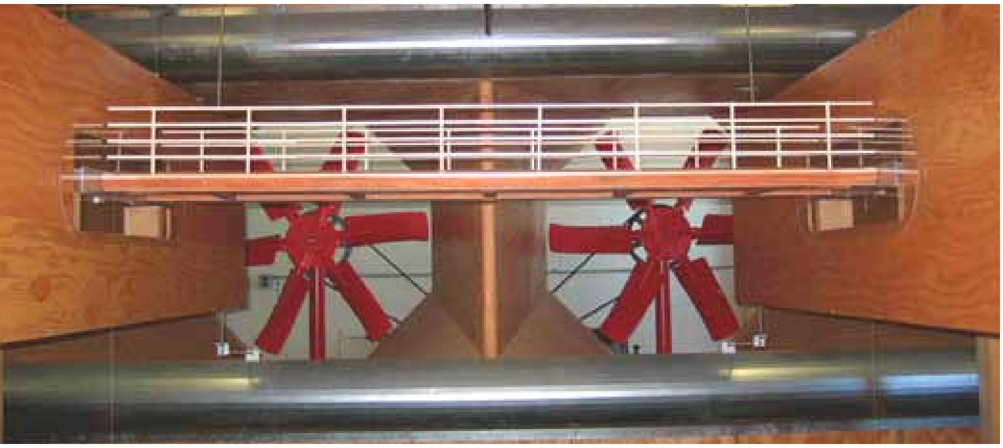
BRIDGE CONSTRUCTION COST: $8.5 Million ($550/ft^2)

STRUCTURAL COMPONENTS: 87 precast concrete deck panels, 10 ft long, 14 ft wide, and 16 in. thick; six 19-strand bearing cables; six 27-strand post-tensioning tendons, two cast-in-place concrete piers on H-pile foundations, one rock anchor abutment on the north end, and one pile abutment on the south end with four 8-ft-diameter concrete cast-in-drilled-hole piles.

AWARDS: PCI's 2009 Design Award for Best Non-Highway Bridge; California Construction, Best of 2009, Best Small Project; ACEC 2010 National Award; CRSI 2010 Bridge Design Award; National Engineer Week, 2010 Outstanding Civil Engineering Project Award

An early rendering of the David Kreitzer Lake Hodges Bicycle Pedestrian Bridge illustrates its appearance "floating" above the water.

In the dry condition, the bridge appears to "nest" above the trees.



The bridge model undergoing wind tunnel testing.

was placed in the transverse joints between panels, in the longitudinal troughs and in the open-end regions.

Once the cast-in-place concrete reached the specified strength of 6000 psi, the bridge was post-tensioned with 4600 kips of force. This put the deck into compression and increased its stiffness.

Conclusion

On May 15, 2009, hundreds of people were in attendance for the official grand opening and ribbon cutting ceremony. In its first year of operation, the bridge has been well used by the public. The reactions and comments from its users, which include hikers, joggers, recreational bicyclists, and commuters, have been extremely positive. This bridge was a challenge to design and construct, but the results have been well worth it. This elegant bridge is perfectly suited to the site and provides the people of the region with a beautiful and useful crossing of which they can be proud. Further, the structure has a unique place in the field of engineering—the world's longest stress ribbon bridge.

Tony Sanchez is senior bridge engineer at T.Y. Lin International, San Diego, Calif.

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Environmental and Context-Sensitive Solutions

The San Dieguito River Park Authority hired T.Y. Lin International to design a functional and beautiful bridge for pedestrians and bicyclists. However, a good design at this site needed to be consistent with the Park Authority's core values of protecting the natural waterways, sensitive lands, and threatened and endangered species.

The stress ribbon is the ultimate eco-friendly design. Because it can span 330 ft, only two piers were needed. Since the bridge was built by placing precast panels on bearing cables, no falsework was required. This further reduced the impact to the sensitive habitat. Additionally, the stress ribbon design makes effective use of each material: concrete in compression, steel in tension. This results in a minimal use of materials. In this sense, the bridge is a very "green" design.

In addition to environmental issues, aesthetics were important in the selection of this bridge type, and the stress ribbon proved to be the perfect visual compliment to the site. Early sketches and renderings showed the stress ribbon worked beautifully in both wet and dry conditions. The bridge "floats" above the water when the lake is full, and "nests" above the willow trees when the lake is dry. Visually, its slender deck has the smallest impact. From a distance the bridge almost disappears. Up close, its complementary curves fit beautifully into the rolling terrain around the lake. The long spans and thin deck result in a very light bridge that blends into the natural setting.