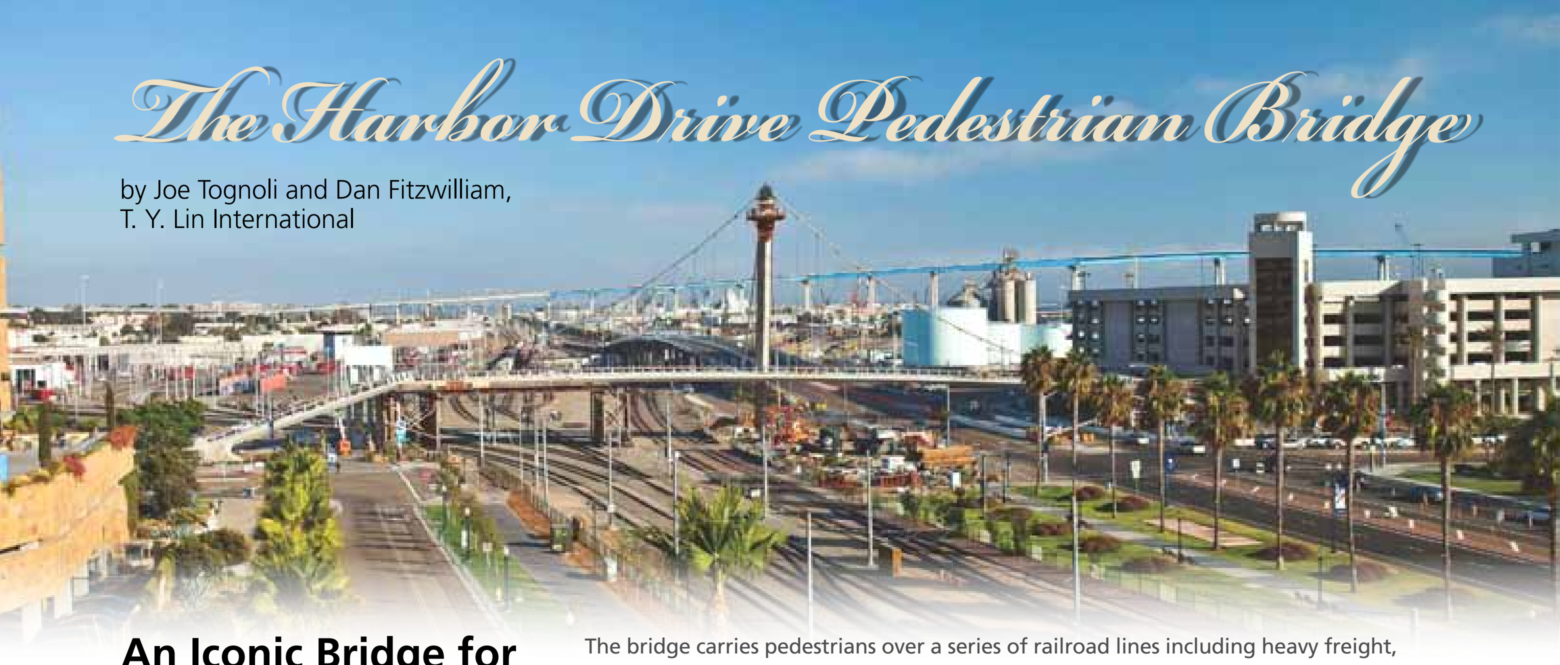
The Harbor Drive Pedestrian Bridge

by Joe Tognoli and Dan Fitzwilliam,
T. Y. Lin International



The bridge carries pedestrians over a series of railroad lines including heavy freight, passenger rail, and trolley lines. It also allows pedestrians to cross over a busy downtown street and connects directly with a multi-level parking structure. Photo: Paul Savage. All other photos and drawings: T.Y. Lin International.

An Iconic Bridge for One of America's Finest Cities

For an engineer, a pedestrian bridge is like a child's blank canvas, allowing nearly unlimited creativity in structural form. There simply are not the restrictions with geometry, structural systems, and details that constrain the engineer on a conventional vehicular bridge design. Winding ramps and stairs, inclined members, challenging cable geometry; are all possible on a pedestrian bridge.

With far more freedom than with a vehicular bridge, the pedestrian bridge allows for greater expression. There are less geometric constraints. Cars just don't like highly curved superstructures, but people do. In addition, the practical monetary constraints on a vehicular bridge can be greatly reduced on a pedestrian bridge. Their smaller scale makes them inherently less costly, even though their unit cost is much higher. Therefore, a community may be able to spend several million dollars more for a unique pedestrian bridge, while this same amount spent on a vehicular bridge would certainly enhance it, but may not be enough to allow for an iconic structure. Fine detail can be incorporated into the design and appreciated by pedestrians, whereas, on a vehicular bridge, a motorist traveling at highway speed cannot possibly see or appreciate such detail. With these freedoms, and the beautiful San Diego, Calif., downtown landscape as the canvas, we were able to create a dynamic, dramatic, and iconic structure.

The City of San Diego downtown area is situated on the San Diego Bay. For many years, it has been the goal of the city to complete a pedestrian and bicycle link between the historic Balboa Park and the picturesque San Diego Bay, dubbed the Park-to-Bay Link. The last section of the Link was blocked by local trolley tracks, several sets of freight train tracks, and a busy downtown thoroughfare. In 2004, the city commissioned the Centre City Development Corporation (CCDC), the city's redevelopment agency, to design and build a bridge to complete the approximately 2-mile-long Park-to-Bay Link. The site chosen for the final bridge link is adjacent to the recently constructed Petco Park, home of Major League Baseball's San Diego Padres and the San Diego Convention Center on the San Diego Bay, covering over 1 million ft^2.

High-Profile Solution

CCDC recognized that the high-profile project location needed a landmark structure to act as the gateway to the city and as an icon of the revitalized downtown area of San Diego. They hired the design team to develop a concept and plans for the bridge and surrounding plazas. Although many alternatives were considered for the site, the final bridge type selection was a self-anchored suspension bridge with an inclined pylon.

The horizontally-curved superstructure of the 355-ft-long main span is a 3-ft-deep, single-cell, hollow, box girder section. The full 19-ft 7-in.-section width includes a 9-ft 1-in.-wide

profile

HARBOR DRIVE PEDESTRIAN BRIDGE/ SAN DIEGO, CALIFORNIA

CLIENT: Centre City Development Corporation, San Diego, Calif.

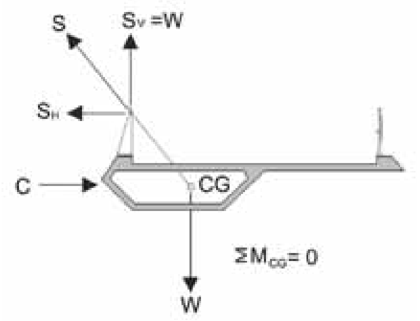
BRIDGE DESIGN ENGINEER: T. Y. Lin International, San Diego, Calif.

ARCHITECT: Safdie Rabines Architects, San Diego, Calif.

CONCEPT COLLABORATION AND INDEPENDENT CHECK: Strasky and Anatech, San Diego, Calif.

PRIME CONTRACTOR: Reyes Corporation, National City, Calif.

CONCRETE SUPPLIER: Hanson, San Diego, Calif.



Ideally, the line of action of the suspenders should pass through the center of gravity of the section to achieve equilibrium for dead loads.

cantilevered slab extending out on one side from the thin-walled closed box portion of the deck. The asymmetric section shifts the centroid of the shape as close as possible toward the edge of the deck that is supported by the single row of inclined suspension hangers. The typical thickness for the deck slab, webs, and soffit of the box is 5½ in. Transverse deck ribs and internal diaphragms spaced at 10 ft on center combine with the 8000 psi compressive strength concrete to add stiffness to the structure.

The pylon is 130 ft tall and inclined at a 30-degree angle from vertical. It leans over the deck to support the suspension cables. Thirty-four individual suspenders are attached to the main cable to support the deck from the top of the railing at only one edge of the superstructure. The pylon cross-section has a tear drop shape that is a constant 5 ft 10 in. wide transverse to the bending direction for the full height of the pylon. The length of the shape in the primary bending direction tapers from 14 ft 0¾ in. at the base to 5 ft 2½ in. at the top. The pylon is constructed using 6000 psi compressive strength concrete and was internally post-tensioned with 128 0.6-in.-diameter prestressing strands. These were stressed from anchors in the footing at four stages during construction.

Main Cable Trajectory

For most bridges, the structural system is relatively straightforward. In this case, the mechanics of the self-anchored suspension system presented the first challenge. In conventional suspension bridges, the main cable element is typically draped between two main pylons. The tension in the main cable, caused by the weight of the suspended bridge deck, is resisted by massive cable anchorages in the ground. In a self-anchored suspension bridge, the tension in the main cable is resisted by longitudinal compression in the superstructure. Consequently, the complete superstructure has to be in place before any part of it can be suspended from the main cable.

The 130-ft-tall concrete pylon is inclined at 30 degrees from vertical and reaches over the deck to produce a lateral curve in the main cable necessary to provide equilibrium to the structure.

For this bridge, the main cable configuration is further complicated by the bridge deck not being linear. It has a vertical kink at the ends of the bridge due to the approach span stairs. The solution was to continue the main cables all the way to the base of the stairs and anchor them in the abutments at the bottom of each set of stairs. In order to handle the angle change from the deck to the stairs, the cable passes through a steel deviator device placed at the top of each stair span and embedded in the concrete bent cap at these locations. This solution means that some of the tension in the main cables is resisted by the abutment foundation, but the majority of the force from the main cable is still resisted by the much stiffer stair and superstructure section.

The Harbor Drive Pedestrian Bridge is a self-anchored suspension bridge with a 355-ft-long concrete main span situated in downtown San Diego adjacent to Petco Park, home of the San Diego Padres.

SELF-ANCHORED, CAST-IN-PLACE CONCRETE BOX GIRDER SUSPENSION PEDESTRIAN BRIDGE WITH CAST-IN-PLACE CONCRETE INCLINED PYLON / CITY OF SAN DIEGO, OWNER

POST-TENSIONING CONTRACTOR: Dywidag-Systems International USA Inc., Bolingbrook, Ill.

STEEL FABRICATOR: AMECO, Cleveland, Ohio

CABLES: Pfeifer, Memmingen, Germany

BRIDGE DESCRIPTION: Self-anchored suspension bridge with 355-ft-long main span comprising a cast-in-place concrete single-cell box girder superstructure with 16-ft-wide walkway and cast-in-place concrete pylon, 130 ft tall inclined at 30 degrees from vertical

BRIDGE CONSTRUCTION COST: Bridge cost $15 million ($1760/ ft^2); Project cost $21 million (includes dual glass elevators and plazas)

Asymmetric Equilibrium

Supporting the bridge deck with cables attached to only one side of the deck was an extremely challenging design feature. Looking at a typical section of the bridge, the unbalanced nature of the deck becomes very apparent. It seems as if the weight of the deck wants to roll the section about the suspender support. The torsion generated by the unbalanced support location must be compensated in some way. The best solution would be to get the line of action of the suspender supporting force to pass through the center of gravity of the bridge section. An unsymmetrical cross-section was developed to try to move the center of gravity of the section as far toward the suspenders as possible. Unfortunately, the center of gravity could not be shifted far enough toward the suspenders to achieve a balanced design. The support point was then moved to the top of the railing in an effort to shift the line of action farther toward the center of gravity of the section and thereby achieve a balance between the dead load of the bridge and the suspender force.

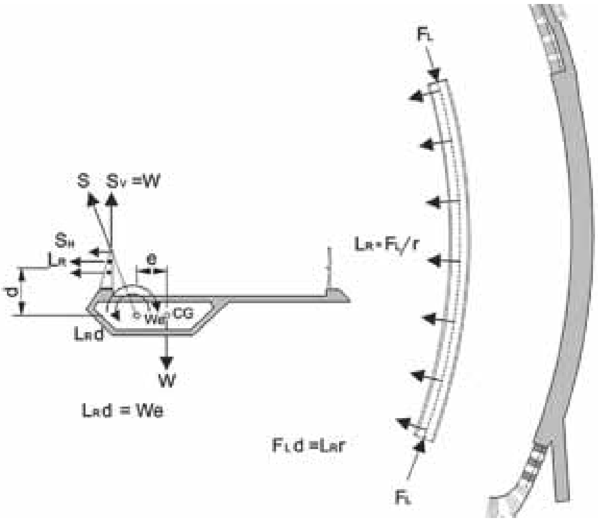
It turns out, it wasn't quite that simple. The dead load torsional force was still greater than the resisting horizontal component of the suspenders; the bridge wasn't balanced for torsional dead loads. In order to achieve equilibrium, an additional horizontal resisting force was needed. To provide this necessary horizontal balancing force, an additional longitudinal post-tensioned cable was added along the top of the railing post. Due to the curve of the bridge in plan, this created an additional radial inward force at the top of the railing to provide the balancing torsion needed.

Main Cable and Hangers

The main cable is 36 strands of 0.6-in.-diameter waxed and sheathed strands inside a grouted stainless steel guide pipe. The cables from each side of the main span are anchored at the top of the pylon. The bundle of 36 individual strands was laid out adjacent to the bridge and taped together in a compact bundle. The entire bundle was pulled through the stainless steel guide pipe which was suspended in position using a temporary support wire. The hangers were cut to a predetermined length. They were attached to the main cable guide pipe while the pipe was in a slack position. After all the hangers were attached, the main cable was stressed, which removed the slack and put the final load in the hangers and lifting the bridge off the falsework. The pipe was then grouted.

It's in the Details

For a pedestrian bridge, the user is much closer to the details of the bridge and is travelling at walking speeds. The details of the connections and hardware on the bridge take on a much more important role in these types of bridges. The guide pipe eliminates the need for cable bands and provides a smooth line along the length of the main cable without any discontinuities. The suspenders are in turn attached to gusset plates on the pipe rather than directly fastened to the main cable via a cable band, also providing a smooth, clean look and further adding to the pedestrian experience.



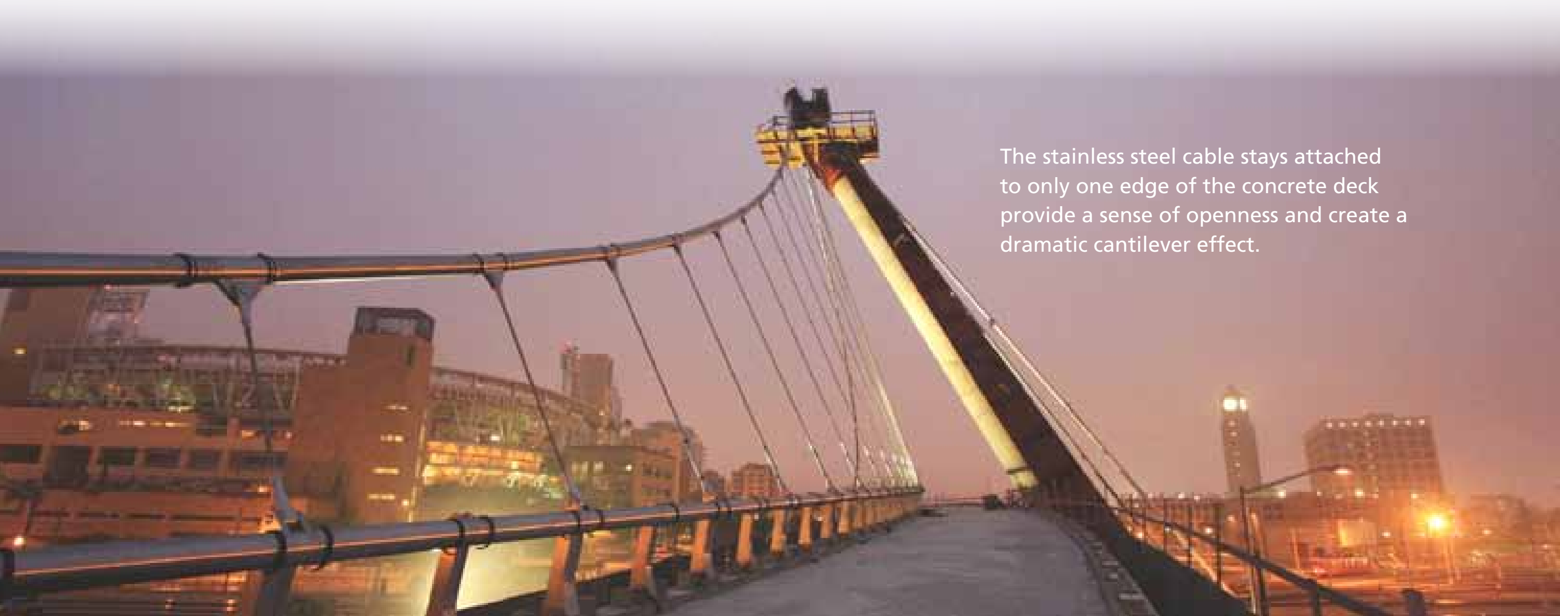
An additional longitudinal tendon was stressed at the top of the railing. Coupled with the curvature of the bridge, this tendon creates an inward radial force to provide the restoring torsion needed for equilibrium.

Conclusion

The Harbor Drive Pedestrian Bridge completes the final piece of the City of San Diego's Park-to-Bay Link, and provides the city with a structural icon for the community. The new self-anchored suspension bridge, with its 130-ft-tall pylon inclined over the horizontally curved bridge deck, and suspenders only attached to one side of the bridge deck, truly is a bridge fitting for one of America's Finest Cities.

Joe Tognoli is vice president and principal bridge engineer and Dan Fitzwilliam is senior bridge engineer, both with T. Y. Lin International in San Diego, Calif.

For additional photographs or information on this or other projects, visit www.aspirebridge.org and open Current Issue.



The stainless steel cable stays attached to only one edge of the concrete deck provide a sense of openness and create a dramatic cantilever effect.

With both the deck and pylon built using in cast-in-place concrete, work on both proceeded simultaneously. Specially designed steel forms, shown in this photo, were used to construct the pylon in five lifts.

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The concrete deck was cast in place on falsework that had to be designed to allow for over 3 in. of lateral displacement during stressing of the cables.

The main cables extend to the base of the stairs and anchor in the abutments. The angle change from the deck to the stairs is accommodated by a steel deviator placed at the top of each stair span and embedded in the concrete bent cap.