Highlights

- ONE SET OF DECK FORMS USED FOR THE ENTIRE PROJECT FIRST ABOUT THE WEST TOWER
- MAN-MADE, COLLISION PROTECTION ISLANDS USED TO FACILITATE CONSTRUCTION OF BRIDGE.

SPANS

Hillsborough County Florida

Public Works Department
Bridge Team

The Quarterly Newsletter of Inspired Bridge Technologies *January 2009, Volume 7*

TOWERS TOPPED WITH THE KING'S PARASOL

The time was 1981 and the Kingdom of Malaysia was beginning to flex its economic muscles with its gathering oil and gas revenues. Bids were let for the high level crossing of the south approach to the main shipping channel segment of the new 8.4 mile project that was to connect the City of Georgetown, on Penang Island, with the Malay Peninsula, across 5.2 miles of the Malucca Strait. The total project consisted of two major highway interchanges, one on each side of the channel, low level approaches, a high level, long span over the north-south shipping channel and pier protection islands around the four main span piers (Figure1).

Bids were very close for the two advertised alternates (concrete cable - stayed span and steel, tied-arch span) and the concrete was chosen by the owner because more labor and materials would be by Malaysians with this choice. Moreover, the Government felt that the project could be started and built in less time than a steel bridge and, as a consequence, the cost of funding for this toll bridge would be reduced with the concrete bridge's 36 month, specified, construction time.

This contract was for $98.8 million Malaysian or, at the then conversion rate, $US 43.2 million when bids were opened on February 2, 1981. The contract award was made in 1982 to the Hyundai Engineering and Construction Company Ltd. of Korea and the design was by the American bridge consultants, HNTB.

FIGURE 1: Bridging 5.2 miles of the Malucca Strait, between Penang Island and the Malay Peninsula, over Georgetown's south shipping channel.

The '82 award was the end of the trail of studies that began in 1971 which resulted in the recommendations made in 1974. Their idea was to build low level approach causeways, on fill, from the east and west shorelines which were to be connected by a low level trestle, all of which were designed to carry 4-lanes of highway traffic. The Malaysian Highway Authority (Lembaga Lebuhraja Malaysia) rejected this proposal because it would block the southern approach to the Georgetown harbor and, in 1976, chose another consultant group to study a high level channel crossing instead.

The second Consultant's Report was submitted to the Malaysian Government in 1977 and their recommendations were for a crossing just south of the alignment recommended in the 1974 study but to initially have 4-lane trestle approaches that were expandable to 6 lanes and the main channel span was to be built, at the outset, as a 6-lane structure. Five, long span, high level, main span alternates were considered for the bridging of the 492 foot wide and 98.4 foot high navigation channel of which only the two were carried through to bid documents.

The late Louis G. Silano, P.E., who spent his entire professional career of 50

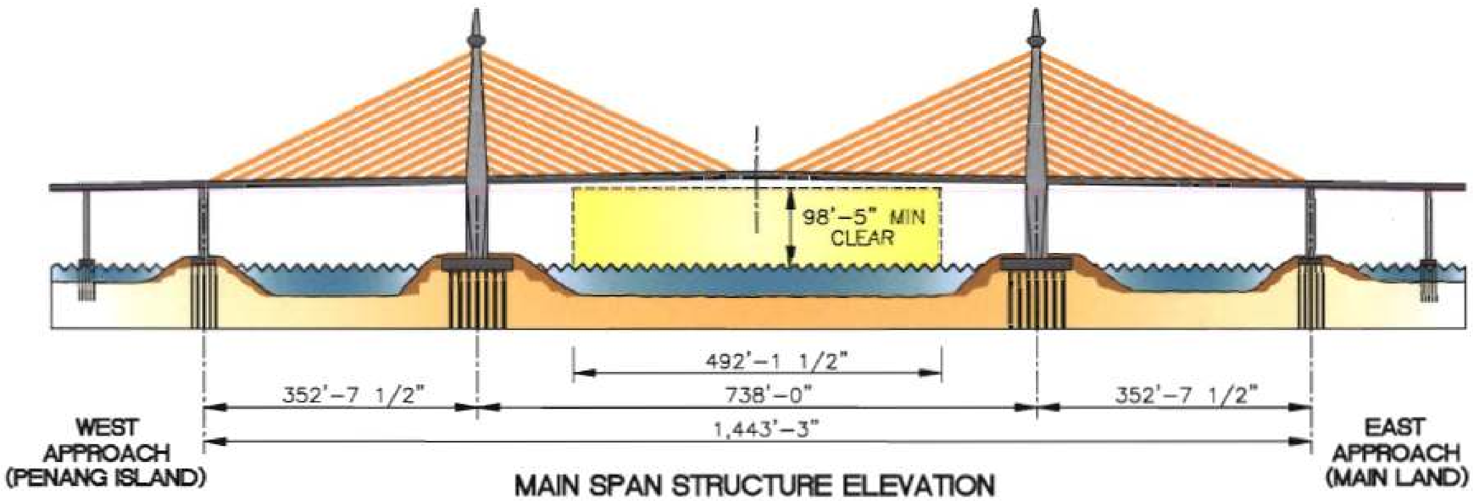


FIGURE 2: The 1,443.25' long, three span, harped pattern, cable-stayed, main channel crossing with all four piers protected from ship collision by man-made islands.

years with PBQD and was their Chief Bridge Engineer, recommended DRC Consultants Inc. to Hyundai for the Construction Engineering phase of the Penang main span, bridge construction. Hyundai sent two of their young engineers to work with the DRC staff in the DRC New York offices for 3 months. Once superstructure construction began, DRC sent Mr.York K. Chan, P.E. to Malaysia to provide field support during the initial phases of the cable-stayed, cast-in-place girder construction.

All four main span piers were protected from ship collision by man-made islands. The main span center to center length of 738.00' was a function of the shipping channel width and the attendant island widths (Figure 2). The overall, cable-stayed bridge is 1,443.25' long and is comprised of two vertical planes of cables, all positioned in a harp pattern. The stays are attached to two, longitudinal, edge-girders that are 7'-3" wide and 5'-9" deep and are centered on the two planes of cables which are 90'-3" apart. The total, out to out dimension of the typical deck girder is 97'-5". The typical, 9-1/2" thick concrete roadway deck spans the 9'-10" distance between the transverse deck girders that are cast monolithic with the slab and carry all deck loads to the cable-stayed, edge girders (Figure 3).

The deck narrows, at the main span towers, to a width of 81'-0" and hangs free, suspended by stay cables with no vertical bearing points at this location. Transverse, transient movements are accommodated by bumpers between the towers and the suspended deck. The transverse, seismic and wind loading is restrained at the two end piers, separated by the total, continuous length of the 1,443.25' suspended deck. Two, 12" expansion joints, one at each end of the suspended, continuous deck, accommodate the anticipated, longitudinal movements of the deck girder.

Accordingly, the cable-stayed deck was built in balanced cantilever fashion by a form traveler that built segments, first on one side of the tower and then the other side, with the maximum imbalance of one full segment. During these alternating, construction sequences the pier table was temporarily locked to the towers to resist these unbalanced, horizontal forces. Once the cable-stayed girder reaches the end piers the girder is thickened to provide a counterweight for the mid-span, cantilevered, closure-pour at the opposite end. When the mid-span, closure pour cured and the total cable-stayed girder is hung in place, the temporary locking mechanisms, between the girder and the tower, are removed (Figure 4).

These towers are founded on massive pier footings that measure 177'-2" parallel to the channel and are 93'-6" wide and 14'-9" deep. The footings and their tower loads are supported on 9'-10" diameter, hollow, pre-stressed concrete friction piles driven, open ended to 200' depths into sand and clayey sand material.

The Malaysian Government has endeavored to build their national infrastructure and they want to do it with a certain style that reflects their pride in the rich, cultural heritage of the Malay people. This is evident today with the great pains taken with the Petronas, twin-towers in Kuala Lumpur, the headquarters building of the National Oil Company. The architect, Caesar Pelli, has been very successful in his magnificent effort to incorporate the sense of the Malaysian

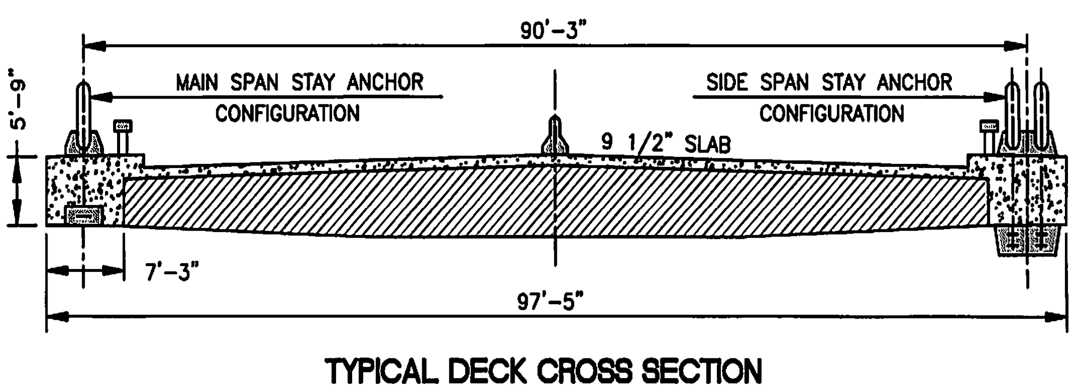


FIGURE 3: Cable-stayed edge girders, 7'-3" wide x 5'-9" deep, are locked together by monolithic, cast-in-place, transverse floor beams and 9 ½" thick deck slab.

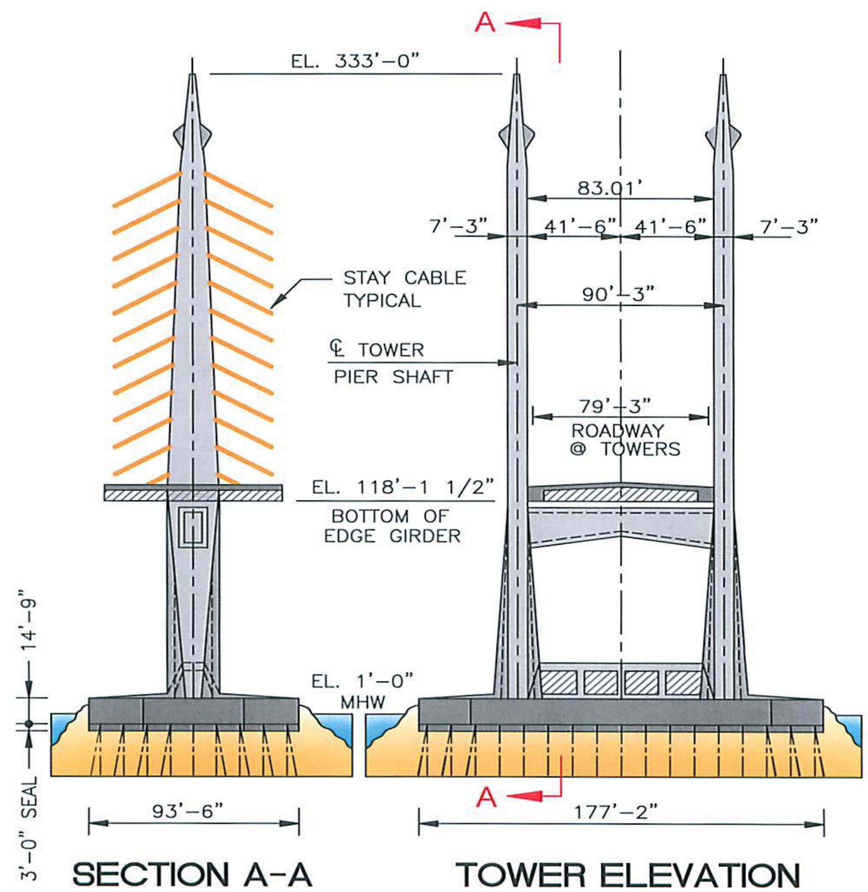


FIGURE 4: Towers founded on 8,850 cubic yard footings supported by 139-9'-10" diameter, spun, concrete piles.

culture into these giant, Asian skyscrapers. Similarly, just a little more than a decade earlier, the government requested that the Penang Bridge tower spires be left free standing, without connecting struts above the roadway decks, in order to capture this same, freestanding spirit (Figure 5).

Today, we can drive on a modern highway from the capitol city of Kuala Lumpur and travel 110 miles north to the City of Butterworth and take the interchange, at the east end of the Penang Bridge, and drive to the toll booth, then across the 5.2 miles of the strait before connecting to the west interchange, on the island, and then arrive at the centuries old trading port and modern tourist center of Georgetown. In passing, we notice the distinctive, architectural treatment done to the bridge tower heads.

For more than 13 centuries the Malay people were ruled by their kings and a traditional symbol of the King's authority was taken from the practice of shielding the monarch from the sun, during his public processions, with a canopy held over his head as he walked about. The Penang Bridge incorporates this theme with the blisters near the peak of the towers symbolizing a folded parasol stored in an upside-down orientation. The Constitutional Monarchy was reinstituted in 1971 and the country has since, essentially followed the rule of their Parliament.

The west pier protection island was built up to a level where pile driving barges could be floated into position and spud-locked to the shallow bottom. The west, main pier had 139 piles and once driven the island was raised in elevation, sheeting for the cofferdam was driven, excavation completed, the cofferdam was tremie sealed and dewatered. The reinforced concrete tower footing was then cast on the pile foundation in three 2,950 cubic yard lifts of fresh concrete supplied by a floating batch plant. Once the footing was in place the island was brought to its final elevation and a land based, batch plant was set-up.

The tower pylons were then built in 14' lifts and the tower struts, at the footing and just under the pier table, were built on false-work. Free standing tower cranes were used for vertical material deliveries and the installation of the high strength steel Dywidag bar stays. When the pier-table was completed it was locked to the towers and suspended by stays then the false-work was removed.

The deck girder construction was done in two stages but with one set of forms. Two edge girder forms were first cantilevered 29'-6"off the pier table then stays were attached to the forms with partial pre-stress applied. The edge girders were cast and the after-runner was advanced with the forms spanning between the two edge-girders. These trailing forms framed three transverse deck girders, monolithic with the slab and edge-girders. With pumped concrete, and super-plasticizers, a 10 day cycle was achieved for the cable stayed deck segment installation, one side of the tower at a time, until the end span was secured at the west end pier.

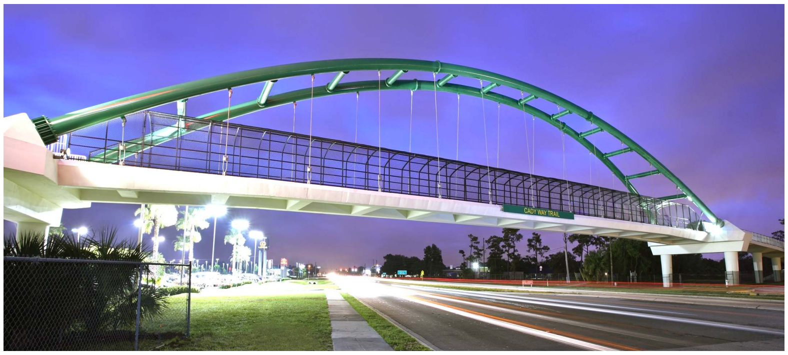
When the west half of the channel crossing was in place the forms were relocated to the east tower pier-table and the process was repeated. Once the east half span was secured to the east end pier, stays were adjusted and the main span closure was cast. With the total girder in place the locks between the deck and towers were removed. Much to the satisfaction of HNTB's Chief Bridge Designer, Mr. Herbert Globig, P.E. the bridge was opened to traffic in July, 1985.

FIGURE 5: Free standing pylons topped with symbolic parasols.

Guest Commentary

By: Mike Bernos and Peter Rogas, PE

TALE OF TWO BRIDGES



When Orange County proposed two pedestrian bridges six years ago, they knew they were planning two distinct projects whose desired results were opposite from the other: one was to be "invisible" (above) and the other a "city showcase" (below). They were also projects that demanded expertise in architecture for one and engineering for the other. The challenge for the RS&H design team was to "think outside of the box" for each site but to also work within the boundaries presented in each location.

Cady Way Trail Pedestrian Bridge over SR 436 required a main span of 245 feet, a length needed to span not only the highway, but also the projected FDOT right-of-way width through the project site -- all this while remaining "unobtrusive."

The Orange County / RS&H design charrette team eventually chose a basket-handle tied-arch design in which the bridge's arches tilted in to each other thereby creating a tripod to provide lateral stability and resistance to wind load, while achieving an "invisible" look. The invisible look was also enhanced by using a post-tensioned bridge deck as the structure's tie. Utilizing the bridge deck eliminated the need for an additional element, the tension tie, once again adding to the light atmosphere presented by this large structure.

The secondary challenge for the project was to maintain the trail's serpentine alignment on the bridge approach spans while also meeting the project's elevated aesthetics treatment with the approach and main spans blendeding as one. To accomplish this, inverted tapered columns, similar to the main piers, capped with a large inverted trapezoidal capitol were placed along the serpentine curves and closed with a constant depth span. The final effect of this arrangement was an economic structure similar to the main span aesthetic.

While the Cady Way Trail Pedestrian Bridge was designed to be invisible, the West Orange Trail Pedestrian Bridge in Apopka, Florida was designed to be a gateway, while blending into the historic downtown architecture of that city and accommodating businesses on each side of the bridge.

For the RS&H architects, this meant working with Apoka's dominant architectural feature, redbrick cladding, which adorns many buildings that date back to the early 1900's. In addition to that feature, Apoka is known as the "Indoor Foliage Capital of the World", a theme that also needed to be incorporated into the bridge's aesthetics.

Also, because the bridge was downtown, city planners knew the public would use the space on the trail as well as the space below the trail structure. This created a unique consequence of meeting the public use as well as the aesthetic requirements on two planes. The chosen main span was a bowstring truss in which the curved top chord represented the gateway into downtown Apopka. This main span was then embraced with bookend overlooks enhanced with spires at each corner, each spire supporting a fern sculpture. A heavy ironwork style railing and a well-adapted red-brick architecture for the bridge both worked together to blend the bridge architecturally with the surroundings.

Additionally, a rain garden and sitting area were incorporated into the south approach structure. The rain garden uses the rainfall runoff from the bridge to irrigate the gardens while the structure provides a covered sitting area sheltering the public from either Florida's rains or sunshine. Eventually the trees in the garden will encompass the structure in the historic Florida style, continuing the aesthetic development of the site.

The bridge was designed not only to cross a state road, but also because of its urban location, the red brick theme was used as the borders for the landscape under the bridge. All of these features worked in harmony to provide a functioning structure hidden amongst the beauty that is the West Orange Trail Bridge in Apopka, Florida.

The tale of these two bridges exemplifies the challenges presented to any design team: develop original ideas for the site while working within the project boundaries, especially within the budget. The measure of the success at each site is by the many awards each has won including the 2006 and 2007 Award of Merit from the Orange County Design Excellence Awards for the Cady Way Trail Pedestrian Bridge and the West Orange Trail Pedestrian Bridge, respectively, each an indication of the clients satisfaction with the projects.

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http://www.hillsboroughcounty.org/publicworks/resources/publications/home.cfm

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