Services provided by member firm:

Louis Berger and Ammann & Whitney were responsible for the preparation of two primary deliverables – an Investment Project Report for Construction Works and an Engineering Design Report. Development of the Investment Project Report required Louis Berger and Ammann & Whitney to detail the necessity of construction of the new bridge, determine the total required investment, analyze potential sources of capital, develop at least two distinct build options, and provide a recommendation for construction in accordance with Vietnamese engineering practices.

Following client approval of the Investment Project Report and selection of the desired build option, Louis Berger and Ammann & Whitney began development of the Engineering Design Report. The report details the bridge's exact dimensions and technical parameters, specifies materials to be used, provides engineering design drawings, and estimates for cost of all materials. Louis Berger and Ammann & Whitney also redesigned roadways and public spaces in the bridge's approach areas.

Summary:

To reach its full economic and tourism potential, the port city of Da Nang, Vietnam needed a new bridge across the Han River to its developing eastern sectors, famed beach resorts and the route to the historic town of Hoi An. Charged with initiating a bridge plan, the Da Nang People's Committee (DNPC) sought a unique structure that would become an attraction unto itself.

A city of about 1.1 million people on the Eastern Sea in south central Vietnam, Da Nang is a transportation hub and important commercial and educational center. The DNPC wanted a bridge that would complement and enhance its surroundings, including the nearby Museum of Cham Sculpture.

The DNPC sponsored an international competition in 2005 to find a bridge design fitting for Da Nang. Six entrants presented their concepts to the committee in a public meeting.

The team of Louis Berger and Ammann & Whitney won the competition with a design that caught the DNPC's imagination. It also provided safe and seamless road access to the city center on the west end with a low deck that did not block scenic views of the river and city.

The signature feature of the bridge was the massive undulating support structure resembling a dragon flying over the river. The dragon is prominent in Vietnamese culture as a symbol of power and nobility. Fittingly, the-six lane Dragon Bridge opened on March 29, 2013, the 38th anniversary of the liberation of Da Nang City.

Dragon Bridge became an instant icon and a major tourist attraction, especially on Saturday and Sunday nights when the dragon breathes fire, delighting thousands of wide-eye spectators. Even on other nights, the bridge illuminates Da Nang with 15,000 multi-colored LED lights that reflect in the river below, providing an instantly recognizable icon for Da Nang's skyline.

Innovation:

Dragon Bridge stands out as a model of innovation. It has received worldwide attention in the design community and from the global media for its unique arch support system.

The idea began with a simple sketch of a bridge superstructure intersecting a flying dragon .The architectural concept required the undulating back of the dragon to be placed along the center line of the superstructure. The dragon needed a suspended head and tail and the body was to be covered in scales – spiking upward along the spine.

Louis Berger and Ammann & Whitney designed a parkway-style bridge with a low profile deck that prevented view-obscuring raised approaches and that lent itself to the dragon-themed suspension system. It has an at-grade approach on the western end so vehicles can move smoothly on and off the bridge deck.

Unlike most structures of similar width that have two arches at the outside of the bridge deck, Dragon Bridge has a single arch. The central rib arch has five steel tubes of constant diameter that carry the bridge's superstructure through "spider frames" and suspenders placed at 8-meter intervals.

Each frame connects the five tubes in a horseshoe pattern to spread the suspender load evenly. The spider frames also form a support base for the dragon's scales. There is no diagonal or horizontal bracing between the tubes. Each suspender has three one-part 66mm diameter strands and each strand end is attached to the spider frame and steel box girder with open-ended spelter sockets.

The bridge's center three spans use a unique design in which 14-meter-wide hybrid steel box girders are supported by a central rib steel and concrete arch. The box girder has a triple-cell steel box for the suspended portions and pre-stressed twin-cell boxes for sections over piers.

Cantilevers measuring 10.5 meters extend from the box girders to complete the superstructure cross section. The width of the bridge deck ranges from 36 to 37.5 meters because of an undulating pedestrian walkway. Under the bridge deck the arch structure is reinforced concrete and integrated into the piers.

Environment:

Dragon Bridge crosses the Han River in a moderate tidal zone, subject to occasional flooding in monsoon season. The six-lane bridge, 666 meters long, is about 3.7 kilometers upstream from where the Han River flows into the sea.

The low profile left very little vertical clearance over the waterline. To address that concern, the westernmost span consists of variable-depth cast-in-place pre-stressed concrete integrated into the pier. This solution required moving the river's navigation channel slightly east so there would be enough clearance for watercraft to pass under the bridge even at high tide.

As designed, the bridge fulfilled the goal of the client and the community to have a prominent but not dominant structure. The bridge increased mobility and became a landmark that does not overpower neighboring cultural and historic areas.

Quality and Professional Excellence:

Soil conditions at the project site presented design and construction challenges. The soil profile consisted of interlaced layers of sand, silt, clay and clay-like sand over severely weathered rock. The team determined that the competent bearing layer of weathered rock had an average depth of 43 meters below the waterline. The piers use a partially left-in-place cofferdam to provide a permanent fixture below the existing river bottom and to prevent scouring of drilled shafts. Two-meter diameter drilled shafts extend into the rock layer. The concrete pile caps end at approximately the existing mud line. The piers are designed with as much voids volume as possible to save concrete and alleviate temperature and shrinkage issues.

To understand the behavior of the complex and unique structure, the design team created computer models to analyze the bridge as a whole. Models were also created to analyze the spider frames, suspenders, central arch rib, box girders, drilled piles, and support piers. The analyses covered 14 potential load cases, including dead, live, wind, thermal, longitudinal wind and asymmetrical live loads. In all cases, the analyses were based on both local and U.S. standards.

No bridge with such unique structural characteristics had ever been built in Vietnam, so the client relied on the international expertise of Louis Berger and Ammann & Whitney, combined with the local knowledge of contractors. Da Nang-based TDIC JSC 533 served as primary subconsultant, assisting with preparation of technical documents. BAECCO, now PICON, of Ho Chi Minh City, produced detail quantity estimates for cost engineering, prepared some detail drawings and translated documents from English to Vietnamese. CIENCO 1 of Hanoi, CIENCO5 of Ha Long and CIENCO8 of Hanoi were responsible for construction.

Safety was an overarching concern in Dragon Bridge's design and construction, especially in the wake of the collapse of the Can Tho Bridge in September 2007. That disaster, the worst in the country's construction industry history, killed dozens of engineers and construction workers. The Dragon Bridge was held to the highest design and construction standards.

The design team weighed several potential designs for the superstructure, with safety in mind. One consideration was to erect the arch rib first, using tie-back cables, with steel girders erected from barges and supported on permanent hangers. Another idea was to erect long girder segments on isolated temporary bents followed by long preassembled arch rib segments supported by extending the temporary bents above the deck level. In all cases, the concrete deck was to be built after all steel was in place.

To minimize risk for construction contractors, the team chose the conventional method of erecting the superstructure on the temporary falsework. The team also recommended using bent steel pipe instead of formed steel plate segments in the arch support structure. The client had proposed the steel plate segments. The team's decision limited the pool of qualified fabricators but insured the superstructure could be built in the safest manner and would support the necessary loads.
The bridge has been recognized by various national and international industry associations for its unique design and technical excellence. In addition to winning an Engineering Excellence Grand Award from the American Council of Engineering Companies, the bridge was named Best Bridge/Tunnel of 2014 by Engineering News-Record and earned the Eugene C. Figg Medal for Signature Bridges from the International Bridge Conference.

Transparency and Integrity:

The iconic nature and regional importance of the bridge drew increased attention during the construction phase, beginning with the July 2009 groundbreaking by Vietnamese Prime Minister Nguyen Tan Dung. Local politicians visited the site to observe and discuss progress with consultants and contractors.

To complete the project on schedule, the contractors hired hundreds of workers throughout Vietnam through the Tet holiday in 2013. That effort demonstrated the project team's commitment to deliver a quality structure within the promised time frame. The $86 million bridge was completed within budget, largely due to the experience of the team in managing large infrastructure projects.

Dragon Bridge serves as an example of how aesthetic quality of a design can serve cultural, economic and functional purposes. The bridge not only draws attention on weekend when the dragon breathes fire but has inspired enduring civic pride. Visiting the bridge is on the local tourism board's list of "Top 10 Things to Do" in the city. Visitors can take boat tours under the bridge and

buy assorted bridge souvenirs. The DNPC has petitioned the *Guinness Book of World Records* to certify the bridge as the largest dragon in the world.

The Vietnam media has dubbed the bridge a symbol of Da Nang's growth and development. *LeMonde,* the French daily, said the bridge underscored Da Nang's status as "Vietnam's new economic dragon."

In a matter of months after it opened, the bridge contributed to the local economy. Tran Chi Cuong, deputy director of the city's Department of Culture, Sports and Tourism, said "the bridge has been central to our overall growth" and could help draw about 3 million tourists a year to the city. The bridge provided important new access to renowned beach resorts along the sea and to the UNESCO heritage town of Hanoi. Many tourism-related businesses got a boost from the bridge, which has benefited the city's whole economy.

At the ceremony to mark the opening of Dragon Bridge, deputy prime minister Nguyen Xuan Phuc said the bridge supported Da Nang's effort become the center of cultural and economic development not only in central Vietnam but nationwide.

The bridge raised Da Nang's international profile. It has been featured on news outlets such as CNN, Time, Wired, Yahoo! News, NBC and MSN. Philips, the LED lighting manufacturer, has featured the bridge in advertising in subways in New York and Washington, D.C., helping draw attention to the people and culture of Da Nang.

CNN said it quite literally in calling Dragon Bridge "Da Nang's fiery new success symbol."