December 2010

Structural Engineering &DESIGN

Sustaining the memory

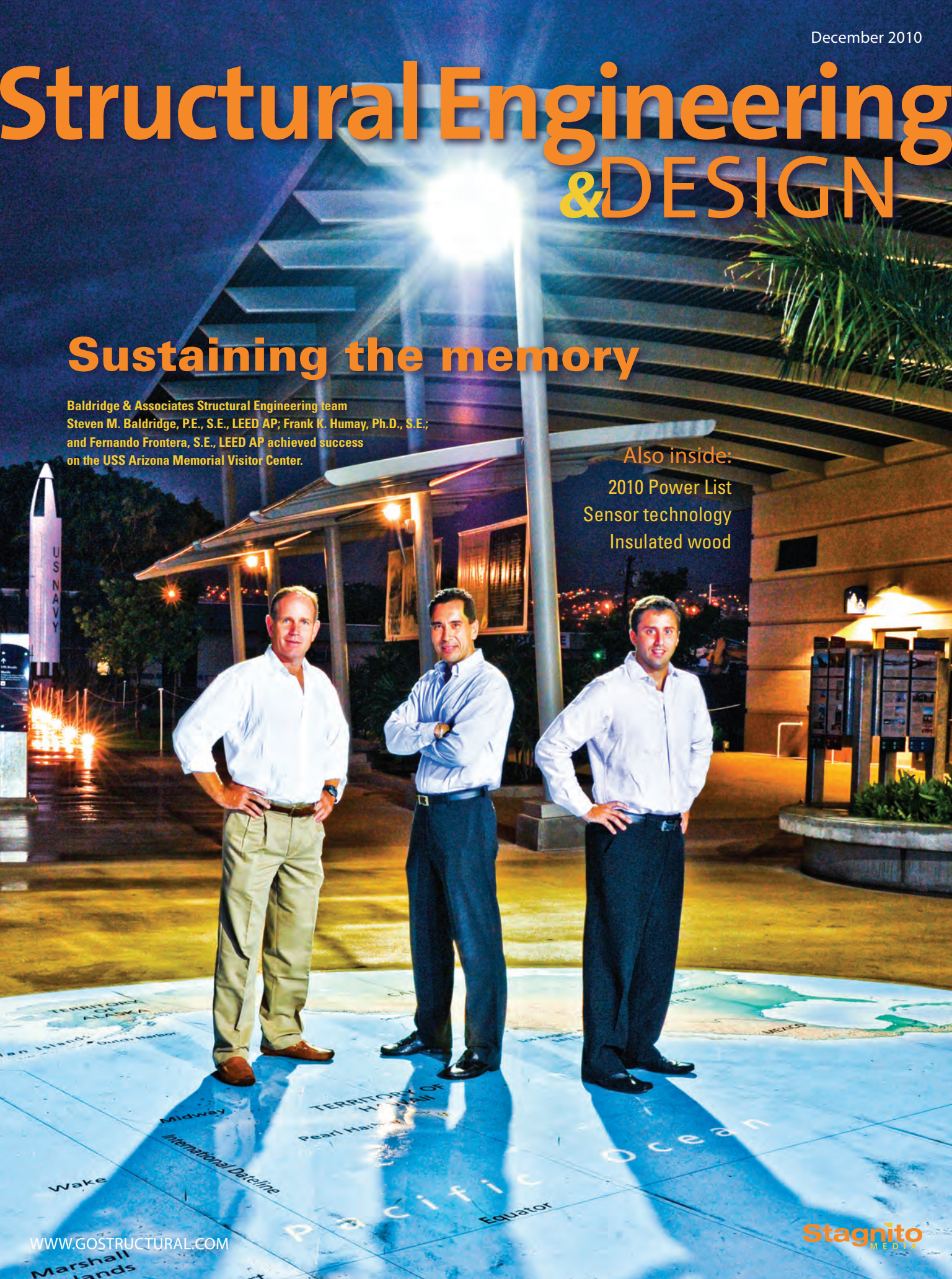
Baldridge & Associates Structural Engineering team Steven M. Baldridge, P.E., S.E., LEED AP; Frank K. Humay, Ph.D., S.E.; and Fernando Frontera, S.E., LEED AP achieved success on the USS Arizona Memorial Visitor Center.

Also inside:

2010 Power List

Sensor technology

Insulated wood



WWW.GOSTRUCTURAL.COM

Stagnito MEDIA

On Dec. 7, 1941, naval and air forces of the Empire of Japan attacked the United States, propelling the "sleeping giant" into World War II. The United States suffered great losses at Pearl Harbor, Hawaii, including the USS Arizona, which now lies underwater as the final resting place for many of the 1,177 crewmen killed during the bombing. This loss of life represents more than half of the Americans killed during the worst naval disaster in American history. After the war ended, people began coming to the shores of Pearl Harbor to remember those lost on what President Franklin D. Roosevelt called "a date which will live in infamy."

In 1962, a memorial was constructed above the sunken hull of the battleship. The memorial provides a place of visitation accessible only via boats operated by the National Park Service (NPS). To handle increasing visitation, a shoreside visitor center was built in 1980 at the mouth of Halawa stream. This facility was designed to handle approximately 750,000 visitors a year. Today, visitation has increased to 1.5 million visitors, requiring replacement of much of the original facility with a larger, upgraded center.

In December 2008, President George W. Bush designated the entire area to be part of the World War II Valor in the Pacific National Monument, and on Dec. 7, 2010 — 69 years after the infamous attack on Pearl Harbor — a new $58 million museum and visitor center will be completed. The new facility not only will honor and memorialize those who lost their lives in the attack, but also will preserve the story of Pearl Harbor for future generations.

Original visitor center

The original USS Arizona Memorial Visitor Center was completed in 1980 and constructed on an area created by land reclamation in the 1940s. The facility consisted of three one-story buildings situated around a courtyard, and it housed a museum, a bookstore, offices, a concession area, and several theaters. Adjacent to the theaters are floating boat docks used as the embarkation point for the memorial. The entire visitor center was constructed over a crawl space. This unremarkable space primarily was used for storage; however, it also was an integral part of an innovative structural system.

The reclaimed land under the USS Arizona Memorial Visitor Center contains thick, soft, and highly compressible submerged estuary deposits with organic matter. These deposits extend to depths of approximately 130 to 150 feet below the existing ground surface. It was clear at the time of the original construction that the building could not adequately accommodate the anticipated differential settlements with traditional spread footings.

For this reason, the original structure was designed to allow for re-leveling of the entire building from within the crawl space. Precast concrete stub columns were supported on shims that permitted approximately 8 to 10 inches of upward movement and 6 inches of downward movement. Standard spread footings were used and built directly over an existing asphalt parking lot.

Since the opening in 1980, the building was re-leveled on four occasions, and the structural system worked as intended. Unfortunately, portions of the building were settling at a much faster rate than originally estimated (30 inches, as opposed to the original estimate of 18 inches), and many of the columns were at or near their maximum allowable vertical movement.

In addition, it was becoming more difficult to find contractors willing to cost-effectively bid the re-leveling. Studies indicated that structurally upgrading the current building did not make economical sense, especially for a facility that is somewhat dated and significantly undersized.

New museum and visitor center

The new museum and visitor center facility is approximately 55,000 square feet of shaded or enclosed space, more than double the size of the original facility. Covering more than 17 acres, the new facility is arranged in a "campus style" layout that integrates the buildings within liberal green spaces. The site plan takes advantage of the mild Hawaiian weather and trade winds to maximize visitor comfort and energy efficiency. Visitors flow through a combination of conditioned and unconditioned interior and exterior spaces that maximize views of Pearl Harbor and the memorial. The facility is designed to achieve LEED Silver Certification from the U.S. Green Building Council.

Integration of the structural design and material selection into the sustainable footprint of the project was a key element of the design. To increase cost-effectiveness and durability,

The new museum and visitor center facility is approximately 55,000 square feet of shaded or enclosed space, more than double the size of the original facility. Covering more than 17 acres, the new facility is arranged in a "campus style" layout that integrates the buildings within liberal green spaces.

www.vitopalmisano.com

USS Arizona Memorial Visitor Center

Structural engineer
Baldridge and Associates Structural Engineering, Inc., Honolulu

Design architect
The Portico Group, Seattle

Technical/Local architect
Mason Architects, Inc., Honolulu

Contractor
Watts Constructors, LLC, Honolulu

Construction manager
NAVFAC Pacific of the U.S. Navy, Pearl Harbor, Hawaii

Spotlight: Baldridge and Associates Structural Engineering, Inc.

Q&A with the structural engineer

Baldridge and Associates Structural Engineering, Inc.'s Frank Humay, Ph.D., S.E., (FH), discussed the USS Arizona Memorial Visitor Center with **Structural Engineering & Design** Editor Jennifer Goupil, P.E. (JG).

www.vitopalmisano.com

JG: What was the first task you did to get started on the design?

FH: Because of the poor soils at the site, selecting the most appropriate foundation system was crucial. One of the primary reasons for building a new visitor center was because the original facility was sinking too fast.

JG: What types of structural systems did your team evaluate?

FH: Our team evaluated numerous different foundation systems, including precast driven piles, micropiles, drilled shafts, auger cast-in-place piles, and soil stabilization. In the end, precast driven piles were the only appropriate solution for the soft soils.

JG: Was building information modeling used on this project?

FH: Because of the difficulties involved with stabilizing a 30-year-old building, Revit was used to help better visualize and coordinate the underpinning work. The Revit model was a collaborative effort between the structural engineer and contractor.

JG: How was the most unique problem on the project solved?

FH: The most unique problem was underpinning the existing theater building. The decision to support the existing theater on piles came after construction had already begun. Our office was given only six weeks to complete the entire design while performing construction administration on the ongoing work. We worked closely with the contractor to engineer a solution that supports the theater on steel beams that span the entire width of the structure within the crawl space. Holes cut in the exterior precast concrete walls allow the steel beams to frame into exterior-grade beams that are supported on clusters of precast piles. The design and construction of the theater stabilization was done without impact to the original construction schedule.

JG: Were any new structural products used or specified?

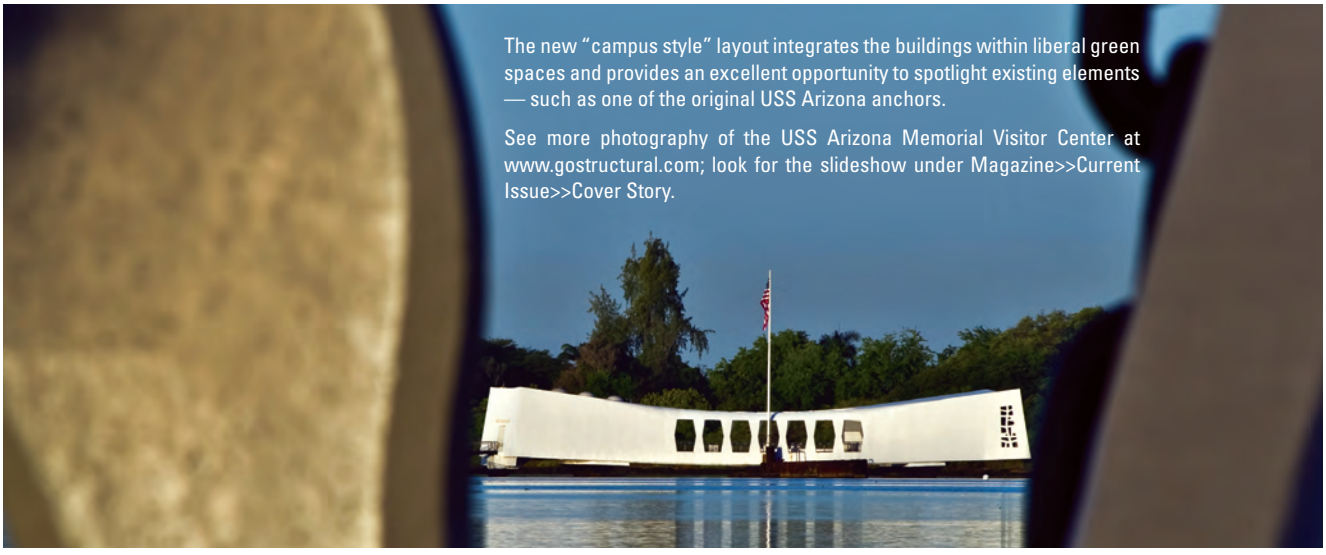
FH: Although not a new product, we worked closely with the architect to incorporate interesting steel roofs constructed with exposed HSS sections with various curvatures. The shape of the roofs allowed air to naturally flow through the building and minimized the need for expensive finish/cladding systems.

JG: What sustainable aspects were pursued by the design team?

FH: The most tangible sustainable design strategy was to limit the amount of mechanical cooling used on the project while maintaining visitor and staff comfort levels throughout the year. By creating spaces that could function without air conditioning, we were able to "buy" more program space for the client, because conditioned space has significantly higher costs. We also limited the experience of thermal "shock" that happens when people have to move in and out of conditioned spaces, and we created spaces with mechanically assisted breezes: fans and shaped roofs pull the air through the buildings when the prevailing winds are not strong enough to provide enough air movement. This strategy impacted all aspects of the project — from the siting of the buildings to the design of the structural systems to the selection of materials.

Firm Facts

Established in 1995, Baldridge & Associates Structural Engineering, Inc., is a full-service structural engineering and forensic consulting firm. The Honolulu-based firm — which also houses offices in Guam and Chicago — has completed projects in Hawaii, Guam, India, Korea, Palau, and on the mainland United States.



The new "campus style" layout integrates the buildings within liberal green spaces and provides an excellent opportunity to spotlight existing elements — such as one of the original USS Arizona anchors.

See more photography of the USS Arizona Memorial Visitor Center at www.gostructural.com; look for the slideshow under Magazine>>Current Issue>>Cover Story.

www.vitopalmisano.com

Integration of the structural design and material selection into the sustainable footprint of the project was a key element of the design. Exposed structural steel enabled the creation of swooping roof lines that efficiently move air through the buildings and eliminated the need for costly finishes.

www.vitopalmisano.com

concrete-masonry-unit (CMU) walls were selected because they provide a cool interior surface that enhances visitor experience in tropical environments. Exposed structural steel allowed the creation of swooping roof lines that efficiently move air through the buildings and eliminated the need for costly finishes.

The new facility includes eight new buildings connected by pathways and green space. Designed to enhance the visitor experience, the new complexes include exhibit space, retail and office space, ticketing, security, vending, restrooms, classrooms, and outdoor/indoor theaters.

Project challenges

Design of the new visitor center took many years to come to fruition and involved creative solutions to many difficult challenges. One of the main challenges was to understand and integrate the needs of a diverse group of stakeholders. The replacement of the visitor center is a partnership between the NPS, Pacific Historic Parks (PHP — formerly the Arizona Memorial Museum Association), and NAVFAC Pacific. The NPS manages the Arizona Memorial; the PHP provided the majority of the fundraising efforts; and NAVFAC Pacific awarded and administered the design and construction contracts. The project was built on Navy-owned land at Pearl Harbor to the design and construction standards of the Department of Defense (DoD).

Placement of the new facility on the existing site required consideration of many factors, several of which were in direct conflict with one another. The primary factors included the following:

- increasing visitor comfort,
- providing coherent visitor flow that enhances the telling of Pearl Harbor's story,
- maximizing views of Pearl Harbor and the memorial,
- designing all areas of the visitor center to be safe and accessible to everyone,
- creating a sustainable facility that makes use of trade winds and natural lighting,
- providing a secure site that meets DoD antiterrorism measures,
- locating buildings in areas with "better" soil conditions, and
- creating construction sequencing that allows the facility to remain open.

Developing the appropriate synergy between all these factors required many iterations and a very coordinated effort among the architecture and engineering design team, NPS, PHP, and NAVFAC Pacific. The "campus style" facility integrates the above criteria in a very successful manner. In addition, the site layout provided an excellent opportunity to incorporate existing elements — such as one of the original USS Arizona anchors and one of two original USS Arizona bells — in the new design.

Structural solutions

The primary structural challenge was selecting an appropriate foundation system for the new visitor center. Although the original structural design achieved its intended purpose, the NPS wanted a solution that minimized future maintenance. Numerous foundation systems were evaluated, including drilled shafts, auger cast-in-place piles, micropiles, and soil stabilization. None

By the numbers: USS Arizona Memorial Visitor Center

Size, shape, and type

- Number of square feet: 55,000
- Number of stories: 1 and 2 (depending on the building)
- Structural system: Masonry shear walls, cantilever round HSS steel columns, arched rectangular HSS and WF beams, composite metal floor deck with semi-lightweight concrete topping, and metal roof deck
- Foundation type: Structural concrete beam and slab on-grade system supported by octagonal concrete precast prestressed piles

Quantities

- Tons of structural steel: 337
- Tons of rebar: 290
- Cubic yards of concrete: Approximately 4,200
- Square feet of metal deck: 60,300

Schedule

- Design completion: 12 months
- Construction completion: 12 months per phase
- Cost: $52 million for overall project ($33 million for construction)

of these other systems were appropriate for the poor soil conditions at the site. After significant study and input from the geotechnical engineer, 16-1/2-inch octagonal precast, prestressed driven piles with lengths of 150 to 200 feet were chosen to support the new facility.

After inclusion of considerable down-drag forces caused by consolidation of the soft deposits at the site, the piles were designed for a net axial load of 75 tons. The new visitor center was designed in accordance with the International Building Code (IBC), 2003 Edition, using a site class of E and a seismic design category of D. Special seismic detailing was required, including an extremely tight pitch of the spiral confinement in the top 35 feet of the piles.

It was not deemed sufficient to only support the new building structures on

Precast, prestressed driven piles with lengths of 150 to 200 feet support the new facility, including much of the exterior plaza slabs. The ground floors of the buildings are constructed of a grid of reinforced-concrete-grade beams that act as pile caps and support a structural concrete slab.

www.vitopalmisano.com

piles. Since the NPS made it a priority to maintain a safe and accessible site at all times, much of the exterior plaza slab adjacent to the buildings also is pile supported. Careful consideration was made to include transition zones — areas between pile-supported and non-pile-supported slab — which could be repaved in the future. The ground floors of the buildings are constructed of a grid of reinforced-concrete-grade beams that act as pile caps and support a structural concrete slab.

One area of the original facility that was not re-leveled in the past and was still in excellent condition is the theaters adjacent to the dock. For several reasons, the existing theaters were the only element of the original construction that was to remain. The original design concept was to maintain the existing foundation system under the theaters and re-level in the future as required. However, once Watts Constructors came on board, a creative solution was developed that allowed the existing theater to be underpinned with driven precast piles.

The solution required that holes be cut at the bottom of exterior precast wall panels so large steel beams could be run through the crawl space. The steel beams support the weight of the theaters and transfer the load to steel- and concrete-grade beams located on the exterior of the building. Groups of piles support the exterior-grade beams.

One additional structural concern was long-term durability for a facility adjacent to the ocean with many exterior and unconditioned spaces. Special attention was paid to material selection, the concrete cover for reinforcing steel, steel galvanizing and paint systems for structural steel framing, among other details. Nearly 60 years after the December attack and 30 years after the original center opened, the new USS Arizona Visitor Center will serve millions of visitors and provide a lasting tribute to Pearl Harbor. ▼

Steven M. Baldridge, P.E., S.E., LEED AP, was the structural engineer of record for this project. **Frank K. Humay, Ph.D., S.E.,** was the project manager, and **Fernando J. Frontera, S.E., LEED AP,** was the lead designer. All three of them are with Baldridge and Associates Structural Engineering, Inc., and can be reached at 808-534-1300.