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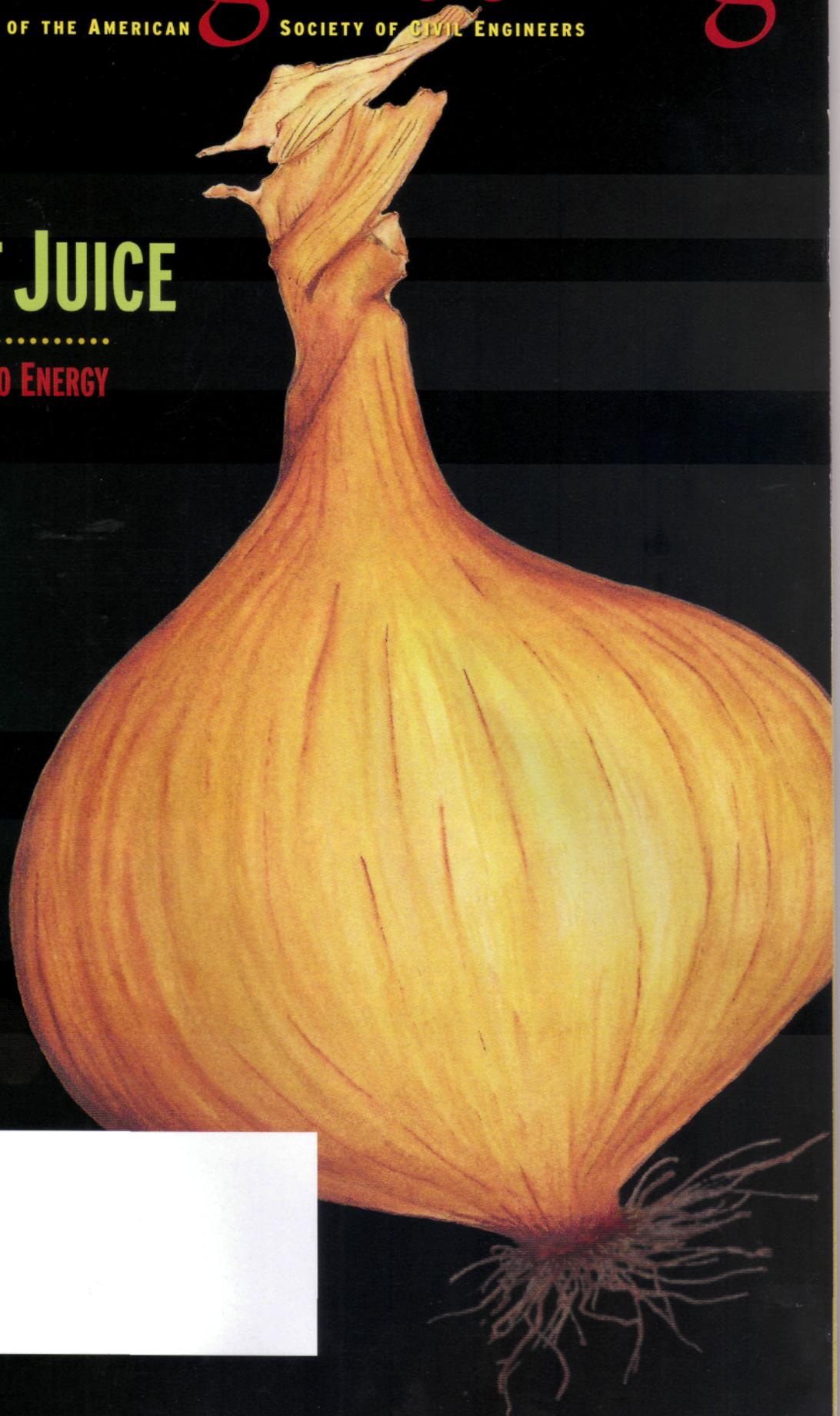
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overall market. In addition to providing expertise to private- and public-sector clients with regard to emissions inventories, carbon footprints, carbon trading, and greenhouse gas compliance schemes, these firms supply analysis for all of the other segments of the industry, Ferrier said. EBI estimates that in 2009 climate consulting and engineering services generated \$1.2 billion in revenue in the United States and \$7 billion worldwide. Those numbers are expected to increase steadily, reaching more than \$3 billion in the United States and nearly \$17 billion globally by 2012. Consulting and engineering “firms will continue to play a key role in designing solutions to complex problems as well as evaluating and specifying technology or operational solutions,” Ferrier said in response to written questions from *Civil Engineering*. In his opinion, “The key for firms will be to develop and demonstrate expertise in specified areas and use that to build broader practice areas.”

The American Recovery and Reinvestment Act of 2009 also is expected to influence the expansion of the climate change industry. In March 2009 the *Climate Change Business Journal* and the *Environmental Business Journal* surveyed companies in their industries and found that 60 percent of the 177 respondents saw the stimulus package as having great importance in their sectors. While it is difficult to quantify all of the provisions in the 2009 bill that are directed toward energy and climate change, the *Climate Change Business Journal* estimates that the package includes \$76 billion for the industry—\$52 billion in direct spending and \$24 billion in tax provisions. Several federal agencies have been charged with dispensing American Recovery and Reinvestment Act funds, including the U.S. Department of Energy, which received at least \$31 billion for programs geared toward energy efficiency and innovative technology.

For additional information about EBI Report 4000: *The Climate Change Industry*, visit www.ebiusa.com.—JENNY JONES



PRESERVATION

Miami Marine Stadium Undergoes Structural Analysis

MIAMI MARINE Stadium, located on Virginia Key in Miami, appears as though it has long been forgotten. Salt water has eroded portions of the concrete, harsh weather conditions have taken a toll on the wooden seats, and vandals have covered much of the structure with brightly colored graffiti. Despite the stadium's neglected condition, a crusade is under way to resurrect it to its glory days, when spectators eagerly filled the 6,566-seat grandstand to take in everything from powerboat races and rock concerts to political rallies and Easter sunrise services. One of the most significant steps in the restoration effort, namely, a structural condition appraisal, was completed earlier this year.

Miami Marine Stadium was built in the early 1960s after the City of Miami hired Dignum Engineers to develop what would become the first purpose-built stadium for powerboat racing in the United States. The engineering firm initially planned to construct a simple poured concrete stadium, but the architect on the project had other ideas, recalls Jack Meyer, who served as the principal engineer on the project at the time. A Cuban-born architect by the name of Hilario Candela designed the stadium with a modernist flare, capping it with a dramatically cantilevered roof involving

Efforts are under way to resurrect the nearly 50-year-old Miami Marine Stadium, located in Miami on Virginia Key, to its glory days, when fans packed the grandstand for such events as powerboat races, concerts, political rallies, and church services.

folded plates. The complex design required a great deal of creativity from an engineering perspective because nearly all of the columns were inclined and the folded plates were convoluted, Meyer says. “It made the project so much more difficult because there wasn't a straight line on the stadium at all,” he explains, noting that “it really merged together to make a very attractive...stadium.”

Miami Marine Stadium opened in 1963, and although it was intended to be used for boat racing, it also became the stage for a wide array of local and national events. Such personalities as Phil Donahue and Mike Douglas filmed television shows there, Jimmy Buffett produced his concert video *Live by the Bay*, and Sammy Davis, Jr., hugged President Richard Nixon on its floating stage. “It's almost a cultural petri dish,” says Don Worth, a cofounder of Friends of Miami Marine Stadium, a group dedicated to restoring the edifice. “So many things happened there.... It was a public gathering place that is fondly remembered by many types of people.”

The stadium remained in active use until 1992, when Hurricane Andrew struck the Miami coast. The City of Miami alleged that the hurricane had damaged the stadium beyond repair and filed

RENDERING BY ARSENI VARABYEU

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a claim with the Federal Emergency Management Agency to fund the structure's demolition. But before the claim could be processed, the insurance company wanted an engineering firm to assess the stadium's structural integrity. It commissioned Simpson Gumpertz & Heger, Inc. (SGH)—a national firm headquartered in Waltham, Massachusetts, that designs, investigates, and rehabilitates structures and building enclosures—to inspect the structure. SGH concluded that the stadium suffered no structural damage from the hurricane and estimated that between \$2 million and \$3 million worth of repairs would be needed, primarily because of insufficient investment over the structure's 28-year operating period.

For many years thereafter, the stadium sat vacant. Vandals moved in, and on more than one occasion Miami officials proposed demolishing the structure. Then in 2008, the group Friends of Miami Marine Stadium was established under the umbrella of the Dade Heritage Trust, a nonprofit organization focused on preserving structures of historical significance in Miami-Dade County. Since then, Friends of Miami Marine Stadium has been working to bring attention to the stadium and to garner support for its restoration. In 2009 the stadium was included in the National Trust for Historic Preservation's list of what it considered the 11 most endangered historic sites, and this year the World Monuments Fund placed the structure on its watch list. In the summer of 2009, Friends of Miami Marine Stadium organized a campaign to raise funds for a new engineering study of the stadium. The effort brought in \$50,000 from local and national organizations led by the World Monuments Fund.

Friends of Miami Marine Stadium hired SGH to study the stadium once again; this time the goal was to isolate the cost of restoring it and to compare potential corrosion mitigation methods. SGH began its investigation by studying the stadium's original design documents and conducting a visual inspection of the structure, including the roof and the sections over the water, to



A recent condition assessment revealed that Miami Marine Stadium needs between \$5.5 million and \$8.5 million worth of structural repairs.

obtain a sense of the damage and deterioration. The team used a boat to survey the stadium's seawall and piles and a man lift to survey the underside of the grandstand. To detect damage in the concrete, team members also "sounded" the concrete with hammers and chains, says Michael Brainerd, P.E., M.ASCE, a senior principal and the national practice leader of structure repair and rehabilitation for SGH. The team then extracted approximately two dozen concrete core samples from different sections of the stadium and surveyed the concrete structure using ground-penetrating radar to determine the thickness of the concrete cover over the steel reinforcement. "We spent about a week in the field...last September," Brainerd recalls. "The purpose of our work was to ...figure out how extensive the damage was so that we could quantify how much concrete repair there was going to be. Then we needed to know what was [causing] the damage."

The team took the concrete core samples back to SGH's laboratory and analyzed them, measuring the chloride content and looking for signs of carbonation, which occurs when exposure to humidity and carbon dioxide in the air causes the concrete's pH to diminish, eventually leading to corrosion of the steel reinforcement. "Concrete normally protects metal that's embedded in it from corrosion, even if the concrete is exposed to water," Brainerd explains. "The problem is if salt

enters the concrete or if the concrete gets carbonated to the depth of the reinforcing steel; then corrosion can occur and will occur." Miami Marine Stadium is located along the edge of the ocean, so inevitably its chloride content is high, which is causing the reinforcement to corrode. Carbonation is also occurring throughout the structure, but it has not yet reached the reinforcement.

The team also conducted a petrographic analysis of the concrete. That process entails cutting and polishing the concrete cores and then examining them microscopically. These examinations revealed that, despite the high chloride content and carbonation, the stadium's concrete continues to exhibit good durability. "Our fieldwork and our laboratory analysis led us to the conclusion that over forty years of exposure of this waterside structure to salt water and salt in the air had resulted in a situation where...the reinforcement of the structure is now corroding," Brainerd says. "That corrosion is causing spalling of the concrete, and all of the existing concrete damage needed to be repaired if the structure was going to be rehabilitated."

In addition to mending the concrete, SGH recommended that corrosion mitigation measures be implemented to preserve the stadium for the future. "If you only repaired the existing concrete damage, you would be just treating the symptom and not the cause," Brainerd says. "By not only repairing the existing damage but also implementing some level of corrosion mitigation, you extend the useful life of the structure beyond what it would [be] otherwise." For the stadium, corrosion mitigation options range from

RICK BRAVO

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simply applying a waterproof substance to the exterior of the structure to conducting chloride extraction to remove salt that has penetrated the concrete. If external mitigation efforts are used alone, the stadium will probably need additional repairs in just 10 to 15 years, Brainerd says, but if a combination of external and internal methods is deployed, that time may be extended significantly. "Many of these technologies don't have a long use history, so predicting exactly how well these things are going to perform is dif-

ficult," he explains. "We can give estimates, but it really boils down to managing the client's expectations and just making sure they understand that although these corrosion mitigation measures will slow ongoing deterioration, some amount of periodic concrete repair will be required in the future."

Depending on how corrosion mitigation is approached, SGH has estimated that it will cost between \$5.5 million and \$8.5 million to rehabilitate the stadium. Additional funding will be required for other aspects of the renovation, for example, new seats and restrooms, plumbing and electrical work, and renovations to make the stadium

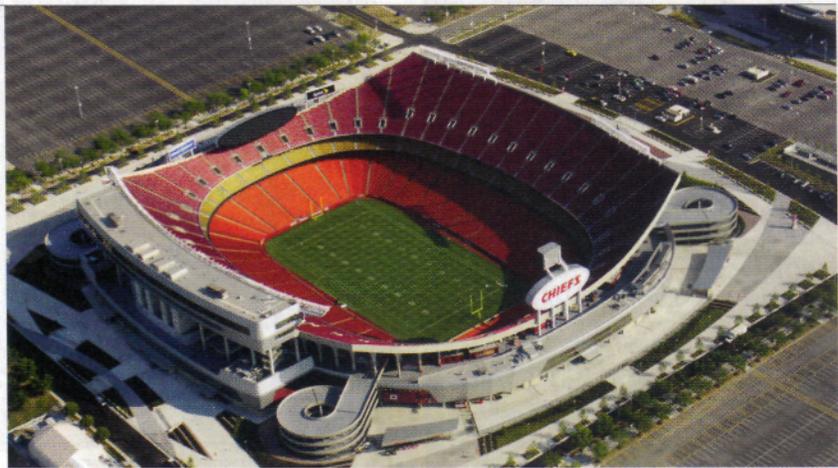
accessible to people with disabilities. SGH has also recommended that an analysis of the stadium's piles be conducted to gain an insight into the life expectancy of the foundations. Friends of Miami Marine Stadium is working closely with the city, which recently approved plans to preserve the stadium, to fund the pilings study and raise additional money for the rehabilitation. "This is not just a building; this is a very, very special place," Worth says. "This is a magical place, and if we're successful, and I think we will be, [it will be] just a marvelous legacy for Miami." For additional information, visit www.marinestadium.org. —JENNY JONES

STRUCTURES

Arrowhead Stadium Undergoes Dramatic Transformation but Keeps Its 'Soul'

IN 1972, WHEN ARROWHEAD Stadium opened in Kansas City, Missouri, as the home of the Kansas City Chiefs, it was considered one of the best sporting venues in the nation. Built expressly for football, it offered unobstructed views of the field from nearly every seat and a seating bowl that, when filled with fans, was one of the loudest in the National Football League (NFL). But as the years passed and professional football became as much about grandiose stadiums as about the games themselves, Arrowhead Stadium began to seem outdated. It lacked many of the amenities fans came to expect of a contemporary stadium, and as structural aging began to set in, it became clear that Arrowhead would need a dramatic makeover if it was to remain a viable venue.

In 2006 voters in Jackson County, Missouri, approved an increase in the sales tax of 0.375 of a percentage point to fund renovations of the Truman Sports Complex, which comprises Arrowhead Stadium and Kauffman Stadium, the home of the Kansas City Royals baseball team. Of the money raised, \$250 million was slated for the modernization of Arrowhead Stadium, supplementing a \$125-million contri-



Arrowhead Stadium, in Kansas City, Missouri, recently underwent a substantial modernization that enhanced the 38-year-old structure's amenities without diminishing its traditional feel.

but ion from the Hunt family, the owners of the Chiefs. The Jackson County Sports Complex Authority, which owns the Truman Sports Complex, broke ground on the renovations immediately after the 2007 football season. The intent of the project was to reestablish Arrowhead as one of the premier stadiums in the NFL without detracting from its distinctive appearance, says Randy Braun, P.E., a principal of Houston-based Walter P Moore and the firm's project manager for the Arrowhead Stadium renovation. "If you look at the tagline the Chiefs are using right now, which is New Body, Same Soul, that's really what they wanted it to be," Braun explains. The Chiefs organization wanted "the same feel, the same soul when you go in there and watch a game, but sort of a new body on the outside [so] fans

could really experience more of what a modern NFL game is like."

Converting Arrowhead Stadium into a cutting-edge venue meant that nearly every inch of it would undergo some sort of improvement, and generally that involved making things bigger and more elaborate. The stadium's service tunnel and all of the concourses were widened, the sound system was upgraded, the facade was enhanced, the seating arrangement was modified to better accommodate fans with disabilities, and the scoreboards were fitted with the latest technology. Furthermore, several new spaces were added, including additional restrooms and concession stands, a premium seating area, a club for field-level ticket holders, broadcast suites, and an area called the Hall of Honor that exhibits Chiefs memorabilia and mementos honoring high school

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