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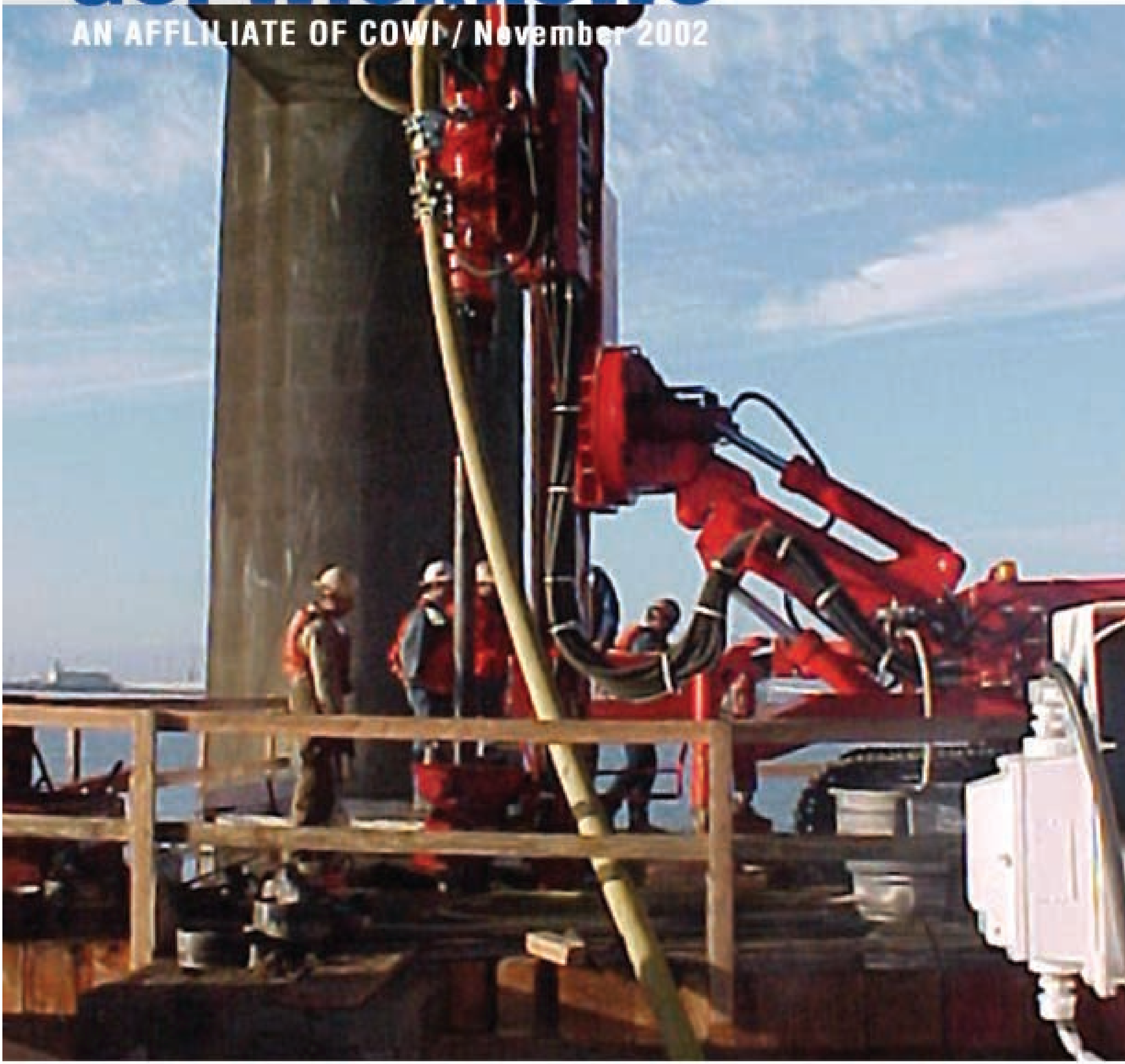

Innovative In-The-Wet Designs

Off-site Prefabrication Creates Cost-effective Solutions

By Paul E. Bach, P.E.

This issue of our Ben C. Gerwick, Inc. NEWS highlights several projects – within the U.S. and internationally – with an innovative approach to challenging marine projects subject to unusually large lateral loads, static and cyclic. The cover shows the micro pile construction for the seismic upgrading of the Richmond - San Rafael Bridge. A common denominator for the success of this and several of the following projects is "off-site prefabrication" with deployment "in-the-wet."

"Creating a cost-effective seismic retrofit for a structure as large and complex as the Richmond - San Rafael Bridge required innovations in nearly every piece of the project." This is the way Jeff L. Brown of "Civil Engineering" describes the ongoing work on this bridge. Read about current progress in the field. Our parent organization, COWI, presents its innovative work on new offshore wind farms designed to sustain cyclic loads from wind, waves and ice. Off-site prefabrication plays a decisive role.

Construction of a new bridge across Cooper River in Charleston has commenced. Due to the high seismicity in the area, hurricanes and the risk of vessel impact, the Cooper River Bridge was designed for large lateral loads. Read about the ship protection, artificial pier protection islands and large diameter drilled shafts. Olmsted Dam design is completed and bid advertisement is announced by the U.S. Army Corps of Engineers. The dam will be built in-the-wet with extensive use of off-site prefabrication. The area is one of high seismicity. Read about the novel method to ensure structural integrity of dam segments after deployment.

The innovative approaches to such projects can only come about in a concerted and coordinated effort between all our engineering skills: large scale erection engineering, advanced concrete technology, state-of-the-art design engineering and accurate cost estimating.

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Published by
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Cover Picture
Richmond - San Rafael Bridge, San Francisco Bay, California, USA

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Ben C. Gerwick, Inc. is an internationally known civil/structural consulting firm based in San Francisco specialized in the construction of major marine structures for more than 75 years, first as a heavy construction company, and as consulting engineers since 1971.

In 1989, Ben C. Gerwick, Inc. joined COWI Consulting Engineers and Planners AS, an engineering company with headquarters in Denmark, founded in 1930. The parent company of Ben C. Gerwick, Inc. operates from 67 offices and employs more than 3,500 people worldwide. The firms augment one another's strengths and share resources to benefit their clients.

Rocky Reach Juvenile Fish Bypass

Pump Station Substructure

Pump Station Substructure on Casting Barge

By Marc C. Gerin, Ph.D., P.E.

"This way little fish." The owners of the Rocky Reach Dam on the Columbia River are building a new fish bypass to help the juvenile salmon on their way to the sea. This will surely provide an enjoyable alternative to taking a spin through the turbines. As part of the new installation, a partially submerged pump station will create a flow along the upstream face of the dam to lure the fish towards a bypass conduit.

Ben C. Gerwick, Inc. is providing engineering services to the prime contractor, Traylor Pacific, for the float-in construction of the pump station substructure. The 150 ft long by 34 ft wide substructure provides the framework to hold the pumps and associated screens and baffles in place. It consists of a 2 ft thick concrete base slab, 44 ft high concrete end walls, 12.75 ft high interior transverse walls on 15 ft centers, and vertical steel pile sleeves braced by horizontal steel pipes. There is one longitudinal wall, a full height bulkhead in the center with large openings for the flow from each of the 30 pumps. Construction is being done in four stages, with the first two now completed: initial construction on the cast and launch barge, launching of the substructure, final construction while afloat, and set-down onto the support piles 43 ft below the surface.

Casting of Concrete and Walls

Since the structure is designed for water to flow through, it is open on the two long sides. Designing side panels that are firmly attached and watertight during construction yet easily removed after set-down proved to be an interesting challenge. Assembled from EFCO steel forms bolted together, the side panels are connected to the structure only along the edges with a minimum number of anchor bolts. These are all accessible from the outside so that divers can easily remove the panels when the structure is submerged.

The stresses in the structure during floating construction are very different than the stresses for which it was originally designed, which are based on the installed condition. In particular, the heavier end walls cause significant bending in the structure while it is afloat. To compensate, the base slab and bulkhead wall had to be strengthened with additional reinforcement. Floating stability, draft and minimum freeboard were estimated in advance of every construction phase. This information allowed Traylor Pacific to develop a construction sequence, which best satisfied the various requirements associated with float-in construction.

The new bypass facility will be completed by spring 2003, when the young salmon in search of adventure head for the wide-open sea.

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Richmond-San Rafael Bridge

Construction of the Richmond - San Rafael Bridge

Seismic Retrofit

By Thomas Dahlgren, P.E.

Ben C. Gerwick, Inc. is currently providing construction services for Caltrans as part of the seismic retrofit of the 4.1mile long Richmond – San Rafael Bridge, located in the northern part of the San Francisco Bay. Prior to construction, Gerwick performed the seismic retrofit design as the lead part of a Joint Venture that also includes DMJM (now DMJM+Harris) and Sverdrup (now Jacobs Engineering).

The $484M construction contract was awarded to a JV consisting of Tutor-Saliba, Koch and Tidewater construction in September 2000. With construction well underway, some of the main retrofit components include:

• Precast concrete jackets that are placed around existing concrete piers. The purpose of these jackets is similar to the more commonly used steel casing typically seen wrapped around concrete columns on freeway overpasses. Due to the harsh marine environment in the splash zone, it was decided to use precast concrete. The elements are fabricated offsite and placed around the piers above water then lowered down to make room for the next pair of jackets.

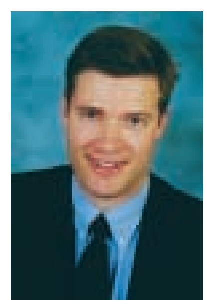
• Precast concrete pile caps with up to 13.5 ft diameter steel piles. The purpose of these precast pile caps is to limit the lateral displacement of the existing piers and thereby preventing buckling of the existing battered steel H-piles. The pile caps therefore act as shear diaphragms. To ease construction in water depths up to 60 ft, the pile to cap connection is pinned. This allows the Contractor to first set the precast pile cap halves and then install the large steel piles using the pile cap as a template. Due to the pinned connection, the steel piles are up to 13.5 ft in diameter.

• Micropiles installed through the existing concrete bells up to 60 ft below water. Some of the existing piers are founded on relative short steel H-piles that are driven to rock. In order to reduce the potential for overturning and to limit the lateral displacement of the pier, micropiles are installed through the existing bells and grouted to become an integral part of the foundation. The construction procedure involves coring holes through the existing concrete foundation and advancing a permanent steel casing until bedrock is reached. A rock socket is then drilled, and the 8-5/8" diameter micropile is inserted and grouted.

• Eccentrically braced steel towers placed on each side of the existing towers. The laced K-bracing in the existing towers is not capable of absorbing the large lateral seismic loads. New eccentrically braced steel towers are therefore placed on each side and the K-bracing removed. The existing tower legs continue to carry the dead load of the bridge whereas the new eccentrically braced steel frames handle the lateral loads. Gerwick has reviewed a large number of shop drawings to date and the erection of the first steel tower is underway.

Construction is scheduled to be complete sometime in 2004.

Precast Jacket Construction from Field



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Nysted Offshore Wind Farm

Rødsand, Denmark

By Christoffer X. Broedbaek

Denmark has formulated an energy policy giving high priority to sustainable energy, where windmills are a very important element. Several offshore wind farms are planned and COWI serves as consultant for the Rødsand Wind Farm.

COWI has carried out bid and detailed design for a Danish construction company for 72 windmill gravity foundations located 6 miles off the coast in the southern part of Denmark. The offshore wind farm has a total capacity of approx. 480,000 MWh, equivalent to the yearly consumption of 120,000 households. The windmills are 225 ft high and the width of the gravity foundation is about 56 ft.

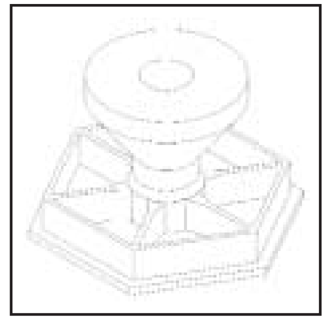
The windmills are founded at 25 to 42 ft depth on stiff clay till. The gravity foundations (see sketch) are open concrete structures filled with ballast and covered with armor stones. The foundation is made of reinforced concrete and consists of three parts: the open caisson, the shaft and the ice cone. The design is based on an optimal utilization of the subjacent soil conditions versus load conditions, when defining the foundation level of each position.

The foundations are designed to sustain cyclic loads from wind, wave and ice forces during their 25-year lifetime.

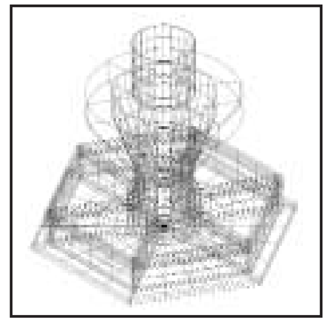
The detailed design included geotechnical, structural and scour protection design, the latter validated by hydraulic model tests. The geotechnical and structural designs were carried out using state-of-the-art numerical tools, e.g. PLAXIS and IBDAS.

These tools allowed the detailed design, including approval by the certifying authority DNV, to be carried out efficiently during spring 2002 in order to meet the project milestones. The many structures of slightly different dimensions could be modeled rapidly and individually by the parametrically working IBDAS system, and the corresponding allowed repetitive documentation to be easily processed.

The foundations are now being prefabricated on barges temporarily harbored in Swinoujscie (Poland) some 125 miles away from Rødsand. Upon completion in the prefab-site the barges are towed to final location where the foundations will be placed in pre-excavated pits by use of floating crane equipment. The typical lift weight of one structure is about 1300-ton. All foundations will be ready by summer 2003, where the erection of the windmills will take place.



Sketch of Foundation



Structural Finite Element Model

Photo: Jørgen Schytte/BAM

Denmark is to have more offshore wind turbines. The country's second largest wind turbine park will emerge from the waves off the island of Lolland in 2003.

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Olmsted Dam

Bid Stage

Catamaran Preparing to Lift the Frame and Shell Off of the Sled for Transport to its Final Location

By Casey L. Bowden, P.E.

The Sverdrup/Gerwick Joint Venture (JV) recently completed the Olmsted Dam design, which was advertised for bid by the U.S. Army Corps of Engineers Louisville District this past summer. The project site is located on the Ohio River, near Paducah, Kentucky, approximately 16 miles upstream from the confluence of the Ohio and Mississippi Rivers. The dam has been estimated to cost approximately $300 million, and is part of a larger project including: twin locks, approach walls, buildings, grounds, utilities, roads, and permanent operations and maintenance equipment authorized at over $1 billion, for the entire project.

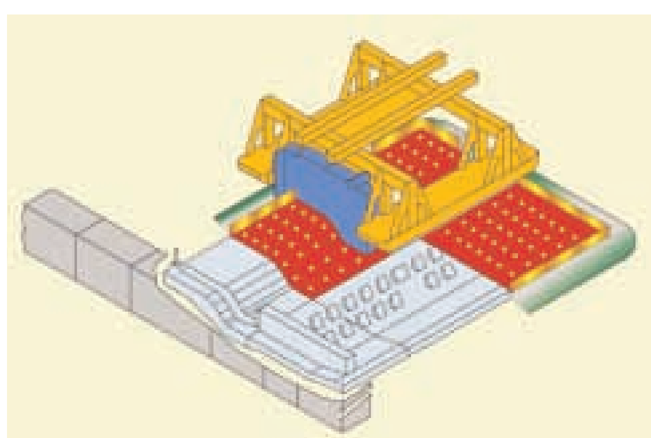
As presented in both the December 1996 and the May 1997 editions of Ben C. Gerwick, Inc. NEWS, the Louisville District decided to build the dam "in-the-wet", using large offsite prefabricated concrete shells that will be lifted into place. The shells will structurally connect to a pre-driven pile foundation using tremie concrete. Although all permanent features of the dam have been designed and specified, there are numerous major construction-related items that must be designed by the selected Contractor for this project. The features, which will be critical to the success of the project, are:

Specialty Floating Equipment:

• The JV has provided conceptual drawings of a 2,800-ton capacity catamaran, as an example of the type of crane barge that must be provided by the Contractor for performing heavy lifts and transport of: pipe pile frames/templates, lifting/tremie frames with associated pre-cast shells, navigable pass paving block frames with paving blocks, tainter gate lower pier wall shells and the navigable pass monolith 12 training wall.

• Prior to placement of the pipe pile frame/template with associated tremie reinforcement cage, the Contractor is required to establish grade within tolerances. The JV has developed conceptual drawings of a screeding barge to accomplish this task. In this concept, leveling course material is delivered as required through an auger mast to a computer-controlled screed auger. The assembly travels via a carriage on a truss spanning two barges. Concrete anchors are used to tie down and ballast the barge hulls prior to operations and prevent wave-induced motion. The Contractor may either adopt and complete the JV conceptual design or select an alternative that will meet the requirements set forth in the specifications.

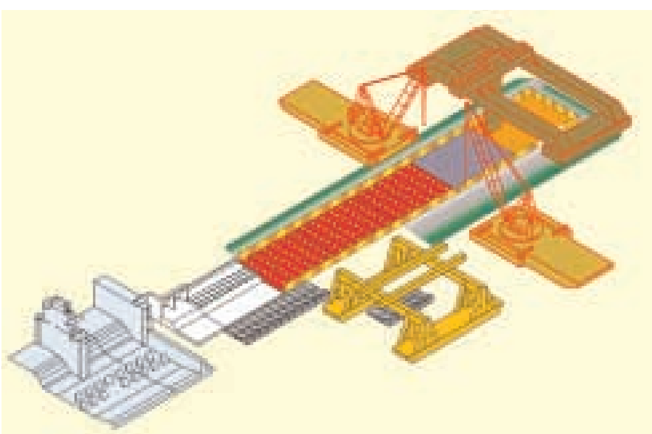
• To fill the void beneath any given pre-cast shell, the JV developed a conceptual design for a floating batch plant that must be able to batch, mix, convey and place tremie concrete at a peak rate of 150 cubic yards per hour. The Contractor may choose another method of tremie production such as transit mixers on barges near the placement site; however, concrete that is mixed onshore and transported to the dam site for placement through either transit mixers or pump-lines will not be permitted, since it would necessitate crossing the operating lock.



Placing Six Precast Lower Pier Wall Shells

Representative Heavy-Life Catamaran (From the Second Hampton Roads Bridge-Tunnel Project)

• Additional specialty construction apparatus to be designed by the Contractor includes vibro-compaction and scour protection placement barges.



"In-the-Wet" Activities During Phase 4 of Construction

Specialty Construction Frames:

• To meet tolerances, the Contractor is required to use a template when driving master piles associated with the sheet pile walls. The JV has shown a conceptual system utilizing a template mounted on barges.

• Pipe pile frames or templates are also required to be developed by the Contractor. The JV conceptual design consists of two initial frames that are modified, as required, as construction proceeds. In addition to driving the pipe piles within tolerances, the frames also must serve as an attachment point for the tremie concrete reinforcement cage, which is hung from the bottom of and thus installed with the pile template.

• Significant JV effort has gone into the partial design of the tremie/lifting frames, which must perform a wide variety of functions. All main members have been designed and typical frame joint details are provided, together with all of the design forces for all of the frame joints. The joints in these frames are indicated as bolted connections for ease of re-configuration; however, the Contractor is responsible for the final design of all joints. The Contractor must design lifting connections at the top of the frame legs based on his choice of heavy lift crane; locations and loads are indicated on the drawings. At the bottom of the frame legs, at the pre-cast shell interface, the Contractor is to design the shell to frame connection utilizing drill collars with the locations and loads shown on the drawings. Additional frame details to be designed by the Contractor include: laitance containment boxes, tremie seals, positioning systems, shear keys and work platforms.

Prefabrication Facility:

The Contractor may select either the job site facility as shown on the Contract Drawing or a remote casting facility for fabrication of the pre-cast concrete elements. Casting and launching from the job site facility was evaluated as the base case because it reduced risks and potential impact to the schedule, although the Contractor may choose to use an alternate facility for some, or all, of the pre cast elements. Using the JV conceptual pre- cast yard, the construction and load-out of a pre-cast shell would be as follows:

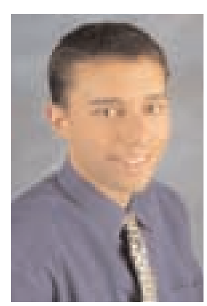
1. Panels making up individual shells are cast and cured.

2. A shell is assembled from the panels on a shell assembly platform (sled) that slides on a landside skidway via gripper jacks.

3. The sled and shell are pushed onto a cradle that slides on a marine skid-way; gripper jacks lower the cradle, sled and shell into the water where the heavy lift crane (catamaran) places the lifting/tremie frame on the shell.

4. Gripper jacks pull the cradle, sled, shell and frame out of the water so the frame can be secured to the shell in-the-dry with drill collars.

5. The cradle, sled, shell and frame are lowered to the catamaran, which connects to the top of the frame with strand jacks and carries the frame and shell, partially or fully submerged, to its final location.



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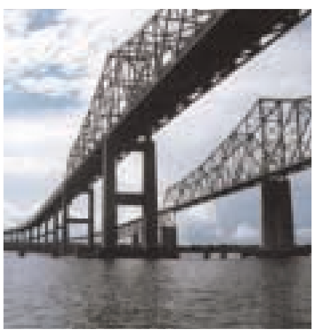
Cooper River Bridge Replacement

Artificial Pier Protection Islands

By Mads P. Jorgensen

Construction of a new bridge across the Cooper River in Charleston has recently commenced under the direction of the South Carolina Department of Transportation (SCDOT). Palmetto Bridge Constructors, a Joint Venture of Tidewater Construction Company, Skanska USA and Flatiron Structures Company LLC are building the new bridge with funding from SCDOT, the State Infrastructure Bank, the Federal Highway Administration, Charleston County, and the State Ports Authority.

Rendering of the New Cooper River Bridge and Artificial Pier Protection Islands



Existing Grace Memorial Bridge

The new Cooper River Bridge, which will be complete in 2005, will replace the existing Silas N. Pearman and Grace Memorial Bridges along U.S. Highway 17. The bridge will connect the historic Charleston peninsula with Mount Pleasant, reaching across the Cooper River, Drum Island and Town Creek. The main span over the Cooper River will be the longest cable-stayed span in North American at 1546 ft. The span will be supported by two diamond-shaped towers, allowing for a l000 ft wide navigation channel with a 186 ft vertical clearance. The Charleston high-level approach is approximately 4351 ft long, while the Mount Pleasant high-level approach is 2090 ft long.

Buckland & Taylor Ltd., in cooperation with Parsons Brinckerhoff Quade & Douglas, Inc., developed the bid design for the new bridge and is preparing the detailed design for the high level approaches along with checking the design of the main spans. Ben C. Gerwick, Inc. is responsible for the foundation design of the main spans and high level approaches. Gerwick is also responsible for the ship impact risk analysis and design of protective islands for the main towers.

The purpose of the rock islands is to protect the two central bridge piers against ship impact. In addition, they are designed to withstand the affects of hydraulic loads, both natural and manmade, throughout the design life of the bridge.

The two pier protection islands are approximately 65 ft in height with side slopes of 2:1, both with a footprint of roughly 200,000 square ft. A toe dike running along the perimeter of the islands provides protection against scouring along the base and ensures stability of the island slopes.

The islands are constructed with an outer layer of rock armor placed on a quarry run core consisting of approximately 225,000 cubic yards of rock, all of which is being shipped from Canada. The islands are founded on the Cooper Marl, which is located between 10 and 40 ft beneath the riverbed. Excavation for the islands involves dredging in excess of 500,000 cubic yards of material.

In order to allow passing of larger vessels, it is intended to widen the existing access channel from 500 to 1000 ft and increase its depth from 50 to 60 ft, bringing the limits of the channel close to the toe of the islands.

Special consideration has been given to the bridge piers of the existing Silas N. Pearman Bridge for which the dredging for the artificial islands encompasses seven of the piers. A concept involving circular sheet-pile cells has been developed which enables the bridge piers to remain as self-supporting columns during the period of dredging and the subsequent placement of rock materials for the pier protection islands.

Separate studies have evaluated the risk of ship collision (including traffic scenarios for the planned extension of the access channel). These were validated by ship collision model testing at a hydraulics laboratory. The seismic performance of the islands as well as settlement of the islands during construction was undertaken by Parsons Brinckerhoff who also provided the geotechnical and hydraulic analysis.

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Large-diameter Drilled Shafts

For the New Cooper River Bridge Foundations

By Osama S. Safaqah, Ph.D.

Due to the high seismicity in the region (the Design Basic Event is magnitude 7+), potential vessel impact and hurricanes, large lateral loads are involved. Among various types of foundations, 10 ft diameter drilled shafts were selected for their high capacity against lateral loading. The main towers will be founded on a group of 11 shafts and protected from ship collision by a rock island. The High-Level Approach piers will be supported on a pair of 10 ft diameter shafts. The water piers in Town Creek will be protected by a fender system also founded on drilled shafts. Permanent casings will be used as forms. The estimated shaft tip elevation for the main piers is as much as 220 ft below water line.

The bearing layer at the site is Cooper Marl, a stiff to very stiff lightly cemented calcareous sandy clay (CH/CL) or sandy silt (ML/MH) and underlies coastal sediments of interbedded clays and sands. The layer is more than 300 ft deep and appears at elevation from 40-70 ft below waterline. An elaborate geotechnical investigation has been conducted on the site including a load test program on full-scale shafts under axial and lateral loads. The results of the tests were used to calibrate the lateral and axial soil resistance.

Structural engineers from Ben C. Gerwick, Inc. design team together with the geotechnical engineering staff of Parsons Brinckerhoff Quade & Douglas, Inc. and the structural engineers from Buckland & Taylor Ltd., who are designing the HLA, have examined the different aspects of a drilled shaft design. Non-linear soil-structure interaction analyses were conducted for each pier under different load cases and site conditions to come up with a detailed shaft design. In some cases, different load groups governed the design of different segments of the shaft. The design process was also marked by a close collaboration between the different design firms to achieve compatibility in the conditions governing the design of the superstructure and the foundation.

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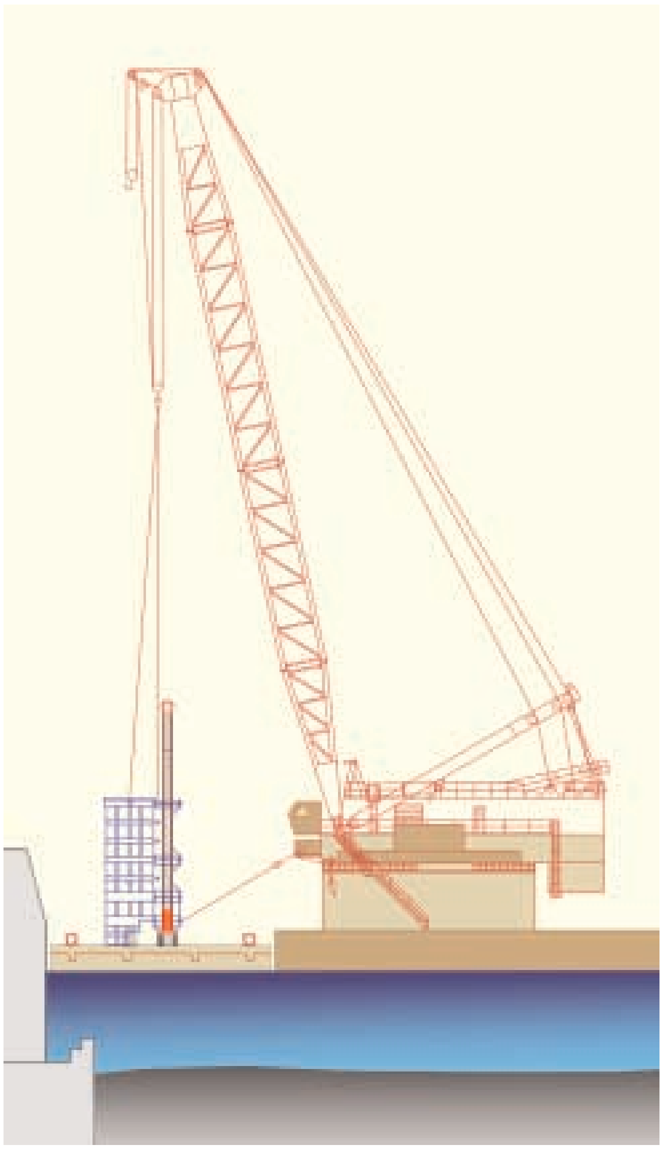
Drilled Shafts East Island

Implementation of a Tainter Gate Stilling Basin Dewatering Bulkhead System



Dewatering Bulkhead System and Heavy Lift Crane Henry Shreve

By Lydia W. Lai

Ben C. Gerwick, Inc., working together with Bergmann Associates, has recently modified the design of a tainter gate stilling basin dewatering bulkhead system for the Louisville District of the U.S. Army Corps of Engineers. The bulkhead system is currently designated for use in repairing stilling basins at the Markland, Cannelton, Newburgh, and J.T. Myers dams; however, the design can be adapted for use at other tainter gate dams, as future need arises. The basic design of this bulkhead system was presented in the August 2001 edition of Ben C. Gerwick, Inc. NEWS, while this article focuses on the recent design modifications made to enhance the operability of the system.

One of the most significant modifications to the design was the use of structural steel with minimum yield strength of 60 ksi. Use of this high-strength steel helped reduce the lifted weight of the heaviest configuration of the bulkhead system from 450-tons to less than 420-tons. This weight is low enough to allow the Louisville District's 550-ton capacity crane barge, the Henry Shreve, to rotate while carrying the bulkhead system. This option is needed if the transport barge cannot be pre positioned between the tainter gate pier walls and the Henry Shreve, as shown in the figure. The design of the transport barge was also modified to better secure the bulkhead system to the barge, allowing the loaded barge to resist larger waves and higher winds.

Other design modifications include:

a) The ability to reconfigure the bulkhead system to accommodate different end-tainter gate bay geometries, as compared to the typical mid-tainter gate bays.

b) Adjustable connection details to allow the bulkhead system to be securely attached to the tainter gate pier walls, with reduced risk of displacement from vessel impact and/or reversed hydraulic water head pressure.

The Louisville District plans to use tie-down rock anchors to stabilize the stilling basin slabs from uplift due to underbase water pressures when the bulkhead system is dewatered. Bergmann Associates is currently in the process of completing the design of the tie-down anchors, which are planned to be installed "in-the-wet", prior to the installation of the dewatering bulkhead system at any given dam. The bulkhead system will be advertised for bid fall 2002, and should be ready for deployment before summer 2004.

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Profile:

Sam X. Yao, Ph.D., P.E.

Doctor Sam Yao is a project manager with Ben C. Gerwick, Inc. Born and raised in Shanghai, China, Sam received a M.S. and Ph.D. in civil engineering from University of Illinois.

Since joining Gerwick in 1993, Sam led or extensively participated in numerous major marine projects. The focus of his work has been design, rehabilitation, and construction support of bridges, locks and dams, tunnels, and intake structures. In 1997, Sam and Ben Gerwick, Jr. received the Excellence Award from ICRI for managing the repair and rehabilitation project at Diablo Canyon Nuclear Power Plant.

In the past four years, Sam has been also involved in research and development of innovative "in-the-wet" technologies. He co-authored eight technical reports/design guides on underwater concrete technologies, prestressed/precast concrete thin-wall structures, heavy lift marine equipment, and positioning techniques in float-in and lift-in construction.

In addition, Sam has served as an expert witness or an investigator on many construction litigation cases involving tremie concrete, corrosion of reinforced concrete, cracking and leakages in water-containing structures, drilled shafts, slurry walls, and pile foundations.

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New Publications, Presentations & Awards

Presentations:

7th U.S. National Conference on Earthquake Engineering
Boston, Massachusetts,
July 21-25, 2002

"Rational Approach to Seismic Shear in Reinforced Concrete"
Marc C. Gerin, Ph.D, P.E.

"Improving the Seismic Response of Asymmetric One-Story Systems by Supplemental Viscous Damping"
Wen-Hsiung Lin, Ph.D.

IABSE Symposium
Melbourne, Australia,
September 11-13, 2002

"Innovative Marine Structures for Better-built Environment"
Paul Bach, P.E.

1st Fib Congress: *Concrete Structures in the 21st Century*
Osaka, Japan,
October 13-19, 2002

"Advances in Structural Underwater Concrete Technologies"
Ben C. Gerwick, Jr. P.E. and Sam Yao, Ph.D., P.E.

1st Fib Congress: *Concrete Structures in Seismic Regions*
Athens, Greece,
May 6-9, 2003

"Recent U.S. Lessons From Seismic Design and Upgrading of Foundations For Major Marine Concrete Structures"
Paul E. Bach, P.E.

Awards

Ben C. Gerwick, Jr., was elected to the National Academy of Construction August 9, 2002 in Denver, Colorado.


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