Tapping technology

Innovation in bridge design and construction is often discouraged because of the perceived risks, but these can be avoided by transferring proven technology from one field to another. *Robert Bittner* reports on how techniques from the offshore industry are being used in the design and construction of bridge foundations

Lifting the precast footing shell off the deck of the casting barge

LOWER cost, faster construction, higher quality and even reduced risk are all advantages which can result from innovations in bridge design and construction. The offshore oil and gas industry is a rich source of proven advanced technologies that are highly applicable to the design and construction of bridge foundations.

These innovations include the use of large diameter steel cylinder piles, the offsite prefabrication of float-in foundation elements and the mating of these elements to the pre-installed cylinder piles. Such techniques were developed by the offshore industry in response to the harsh environmental conditions and the relatively short weather windows available for performing construction work.

Typically, bridge sites are not subject to these same severe conditions, but there are still significant incentives for the application of these technologies particularly in the case of bridge foundations.

Constructing bridge foundations under water is an expensive operation and usually represents 40 to 50% of the total cost of a bridge over water. The major reasons for the high cost are the inefficiencies and hazards associated with working in water. One method of avoiding such costs is to prefabricate as much of the foundation work as possible on shore and then either float or lift completed elements into position on top of pre-installed foundation piles.

This was the main objective in the design of a floating cofferdam system for the new Bath-Woolwich Bridge across the Kennebec River at Bath, Maine.

Client Maine Department of Transportation awarded the design and construct contract for the 1km long four lane bridge to contractor Flatiron Structures Company and consultant Figg Engineers in August 1997. Flatiron then contacted specialist consultant Ben C Gerwick to design a safe and economical cofferdam system for the six main river piers.

Figg's design for the six main river piers called for footings of two different sizes. One was 10.9m by 9.9m in plan, 3.6m deep and supported by three 2.4m diameter steel cylinder piles socketed into rock. The second was 9.6m by 9.6m in plan, 3.6m deep and supported by four of the same size piles.

The typical footings had a 2.7m deep tremie seal and were located in 13m of water with the top of the footing about 1.4m below mean tide level. This design was very efficient from a construction standpoint; it significantly reduced the water depth at which the footings were constructed. However, it created the problem of how to construct an underwater footing 6m above the river bed.

In order to address this problem and reduce the amount of work in the river, Ben C Gerwick proposed the use of a floating cofferdam system constructed in the following sequence.

First move was to install the drilled shafts using a two stage template. A precast footing shell was then precast on shore and a reusable temporary steel follower cofferdam was attached to it. The cofferdam was towed to the bridge site where it was positioned over the drilled shafts and fixed in position with four spud piles.

Next the cofferdam was lowered over the pre-installed drilled shafts by using jacks located on top of the spud piles. The footing was locked to the drilled shafts by placing a 1.3m deep tremie seal. The cofferdam was dewatered and the footing and pier shaft were constructed in the dry. Finally the follower cofferdam was removed for reuse on the next pier.

Use of this system substantially reduced the amount of work that had to be carried out in the water and improved quality control by transferring the work to an offsite dock location. The system also saved four months in the construction of the foundations by allowing the drilled shaft installation to start immediately after contract award and to continue concurrently with fabrication of the floating cofferdams.

The final design for the precast footing shell was a 5.2m deep box with 288mm thick walls and bottom slab, while the typical precast box weighed 340t and was cast on the deck of a barge at the dockside. Two 4.3m high steel followers were made using interlocking steel sheet piles and assembled on the deck of another barge.

Two local shipyard cranes were used to lift the precast footing shells off the deck of the casting barge and into the water. The precast box was then levelled by using compressed air to vary the water level in the open bottomed 3m diameter pile top blockouts. Once the segment was afloat and trimmed, one of the steel followers was lifted into position on top of the precast footing shell and bolted to the top lip of the precast box.

The floating cofferdam was then towed into position over the top of the pre-installed piles and locked in horizontal position with four 1m diameter spud piles driven through the pockets, attached to the corners of the cofferdam.

One of the keys to the successful use of this technique was the installation tolerances of the 2.44m diameter drilled shafts. The drilled shafts had to be installed to a relatively tight tolerance or the holes in the bottom of the precast footing shell would not match the layout of the pre-installed piles. On the Bath-Woolwich Bridge, the inside diameter of the holes in the bottom of the footing shell was 3.15m. This provided a pile clearance of 355mm. The drilled shafts were successfully installed to a horizontal tolerance of ±150mm at the point of cut off, 5m below mean water elevation.

This tolerance was obtained by using a two piece template. The bottom steel frame was positioned with anchor winches to a tolerance of ±300mm and fixed in vertical and horizontal position with four 1m diameter spud piles. The upper guide slid on top of the bottom frame and was positioned to a tolerance of ±50mm before it was fixed to the lower frame. The drill casing was then stabbed through a guide sleeve attached to the top guide.

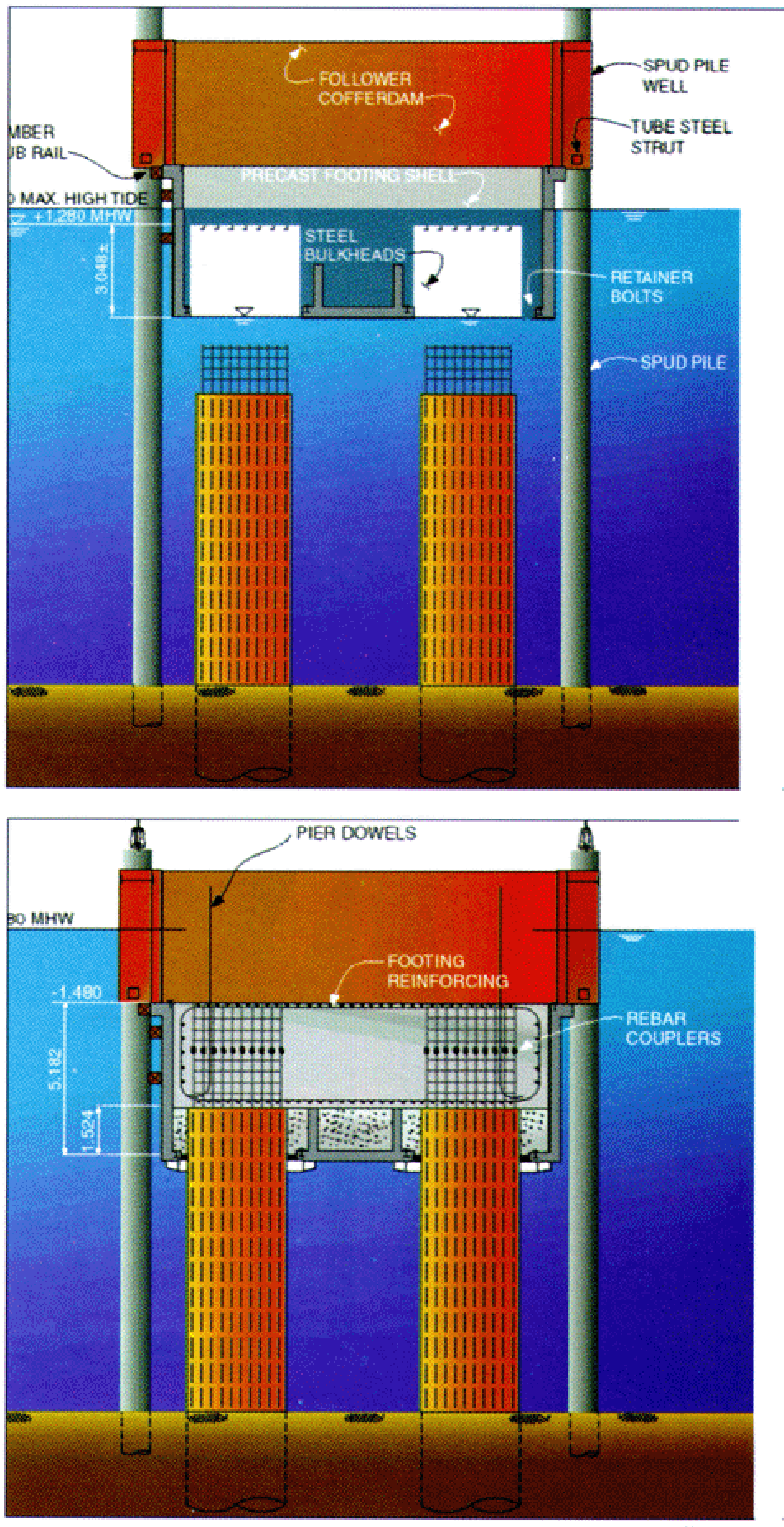
A second important factor was the initial underwater connection between the float-in cofferdam and the pre-installed drilled shafts. This connection was made with a 1.22m tremie seal, and the vertical load was transferred through the bond of the tremie seal to the sides of the drilled shaft. When the cofferdam was dewatered to enable reinforcing steel and concrete for the footing to be placed, the bond prevented the footing from floating up at high tide. When the footing concrete was being placed in the shell and the tide was out, the vertical loading was reversed, and the bond supported the dead load of the fresh concrete. Allowable bond stresses between the tremie concrete and casing were calculated using the American Petroleum Institute Code RP 2A, Recommended Practice for Planning, Designing & Constructing Fixed Offshore Platforms. If greater capacity was required, the bond area could be increased by deepening the tremie or the allowable bond stress could be increased by adding weld beads to the outside of the casing in the zone of tremie contact.

The bridge is currently halfway through construction and is scheduled to be opened late this year or early 2000.

The construction techniques used and the experience gained on the Bath-Woolwich bridge will be applicable on three major new bridges being built on the opposite side of the United States, in the San Francisco Bay area. In this region of high seismicity, large diameter steel cylinder piles filled with concrete offer the proper balance of strength, stiffness and high ductility.

The Benicia-Martinez Bridge will have nine main piers in the bay, where the preliminary foundation design calls for footing blocks 5m deep and 26m by 21m in plan, centered at the water line. Each footing will contain eight 2.5m diameter steel cylinder piles drilled and socketed into rock.

The Carquinez Suspension Bridge will have two main pylons supported on 3m diameter steel cylinder piles drilled and socketed into rock. Each pylon will be supported by two interconnected footing blocks and each of the four footings will contain six 3m diameter steel cylinder piles. The footings will be 5m deep and 22m by 18m in plan.



Installation process for the Bath-Woolwic Bridge foundations

The preliminary design of the new Eastern Span of the San Francisco Oakland Bay Bridge uses 2.5m and 1.5m diameter steel cylinder piles up to 100m in length. Most of the piles will be used in the skyway approach to the main suspension span. The foundations for this approach will contain 16 footing blocks of 6m deep and 20m by 13.7m in plan with six 2.5m diameter piles in each pier, and eight footing blocks of 4m deep and 13.5m square in plan with nine 1.5m diameter piles in each pier. All of the piles for the skyway approach will be driven.

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