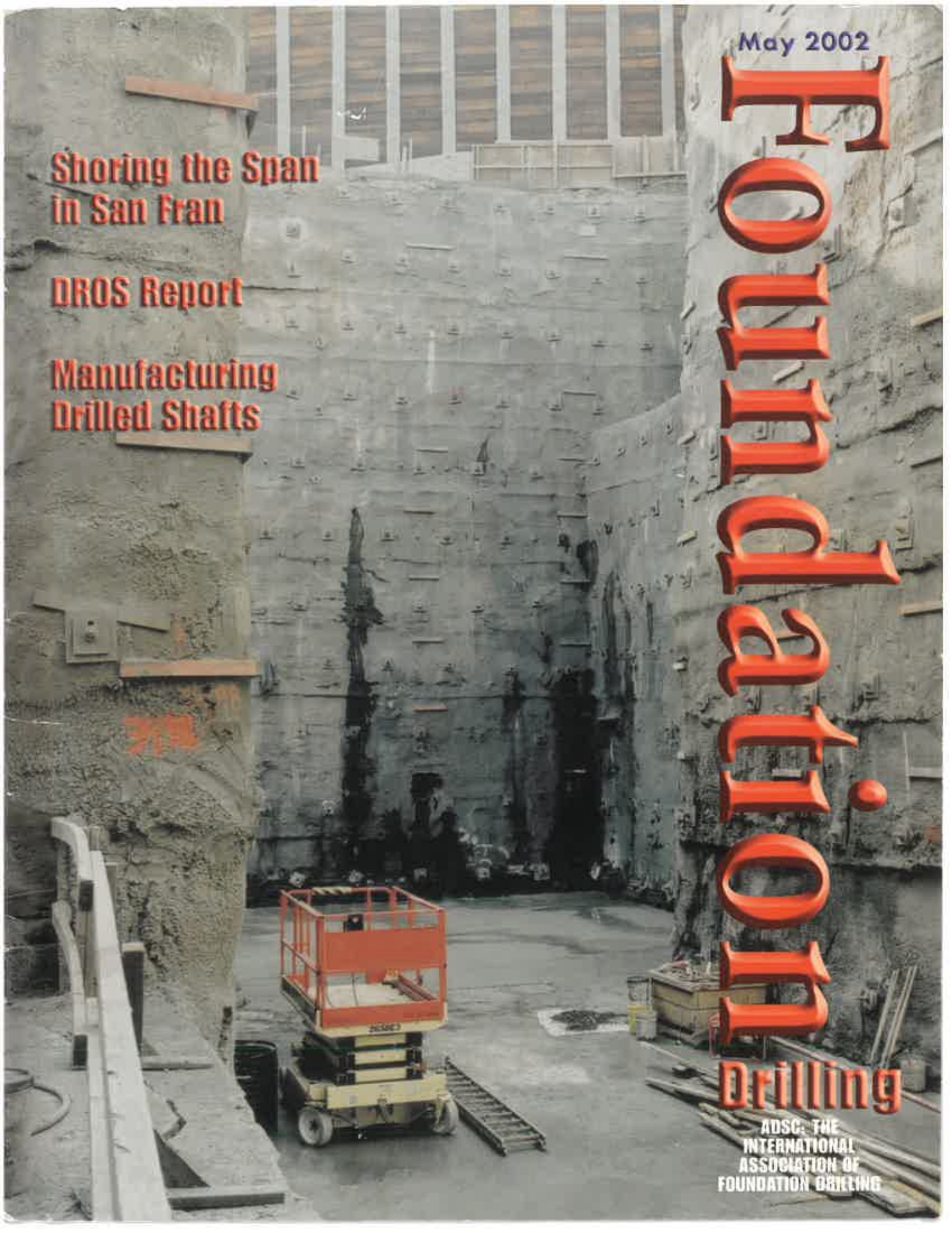

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Shoring The Span

Innovations in Post Tensioned Soil Nailing at the Carquinez Bridge

by Pirooz Barar, S.E.

A major trans-continental artery between New York and San Francisco, Interstate 80, in its final stretch winds its way through the California Central Valley, across the Carquinez Strait at the northeast corner of the San Francisco Bay, over the Bay Bridge and ends in downtown San Francisco. Recent surge in daily commuter activity from the central valley and the outlying areas has led to an overwhelming impact on Bay Area freeways and transportation corridors. The California Department of Transportation, (Caltrans) recognized the Carquinez Bridge as an important link in the interstate and regional Bay Area's transportation infrastructure, and saw the immediate need to alleviate congestion along this stretch of highway and maintain the integrity of the span into the future.

Shoring the North Anchorage of the new span, an incredible task in and of itself, would yield some unexpected challenges which required engineers and contractors alike to rewrite some old ideas and seek new solutions.

Caltrans engineers and the prime consultants Delew-OPAC Stenman designed a new suspension style span reminiscent of the more visible Golden Gate and Bay Bridges. While perhaps less renowned than its cousins to the west, engineers realized that the Carquinez span, standing at a respectable 2,350 feet, was at least as important a factor in the overall transportation needs of the area, and thus demanded the most advanced and reliable engineering systems available to ensure complete success of the project. Shoring the North Anchorage of the new span, an incredible task in and of itself, would yield some unexpected challenges which required engineers and contractors alike to rewrite some old ideas and seek new solutions.

Design Considerations

In order to securely anchor the suspension cables at the north end of the bridge, and to resist the 150 million pounds of pull

(continued on page 11)



83' deep excavation for the North Anchorage of the new Carquinez Bridge, March 2002.

that the cables would exert, Caltrans Engineers designed a U-shaped excavation that reached a depth of 83 feet at the deepest point. The idea being that the cables, serving as the support system for the suspension span, would adjoin in a reinforced concrete beam and straddle the excavation, ultimately securing the anchorage from the immense stress of pull from the span.

Given the precarious positioning of the anchorage and the particular soil conditions that engineers had to work with, the lead joint-venture construction firms of F.C.I./Cleveland Bridge, headquartered in Denver, Colorado, had to take into account several major considerations in the construction of the project.

The most obvious problem facing the project team was the placement of the anchorage between Interstate Highway 80/Carquinez Bridge Toll Plaza and twin Pacific Gas and Electric (PG&E) high tension transmission towers. With the current emergency energy situation developing in California, any damage sustained by the power transmission towers from construction would have resulted in nothing less than a statewide catastrophe. Of course, with the increasing daily flow of traffic across the current span, it was imperative that Highway 80 remain in tact throughout construction. There was concern surrounding the possibility that the highway could settle during excavation or construction, which would again have spelled colossal disaster for the project, the team, and the Bay Area transportation system.

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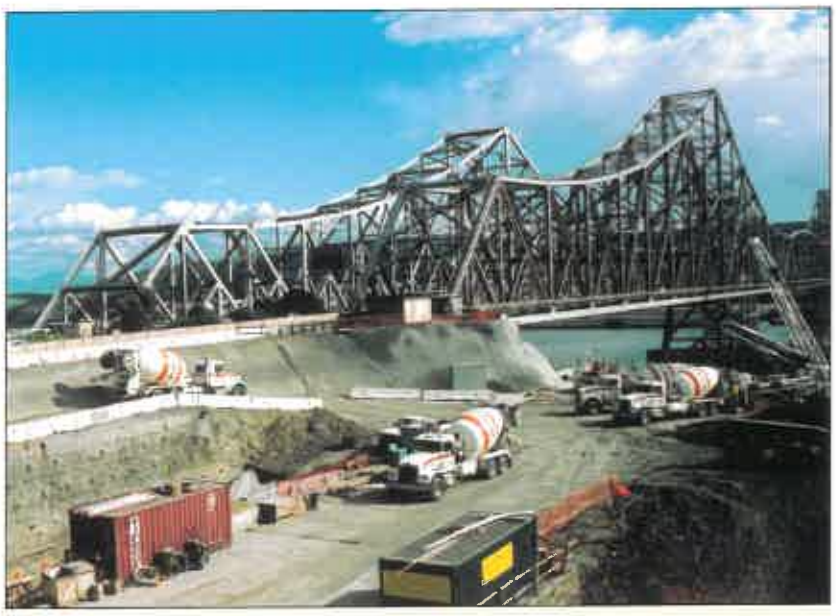

Soil Nail wall for support of Interstate 80 & N. Anchorage Carquinez Bridge.

Other dilemmas were less visible at the outset but would prove imminent. It soon became apparent to engineers that the soil makeup of the area would require serious innovations in technology and shoring techniques. F.C.I./Cleveland Bridge contracted with shoring experts Pirooz Barar & Associates (PB&A, Inc.) to develop these innovations.

Rethinking Shoring Solutions

At the time that PB&A was performing calculations for the preliminary design of the shoring at the project site, review of the log of borings had indicated that the material at the site consisted of a complex, rock formation with very weak, interbedded planes generally dipping in a northwesterly direction. It was suggested that although the strength of the rock varied between 100 to 1500 psi, with an average of 250 psi, the formation had shifted, possibly in a seismic event, and that a residual strength as little as 7 psi be used for the design. Initially it was believed that although the Pinoche Formation could have adverse shearing planes, they existed in such random fashion as to allow the entire formation to be modeled as one homogeneous mass.

Upon contacting the geotechnical engineers for the project, Geomatrix in Oakland, California, Mr. Barar was informed that the interbedded planes were not, in fact, at random and that they could conceivably be continuous, with possible dip angles as low as 25 degrees. This detail, of course, would have to be modeled into the design of the shoring system, dramatically changing the final outcome of the design.

Post Tension Soil Nailing

The methods used in classic soil nail analysis are similar to those used in slope stability. Generally speaking, the design of a soil nailed wall in reasonable and predictable soil types, uses nail lengths between 0.8 and 1.2

(continued on page 12)



Highway Interstate 80 and Carquinez Span.

times the height of the wall, with the nails at roughly a 6 foot by 6 foot matrix. In a simplified version of this method of analysis, once a failure plane is assumed, driving forces in front of the plane can be compared to resisting cohesion and friction forces of the soil behind the plane. A required number of soil nails are then added across the failure plane in order to tip the balance in favor of the resisting forces, thus creating a comfortable factor of safety. The roll of the nails is one that would add resisting forces to the equation. This force, however, is passive, which is to say that it does not exist until there is movement along the failure plane, initiating tension in the nails.

Following the general formula in this case, however, would have resulted in the use of inordinately long nails, approximately 120 feet long. In order to minimize the length of the nails, PB&A engineered a post-tensioned shoring design and turned the system from passive to active. Thus, instead of waiting for earth movement to create force behind the nails, PB&A post-tensioned them with predetermined forces. The end result is a more economical and rigid system, utilizing shorter nails. In order to incorporate these changes into the design, PB&A first had to modify the soil nail software program (Winslope) that they were in the process of developing, as the Caltrans program, "SNAIL" was unwieldy to handle the post-tensioning modifications to the design.

Post-tensioning soil nails is equivalent to applying a horizontal force to the shored excavation. This force is trapped in the nails and the surrounding soils and must be deducted from the nail capacity when the system is analyzed as a soil nailing system. In program "Snail" there is a provision whereby a horizontal external force can be applied which would result in a higher factor of safety. In the "Snail" program it is assumed that forces are applied by external sources and therefore the post-tension stresses are not accounted for in the soil nails. When the source of this external force is nothing but the soil nails themselves, and is being applied by tensioning the nails, it affects the resulting internal stresses of the soil nails and the soil.

In order to minimize the length of the nails, PB&A engineered a post-tensioned shoring design and turned the system from passive to active.

Pirooz Barar called on his long

(continued on page 13)



Southwest wall beneath Highway Interstate 80.

time colleague, Dr. Toorak Zokai, a consultant to PB&A, for assistance. He had previously co-authored program (Slope 18) with Mr. Barar, and in the design of another soil nail design program entitled "Winslope". Modifications to this program would prove to be the answer to the shoring dilemma.

Program "Winslope" is a generalized program for the design of post-tensioned and ordinary soil nailed walls. Mr. Barar and Mr. Zokai created this program on the "Windows" platform, specifically for this project, to accommodate the necessary post-tensioning required for this design. The result is a program that contains generalized geometry – multilinear slope excavation, an infinite number of different soil types, multi-curvature phercatic surface and post-tension nails with positive or negative angles of inclination.

The general premise of the program algorithm is based on a bilinear failure plane, as is "SNAIL." The difference is that the post-tension force is deducted from the capacity of the nail and the post-grouting length is deducted from the total length of the nail. In other words, the nail, being a hybrid between tieback and soil nail, is divided into two distinct elements. One is the post-tensioned nail and the other the initial grouting length deducted from the balance of the length of the nail.

Success

Pirooz Barar & Associates' shoring design installed by ADSC Contractor, Drill Tech Drilling & Shoring, Inc., Antioch, California, was effective in the unpredictable conditions of the shores below the Carquinez Bridge. While only a small part of an enormous project, the importance of this element of the project was fundamental to the progress of the project and its completion. The technological innovations of the shoring design for this monumental effort were the keys to its success.■



Stepped access to excavation.

Project Team:

General Contractor for the Bridge:	F.C.I. /Cleveland Bridge Denver, Colorado
	Project Manager: Curt Weltz
	Project Manager for North Anchorage: Tom Warren, F.C.I / Cleveland Bridge
	Geotechnical Engineer: Geomatrix* – Oakland, CA
Plan Review Process:	Ken Jackura – Caltrans, Sacramento, CA Mahmood Mahremzadeh – Caltrans, Sacramento, CA
Shoring Engineer:	PB&A, Inc.*, Oakland, CA Pirooz Barar, S.E. Joseph Chan, P.E.
Soil Nailing Subcontractor:	Drill Tech Drilling & Shoring*
Pre-stressed Steel Strand Provided By:	Dywidag Systems International*

**Indicates ADSC Members*