Case Study

Micropiles

Date: May 2002 to January 2004
Job Name: Richmond-San Rafael Bridge Seismic Retrofit
Owner: California Department of Transportation
Location: Richmond, California
General Contractor: Tudor/Saliba/Koch/Tidewater Joint Venture
Foundation Contractor: Agra Fondations, Inc.

The Richmond-San Rafael Bridge allows Interstate 580 to cross the Northern San Francisco Bay between Point San Quentin to the west and Point Castro to the east. The 4.5 mile long cantilever and truss span structure was constructed in 1956 at a cost of 62 million dollars. During its design and construction the engineers and contractors were relatively unaware that the bridge was being constructed in an extremely active seismic zone, within 10 miles of both the Hayward and San Andres Faults. While the bridges design was more than adequate to handle the wind and traffic loads common to this type of structure, its ability to withstand a major earthquake was a mystery.

On October 17, 1989, during the seventh game of the World Series being held at San Francisco's Candlestick Park, the Loma-Prieta Earthquake solved that mystery. The earthquake measured 7.1 on the Richter scale with its epicenter approximately 60 miles South of the San Francisco Bay. The Richmond-San Rafael Bridge suffered only minor damage in the quake, however many of the other local highways did not fare as well.

As a result of Loma-Prieta event, and general concern for the safety of the Bay area transportation infrastructure, the Legislators of California enacted the Toll Bridge Seismic Program (TBSP). This initiative mandated State funds for projects to retrofit the aging toll bridges across the bay, including the Richmond-San Rafael Seismic Retrofit Project.

Project Scope

The $442 million dollar retrofit contract was awarded to Tutor-Saliba/Koch/Tidewater Joint Venture (TSKT) in October 2000. TSKT self performed much of the concrete and steel work on the retrofit and subcontracted out the dredging, painting, and other specialized processes to various contractors. The largest subcontract was with Agra Foundations, Inc. (AFI) for the drilling and installation of the CIDH and micropiles designed to strengthen the bridge foundations. In turn AFI subcontracted Northwest Cascade, Inc.'s Geotechnical Division (NWC) to install the superstructure micropiles for the East bridge approach, as well as, assist in the design and bidding process and add micropile experience to the project team. The project personnel from AFI and NWC had built a strong working relationship while installing micropiles and foundation elements on the Macarthur Maze, 980/580/24 Interchange Project in Oakland.

NWC's scope of work included the installation of 282 micropiles for footing strengthing along the East bridge approach. Seventy percent of these micropiles were land based, while the remaining thirty percent were marine based, solely accessible from barges and platforms built over cofferdams. NWC was also required to perform a micropile verification test program in two locations. This test program served to verify the assumptions used to design the micropiles by testing the piles to 200 percent of their design loads. All of this work took place in low overhead conditions, with clearances on some piers as little as 16 feet.

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Construction Procedures

The existing spread footings to be strengthened were for the most part rectangular in shape, ranging from 30 to 60 feet in length and 20 to 30 feet wide, on average there were 12 Micropiles per footing. The design called for the micropiles to be placed on a 2 foot offset around the perimeter of the existing footing with varying on-center spacing. The reinforcing element of the pile extended up along side the footings and attached to the reinforcing steel doweled into the footing, a concrete cap then was poured over the top.

The spacing and depth of the micropiles was designed to offset the seismic loads that would affect the structure in a seismic event. The pile lengths varied from 50 to 80 feet to achieve the required loads. The piles were designed for relatively high compression and tension loads, from 160 to 380 kips. The bonded length and unbonded lengths of the piles changed depending on the subsurface conditions present at a particular location. For the most part the site geology consisted of moderately fractured, very hard greywacke overlain with silty sand and clayey silt (bay mud). This combination of very soft materials over very hard materials caused difficult drilling conditions. The drilling tools and methods to be used had to be able to advance the drill casing through the soft, sticky bay mud, and then pound out a rock socket into the hard, segmented underlying rock. Another factor complicating the installation process was the existence of a myriad of man-made obstructions dotting the site. Timber and steel piles, construction debris from the original bridge construction and industrial waste products were all discovered during drilling on the project.

The piles themselves were comprised of an 8 5/8”∅, ½” wall steel casing placed inside a 14” diameter drill hole. The drill hole was cased with 14” threaded temporary casing until it could be set into rock. Once the casing was seated into competent rock the 12” diameter rock socket could be drilled out with an air driven down the hole hammer.

The 8 5/8” reinforcing element had to be placed in sections to accommodate the overhead restriction, and all splices were made with full penetration welds. Once the reinforcing was in place the hole was tremie filled with 4000 psi, type I-II cement grout. On both ends of the pile shear rings were welded to the casing to provide greater bond between the pile and the surrounding cement. These shear rings were fabricated off site and welded to the pile in the field.

Project Challenges

Environmental concerns were a major factor on this project due to the piles being installed either over, or in close proximity to, the San Francisco Bay. Northwest Cascade implemented a variety of systems to mitigate the chance of contaminates reaching the environment. To start with NWC replaced all the petroleum based hydraulic fluids in the onsite equipment with environmentally friendly food grade alternatives. In addition, all tanks containing diesel fuel were triple lined to prevent spills. NWC also implemented new technologies in spoils containment measures to prevent sediment from reaching the surrounding environment.Drill fluids and spoils flowed through a “closed” system of holding tanks and high-pressure inlet and discharge hoses. These measures, combined with continuous monitoring and proactive attitude, kept environmental concerns from ever becoming an issue.

Setting 8 5/8”∅ Steel Reninforcement

As with most bridge projects the lay down areas provided were extremely limited, and because the majority of the work took place over the water, the marine based contractors staged out of the east and west approaches. Unfortunately, NWC's work took place through the middle of the east approach. To tackle this coordination issue NWC prepped all of the piles off-site and delivered all materials on an as needed basis. Clear lines of communication between NWC personnel, the General Contractors personnel, material suppliers, and other subcontractors were of the utmost importance. While this method did cause a few glitches during the construction process it was the only cost effective and time prohibitive method to manage the project. NWC's contract allowed 12 months after the completion of the test programs to complete the installation of micropiles. This aggressive schedule was to be completed with a single drill crew and a testing crew working both ahead of and behind the drilling operation. Many conflicts to meeting this schedule presented themselves as construction proceeded. These conflicts included unforeseen obstructions, General Contractor provided access issues, and severe weather conditions. As a result of these conflicts NWC was directed by the General Contractor to accelerate production. NWC was able to immediately mobilize another drill crew and support equipment to the project and bring the schedule back on line in a few weeks.

As mentioned previously the biggest challenge to this project was the drilling operation itself. The unusually large diameter of these piles was an issue, and major modifications to equipment had to be made before production drilling commenced. Many of the systems and materials utilized for these micropiles were untested in the industry. As with the implementation of any new technology NWC encountered a number of barriers to success. NWC drew upon the broad experience of its staff and the depth of resources to mitigate the impact of these stumbling blocks. Clear lines of communication, sound field level decision making skills, and fast action prevented these challenges from drastically effecting the schedule or budget for this project.

Project in Review

Many valuable insights were learned on this project. NWC staff gained experience in dealing with the challenges inherent in a project of this size and complexity. New technologies were implemented and proved to be valuable assets. The client received its product in a safe, cost effective, and time sensitive manner, with no claims against the owner. Overall the project was a success for Northwest Cascade.

Installation of Verification Pile

Test Set up for 400 kip Tension Test