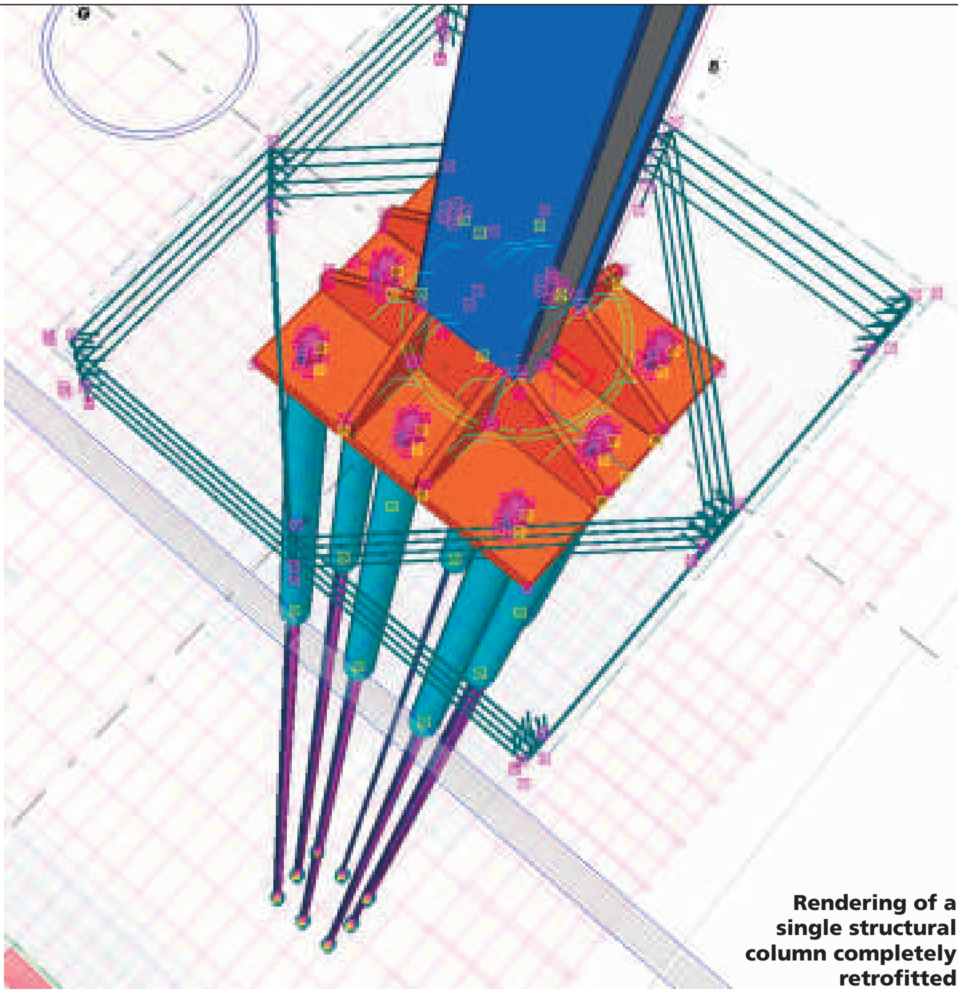

Rendering of a single structural column completely retrofitted

High-Strength Micropiles Solve Problems at Seismic Retrofit Site

The Sharp Memorial Hospital campus in San Diego, Calif. has two towers – the South and Central Towers – that required seismic retrofitting to remain in service beyond January 1, 2015. As part of the seismic retrofit of the Central Tower, the contractors chose to use high capacity, closely spaced, micropiles to strengthen the structure's foundations.

The Central Tower, originally constructed in 1972, is a nine-story structure supported by a steel moment frame. California Senate Bill 1953 was signed into law in January of 1994, as a result of the massively destructive Northridge Earthquake, whose epicenter was just north of Los Angeles. One of the provisions of the legislation established "Structural Performance Categories" (SPC). These categories range from SPC-1 to SPC-5, and are detailed in the California Administrative Code. Buildings assigned to the SPC-1 category have the greatest probability of collapse. At the Sharp Memorial Hospital campus, the Central Tower has been assigned to the SPC-1 category.

To remain in service, the Central Tower must be re-assigned to the SPC-2 category, for structures that provide life safety seismic performance and are allowed to remain in service until January 1, 2030.

According to the structural engineer of record, Luis Toranzo, Ph.D., P.E., of KPFF Consulting Engineers, during structural evaluation of the Central Tower moment frame, inspectors found that the structure could "sustain unacceptable story drift levels at the lower floors." This story drift is the result of low fixity at the base of the columns of the lateral system. The lower level drift needed to be brought to an acceptable level as part of the retrofit. Dr. Toranzo says, "Limiting the drift however, by means of braces, or something similar, was difficult, due to the fact that the lower floor was the main lobby of the hospital and any braces would severely limit many of the operations conducted in this area. Increasing the fixity at the base of the columns therefore was limited to some type of foundation strengthening while maintaining the moment frames as the main lateral system."

Project Planning

In 2010, Sharp Memorial Hospital was named "Most Beautiful Hospital in the World" by HealthExecNews.com. In the spirit of this designation, one of the most important project requirements was to allow the Central Tower to remain in operation during all phases of construction, and to do so in the most unobtrusive manner possible.

Sharp Healthcare released an RFP in March of 2011. In the original RFP, the foundation improvements were to be achieved via installation of a massive mat foundation located beneath the existing spread footings supporting the structure's steel columns. The depth of the proposed mat foundation ranged from 4 ft to 8 ft (1.22 m to 2.44 m) below the existing spread footings. To maintain an operational facility and preserve a newly remodeled lobby, excavation, as originally planned, was to be accomplished by tunneling beneath the existing structure.

The prospect of tunneling beneath a fully operational hospital and its load bearing columns carried a great deal of risk. Some of these included: difficult tunneling conditions, undermining of existing columns and active slabs, preservation of existing underground utilities, dust control,

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In the enclosed work area, the TEI TD75 is in drilling position on a difficult access hole

spoil removal and equipment access; all below and through an operational hospital.

To mitigate these risks, Condon-Johnson & Associates, Inc (CJA) proposed micropiling, which Sharp Healthcare found acceptable as a foundation strengthening solution. Sharp Healthcare's project team: Swinerton Builders – General Contractor, KPFF Consulting Engineers – Structural Engineer of Record, gkkworks – Architect, Leighton Consulting, Inc. – Geotechnical Engineer and Condon-Johnson & Associates, Inc – Micropile Installation Contractor.

Site Conditions and Testing

The site is generally underlain by the dense sand/sandstone matrix known of the Lindavista formation, which extends approximately 25 ft to 30 ft (7.62 m to 9.14 m) below ground surface (bgs). The Lindavista formation lies on top of the Stadium Conglomerate, a very dense, locally cemented conglomerate of sands, sandy gravel and cobbles.

Design assumptions had to be verified as a requirement for Office of Statewide Health Planning and Development (OSHPD) approval of the micropile solution. The pre-production test program performed in August of 2011 included installing three sacrificial piles, two reaction piles on either side of a test pile. All three piles were installed to a depth of 85 ft (25.91 m) bgs, and reinforced with a 3 in (75 mm) Grade 150 Williams Threadbar. The test pile was instrumented with strain gauges along its long axis at 8 equally spaced locations by Geodaq, and was loaded to 775 kips (351.5 tonnes) in both tension and compression. During load testing the micropile succeeded in transferring the entire 775 kips out of the pile within the top 40 ft (12.19 m) of pile length. The pile instrumentation recorded little to no load transfer in the bottom 45 ft (13.72 m) of pile length.

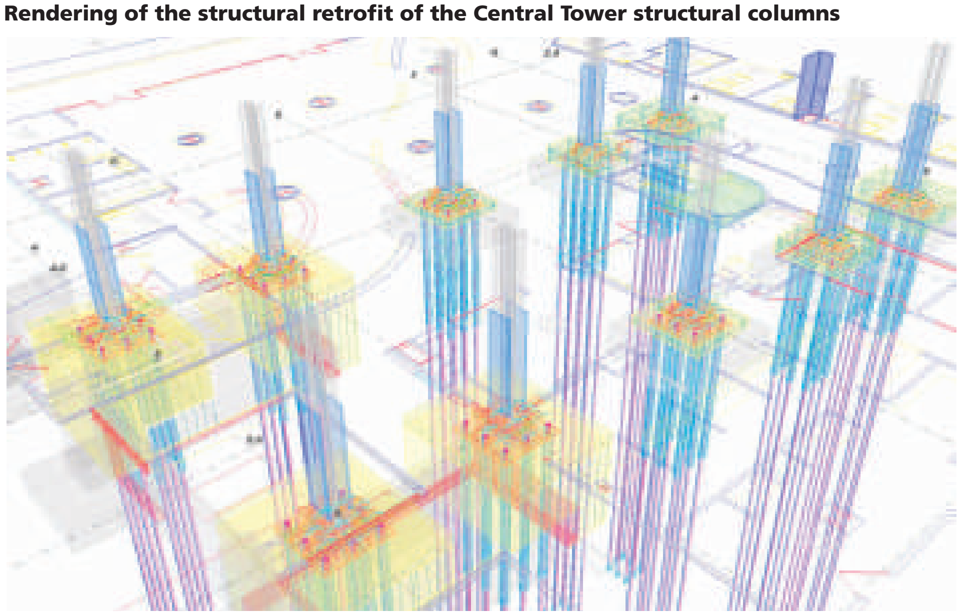
Using the load test results, and information gathered during pile installation, the team provided production micropile recommendations. While drilling the test piles, the water table was encountered at approximately 70 ft (21.34 m) bgs. The project team knew that encountering the water table while drilling inside the hospital would not be ideal. With this in mind, the lengths of the production micropiles were limited to a depth of 60 ft bgs (18.28 m). The final specified micropile dimensions were 10 ft (3.05 m) of permanent casing to be installed at pile top, followed by 50 ft (15.24 m) of uncased pile length, or bond zone. The total pile length was 60 ft (18.28 m), and was required to resist a seismic load of 616 kips (279.4 tonnes) in compression and 339 kips (153.8 tonnes) in tension. Permanent casing is typically used in a micropile to provide additional capacity in compression. In addition, permanent casing is specified in the California Building Code to provide additional capacity under seismic loadings. CJA chose 2.5 in (63.5 mm) Grade 150 Williams Encapsulated Threadbar for use in production micropiles.

Installation and Infection Control

For the Central Tower structure to be designated SPC-2, foundation improvements were necessary at 10 steel columns. CJA needed 76 micropiles for the foundation improvements. Nine of the 10 columns were designed with 8 micropiles. One column was designed with only 4 micropiles due to conflicts with existing improvements. We performed the micropile work in four phases to maintain access through the hospital lobby and required paths of egress.

While working in an operating hospital, during any phase, Infection Control & Interim Life Safety Measures had to be adhered to strictly. These measures are meant to prevent the spread of infection through healthcare facilities. During construction, all work areas were completely contained with temporary barriers and put under negative air pressure. The negative pressure provides a separate ventilation system than that of the general hospital, and prevents room to

Rendering of the structural retrofit of the Central Tower structural columns



room contamination. In addition to the work area containments, no dust was allowed to leave the work areas. All materials or personnel brought in, or leaving, the work area had to be dust free. These working restrictions limited the equipment and methods that are typically used for micropile installation.

Equipment and Methods

To stay in compliance with the Sharp Infection Control policy and general best management construction practices, all equipment operated inside the hospital was electric. All equipment powered by diesel engines was staged outside the hospital. CJA used its electrically powered TEI TD75 drill rig inside the hospital. The pieces of equipment staged outside the hospital were a Sullair 900XHH Air Compressor, an Obermann VS100 Grout Plant and Hurricane 828 Vacuum. The TEI TD75 was selected for its compact size, and ability to work in low overhead conditions. The TEI TD75 was also able to track beneath a standard sliding door, necessary to access the work areas.

All the support equipment was staged approximately 300 ft (91.44 m) away from the work areas, in a parking lot just outside the Central Tower structure. Support lines were run up and out of the staging area, and through the hospital's pristine "Healing Garden." Sharp Healthcare provides this quiet mediation area adjacent to the Cancer Treatment Center for its patients and visitors. It was essential that support lines for water, high pressure air, grout, and vacuum that ran through the Healing Garden were well placed and hidden. For this purpose, we used low maintenance steel hard lines for all but the vacuum line. Two grout lines, one air line and one vacuum line were permanently installed and ran from the staging yard into the work areas.

CJA advanced the micropile holes using single rotary duplex drilling methods. Multiple use drill casing with an outside diameter of 7-5/8 in (193.7 mm) and 3.5 in (88.9 mm) API drill rod provided by Global Drilling Suppliers, OCI Division (OCI), were advanced to pile tip concurrently. The workers excavated the spoils with a 5 in (127 mm) Atlas Copco Down-the-Hole Hammer (DTH) attached to the bottom of the API drill rods.

All spoils were exhausted using compressed air, and controlled at the top of the drill string with a flushing bell and spoil swivel manufactured by OCI. Once spoils were exhausted from the drill string they were directed into a sealed separation tank. Then the workers connected the vacuum line to the top of the separation tank. In the separation tank, the heaviest drill spoil would fall out of suspension and be contained, while the lighter particles, mainly dust, were removed by the vacuum line. When full, the separation tank was removed from the work area and emptied in the staging yard outside of the hospital. Using a separation tank in addition to a small amount of water injection during drilling created a nearly dust-free micropile excavation.

Because conventional hoisting equipment could not access the work areas, the 2.5 in. (63.5 mm) Grade 150 encapsulated Williams Threadbar anchors were set into the excavated micropile hole in sections, using a tripod and electric winch. We lowered a tremie grout line and post grout line into the hole with the bar. After placing the bar, we injected the grout through the tremie line. A neat cement grout was mixed in the staging yard located approximately 300 ft (91.44 m) away from the work area. We used high range water reducer and retarding admixtures in the grout to facilitate pumping. As confirmed by the load test program, no pressure grouting was necessary. All micropiles were gravity grouted. After the initial tremie grout, we removed the drill casing completely, and inserted a permanent casing into the wet grout. The 7-5/8 in (193.7 mm) diameter permanent casing by 0.5 in (12.7 mm) wall was supplied by OCI.

Precise pile placement was necessary to ensure that the new base plate would fit properly. After micropile grouting, the workers placed a laser cut pile template, built by MetalMaster, Inc., over the micropile threadbar reinforcement to hold the threadbar in the correct position to within 1/16 in (1.59 mm). The template remained in place until the cement grout had taken its set.

Load Testing

Production load testing was specified as part of the approved micropile design. Load testing was performed at four locations on production piles. During production testing, we tested the micropiles in compression and tension, to the loads listed above. The testing was accomplished by placing a test beam over three adjacent production micropiles. The outer micropiles acted as reaction piles for testing of the center micropile. A custom hydraulic testing ram was fabricated out of aluminum by Richard Dudgeon, Inc. to reduce weight as no conventional hoisting equipment was usable inside the work spaces. All load testing resulted in acceptable results.

Workers inspect a micropile excavation. Vacuum is shown connected to the duplex swivel.

Conclusion

Due to relatively low impact installation techniques within an operational hospital, the owners and the design team chose micropiles as the solution for the Sharp Memorial Hospital Central Tower Seismic Retrofit foundation improvements. The tower was allowed to remain in operation during all phases of construction, and the micropiles provided the capacity necessary to resist the large overturning forces that were expected at the base of the columns in a seismic event.

The retrofit work on this project was extremely complex and could not have been accomplished without the entire project team. As is usually the case when working in the ground, issues come up. CJA thanks the entire project team, which included the owner, designers and all other project participants for their support. CJA also thanks its suppliers that played an integral part in the project's success, including Williams Form Engineering – Micropile Bar Supplier; Global Drilling Suppliers, OCI Division – Drill Tooling and Casing; C&M Manufacturing – Fabrication of Custom Carts and Hoisting Equipment; Richard Dudgeon – Testing Ram Supplier; and Geodaq – Pile Instrumentation and Monitoring.