TOUCHDOWN FOR O-CELL TEST

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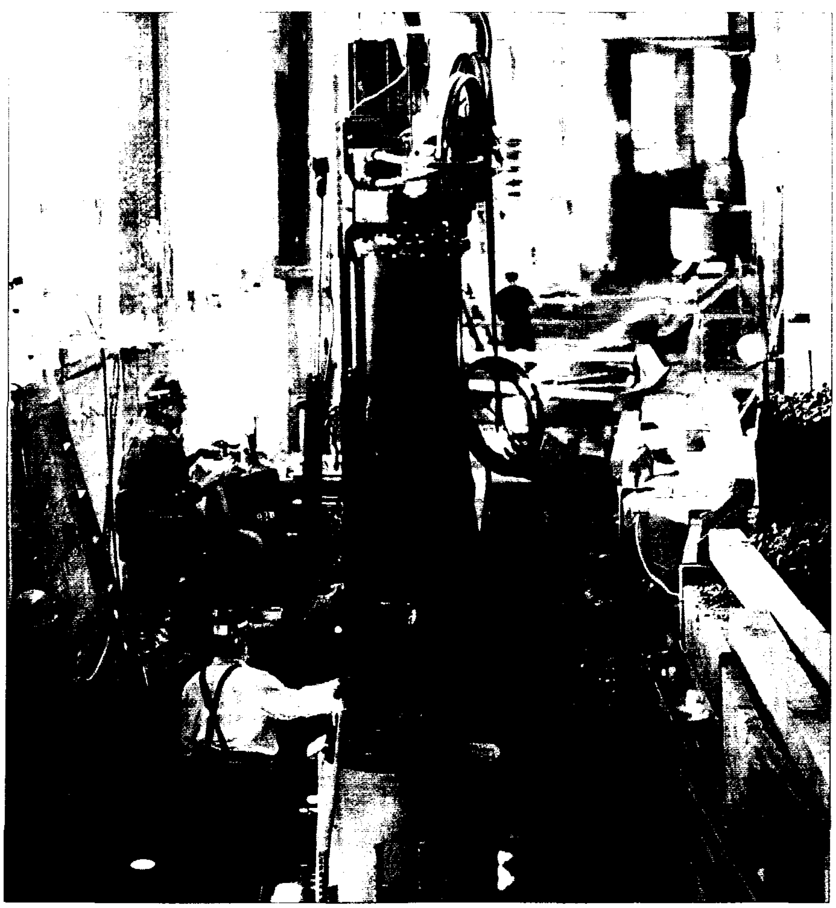
Repairs to the Los Angeles Coliseum, damaged in the 1994 Northridge, Calif. earthquake, had to be completed by the start of football season, just seven months away. By using the Osterberg load cell to expedite drilled-shaft design, engineers beat the odds to finish the project on time.

The Los Angeles Coliseum, home of the Los Angeles Raiders and University of Southern California Trojans football teams, has seen its share of sudden lateral movements and colliding bodies.

On Jan. 17, 1994, however, the Northridge earthquake sent a new kind of shock wave through the 71-year-old arena, cracking and bending the foundation of the Coliseum, and sending construction crews on a seven-month race against the clock to repair the stadium by fall's first kickoff.

One of the job's most difficult aspects was installing high-capacity cast-in-place foundation piles in the interior of the stadium. Cramped spaces within the Coliseum made the work a slow, delay-filled process, and it soon became apparent that revisions were necessary to either the construction plans or the schedule.

By using the Osterberg load cell, a relatively new load-test system also known as the O-cell (see sidebar), engineers sidestepped a major obstacle and got the project back on track. The O-cell allowed load testing of the caissons without squeezing huge, unwieldy reaction beams into the small work space. Engineers also used the O-cell test to consolidate and stiffen the soils at the base of the supports, allowing the piles to be shortened by as much as 30 ft, without sacrificing effectiveness.



LIMITED-ACCESS DRILLING EQUIPMENT WAS USED TO DIG 10 FT TRENCHES AND ACHIEVE A MINIMUM VERTICAL CLEARANCE OF AT LEAST 18 FT IN THE STADIUM CONCOURSE AREA. THE LOW HEADROOM MADE PILE INSTALLATION DIFFICULT AND TIME-CONSUMING.

0885-7024-/95-0002-0057/$02.00+25¢ per page

After the earthquake, Law/Crandall, Los Angeles, the geotechnical engineer for the Coliseum since the 1960s, was brought in by the owner's project manager, Los Angeles–based Cordell Corp., to help evaluate the extent of the damage and make recommendations on the foundation aspects of the repairs. Other members of the project team consisted of HNTB Corp., Nabih Youssef & Associates and Tutor Saliba Corp., all in Los Angeles.

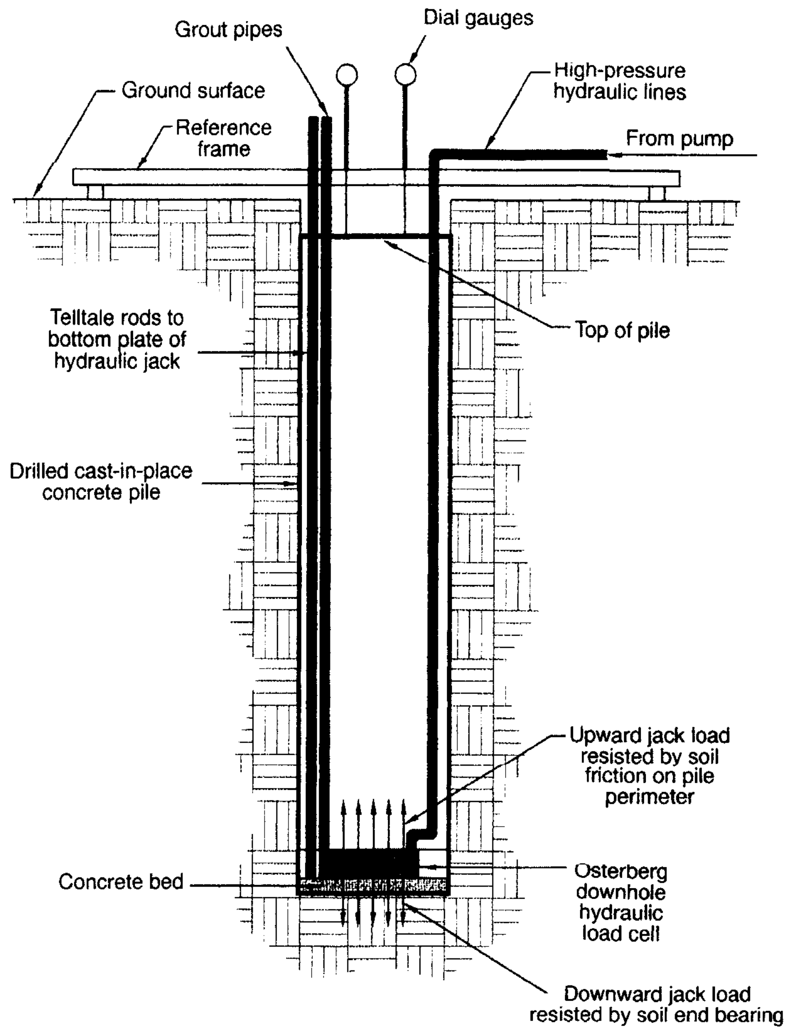
The project was primarily financed with federal disaster funds; at $80 million, the Coliseum cost twice as much to repair as the Santa Monica Freeway. Although early reports indicated that the Coliseum's damage was mostly cosmetic, detailed investigations later revealed that the lower and upper decks had cracked and shifted under the violent shaking.

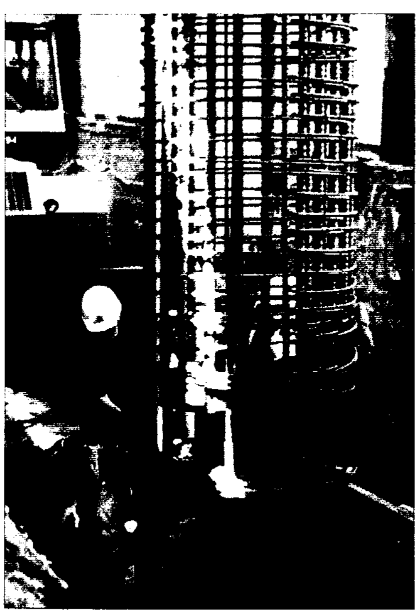
Original construction of the Coliseum was completed in 1923. In 1931, a major addition to the original structure was made, expanding the upper seating area by 30,000 seats and dividing the stadium into two sections. For the lower section, fill soils were excavated from the field area to form an oval-shaped embankment and support the ground-level seating. The concourse area in the interior of the stadium is located on the crest of this 30 ft embankment.

The upper deck of the stadium is structurally supported on drilled and belled caissons that extend through the fill to the underlying and dense natural soils. Most of the damage sustained during the earthquake was caused by differential movement between these two sections. The shaking caused permanent lateral deflection of pile foundations, settlement of shallow foundations supported in poorly compacted fill soils and cracking of many structural elements. The at-grade section of the stadium settled as much as 6 in. and the upper section moved laterally as much as 3 in.

The settlement of the at-grade portion of the stadium was apparently due to consolidation of the fill soils, which is not unusual for older structures that were built with lower soil-compaction standards. Fortunately, damage to the at-grade section was not significant because the settlement occurred over a large area. Although settled soils could have been improved, it would have required completely removing and replacing the seating, concrete decking and adjoining structures; this was not an option, since the Coliseum is a designated historic landmark.

HOW THE O-CELL WORKS





A GEOTECHNICAL FIELD TECHNICIAN INSPECTS AN O-CELL BEFORE IT IS INSTALLED. FOR THE COLISEUM PROJECT, 28 O-CELLS WERE USED, ONE FOR EACH CRITICAL INTERIOR SHAFT.

FAST-TRACK SCHEDULE THREATENED

Law/Crandall investigated the soil conditions in the inner-concourse area of the Coliseum and provided geotechnical input for the design and installation of new drilled, cast-in-place pile foundations, which were to provide increased lateral support for the upper seating deck as well as increased axial support for a new press box and suites that may be added to the stadium in the future.

The especially large piles required for this repair work ranged from 36 to 52 in. in diameter. Their size increased the complexity of an already difficult design and construction problem, since there were severe space limitations for setting the 65–95 ft long piles. Installing these long piles in the tight quarters of the stadium meant workers had to dig trenches up to 10 ft deep, install shoring and remove more than 8,000 cu yd of soil just to achieve a minimum vertical clearance of 18 ft.

TURNING THE FOUNDATION WORLD UPSIDE DOWN

The Osterberg load cell—named for its inventor, Jorj Osterberg—is the only load test that provides separate measurements of a pile's load-bearing capacity and skin friction.

The technique, which won the NOVA Award from the Construction Innovation Forum in March 1994, has been called the upside down load test because the load is applied at the bottom of the drilled pier and the displacement of the pile is up rather than down.

The load cell, also known as the O-cell, was developed 10 years ago by Osterberg during his tenure as a professor of civil engineering at Northwestern University. Honored for past innovations in soil sampling, testing and foundation engineering, Osterberg currently serves as a consultant to Loadtest, Inc., Gainesville, Fla., which furnishes and provides technical support for the O-cells.

Driven piles as long as 127 ft have been installed and tested with the O-cell, both on dry land and over moving water, while loads as great as 6,000 tons have been applied to shafts 3 ft in diameter or larger. Loads of 12,000 tons can be applied by using either a cell of larger diameter than the standard 34 in. or a cluster of several smaller-diameter cells. Also, according to Osterberg, depth poses no problem for the O-cell, which can be installed as deep as a shaft can be drilled.

The Los Angeles Coliseum application is one of more than 100 O-cell load tests that have been performed since the device was created. Other recent or ongoing projects include the following:

- In Wilsonville, Ala., a design featuring elevated, porcelain-lined conduits made settlement and lateral support a primary concern. Engineers from Southern Company Services, Birmingham, Ala., used a 21 in. O-cell to test a 23 ft shaft drilled into soft shale. The ultimate capacity in both shear and end bearing exceeded anticipated values.
- In Albany, N.Y., the Case Foundation Co., Chicago, and STS Consultants, Ltd., Northbrook, Ill., planned a parking garage with slurry-constructed belled shafts founded in glacial till and shale. O-cells were installed at the base of two shafts 133 and 147 ft long. The end-bearing values ranged from 87 tons/sq ft in the glacial till to more than 120 tons/sq ft for the shale.
- In Greene County, Miss., Mississippi DOT used O-cell tests on several state highway projects last year. The latest project involved a replacement bridge spanning the Chickasawhay River. Initially, the shafts were founded in very fine sand, but problems with the integrity of the shaft necessitated the construction of a second test shaft extending into the clay beneath the sand. An O-cell was used to ascertain the end-bearing and shear-resistance values for the shaft.
- At selected sites in Florida, Paul Bullock, a doctoral candidate at the University of Florida, is employing O-cells in his studies of the long-term aging effects on driven piles. By casting O-cells into the tips of concrete piles, Bullock can conduct multiple tests long after redriving the piles.
- In Boston, three firms—Walsh Northeast, Quincy, Mass.; The Millgard Corp., Livonia, Mich.; and GZA, Newton Upper Falls, Mass.—employed five O-cells in conjunction with the $6 billion Central Artery/Tunnel project. The load tests will be used on production shafts from 125 to 175 ft deep.—*KM*

Within the first month of foundation work, the project fell behind schedule during attempts to get the piles in place. Because of severe caving-soil conditions below a depth of about 65 ft, it took three weeks just to install the first two 95 ft long piles.

In its search for an effective solution that would put the project back on schedule, Cordell again consulted Law/Crandall. After assessing the situation, the project team decided that the best way to avoid the caving soils would be to shorten the piles and avoid digging below 65 ft.

To prove the viability of using the shorter piles, Law/Crandall recommended a load test. However, there wasn't enough headroom in the concourse for the large reaction piles and beams needed to load the pile from the top. Under these circumstances, the compact and powerful Osterberg load cell, which exerts force from the bottom, was an attractive alternative.

The Osterberg load cell

The Osterberg cell, named for Jorj Osterberg, is a specially designed hydraulic jack that exerts very large loads at high internal pressure. The device is lowered into a drilled-shaft hole and the pile is constructed on top of the cell. Hydraulic lines, extending from the O-cell to the surface, apply fluid pressure to the previously calibrated cell and, as pressure is applied, telltale rods measure the downward movement of the bottom of the cell, ascertaining the pile's end-bearing behavior. The cell also tests the effects of friction on the sides of the pile (News, CE July 1994).

Law/Crandall and the project team performed the first load test on a relatively lightly loaded pile designed to resist uplift forces. The success of this first test convinced the project manager to adopt the O-cell for the more heavily loaded main supports. Moreover, Law/Crandall realized that, by using the load cell in an innovative way, we could further accelerate the completion of the project.

It occurred to the project team that the Osterberg cell could be used not only to test the pile's load-bearing capacity but also to improve the foundations by preloading each pile to consolidate and stiffen the soils at the base. To do this, we grouted in place an O-cell in each of the 28 critical interior shafts—an expensive option with each cell costing around $14,000. However, by precompressing the end-bearing material under the O-cell, we were able to construct piles 20–35 ft shorter than the original design. Yet the piles handled the required 1,000 ton service load with less displacement (only 0.5 in.).

The Law/Crandall field team worked around the clock as construction moved into high gear. The field technicians were on hand 24 hours a day to observe the delivery, fabrication and installation of the load cells.

Last July, engineers installed and tested the final O-cell–modified drilled shaft, allowing enough time to finish the foundation construction before the seven-month deadline, well under initial estimates that put the project duration at almost three years. On Sept. 3, 1994, the Los Angeles Coliseum opened on schedule to a packed house of fans who cheered as the Trojans beat Washington State University, 24-17.

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