Osterberg Load Cell Testing of a Deep Reinforced Concrete Pile

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ABSTRACT

A pedestrian bridge was constructed between two portions of a hospital in Southern California. Potentially liquefiable soils were present to a depth of about 72 feet below the ground surface. Because of the liquefiable soils, the bridge was to be supported on 30-inch-diameter cast-in-place piles drilled to a depth of approximately 90 feet below the ground surface. A test pile was constructed to confirm the soil capacities for the bridge. An Osterberg Load cell (O-cell) was placed near the middle of the test pile, and the downward load capacities of the deeper soils (below the elevation of potentially liquefiable soils) were tested using the upper portion of the pile to provide reaction.

Instrumentation of the test pile consisted of four pairs of vibrating wire strain gages mounted on the pile reinforcing cage at four depths. The strain gages were connected to a data acquisition unit used to record data during the pile load test. A pair of tell-tale rods connected to electronic dial gages monitored the movement of the lower plate of the O-cell. Another pair of tell-tale rods was used to monitor the movement of the top of pile during the test while a third pair of tell-tale rods was used to monitor the compression of the upper portion of the pile.

The pile load test was successful in confirming the predicted pile capacities, and the production piles were installed. The Osterberg Load cell was an economical method of testing the pile for this particular application.

KEYWORDS

DRILLED PILE, OSTERBERG LOAD CELL, LIQUEFACTION

INTRODUCTION

A pedestrian bridge was constructed between two portions of a hospital in Southern California. The site of the pedestrian bridge contains layers of potentially liquefiable soils to a depth of about 72 feet below the ground surface. Piles were recommended to support the pedestrian bridge loads. The piles were designed based on the use of pile skin-friction resistance below a depth of 72 feet. In addition, the piles could be subjected to possible downdrag loads above a depth of 72 feet during a liquefaction event. The production piles for the bridge were 85 foot long (bottom of pile about 94 feet below the ground surface), 30-inch diameter drilled and cast-in-place concrete piles.

A test pile was recommended to be installed and tested before construction of the production piles. The test pile was drilled to 107 feet below grade. An ordinary pile load test would have had to impose excessively high loads in order to overcome the full static friction of the upper soils above a depth of 72 feet and test the pile capacity below that depth. (This friction would be totally ineffective if liquefaction were to occur and, therefore, must be neglected.) An ordinary pile load test would have necessitated the installation of several reaction piles, which would also be very costly. Therefore, an Osterberg (O-cell) load test was selected, which, with the cell placed approximately at the depth of the base of the liquefiable materials, could test the soils beneath that level using the upper portion of the pile for reaction. The calculations prior to installation of the test pile indicated that the upper soils had sufficient reaction capacity to test the lower soils to failure. Although the test pile could have been used as one of the production piles, for other reasons, it was chosen to use the test pile as a separate, non-production pile.

This paper discusses the installation, instrumentation, and results of the pile load test.

TEST PILE PREPARATION

Pile Excavation

The pile excavation was drilled using 30-inch diameter auger drilling equipment. The ground water at the site was above the bottom of the pile excavation, and therefore, the drilled pile excavation was performed using a mixture of "Slurry Pro" and water to keep the hole open during excavation. The pile was drilled from the bottom of a five-foot excavation similar to that was later used for the production piles because of the depth of the pile cap.

Reinforcement Cage Instrumentation

The pile reinforcement cage was 24 inches in diameter, and placed to a depth of 90 feet below the top of the pile (about 95 feet below the ground surface).

The pile reinforcement cage was instrumented with vibrating wire strain gages or "sister bars". Four pairs of sister bars were mounted to the inside of the reinforcing cage; these consisted of two pairs above the O-cell and two pairs below, as shown in Figure 1 (Elevation of Pile Reinforcement Cage). The sister bars in each pair were mounted 90 degrees apart, as shown in Figure 2 (Plan of Pile Reinforcement Cage). The sister bars were fastened to the reinforcing rings using heavy duty nylon wire ties. The wires from each pair of sister bars were run along the inside of the reinforcing cage, adjacent to the vertical rebar to the top of the reinforcing cage. The wires were carefully secured to the side of the cage using regular nylon wire ties. In order to prevent damage to the wires during the lifting and placement of the cage, periodic strain relief was provided by leaving some slack in the wire. A major strain relief mechanism was also installed at the mid-height of the load cell for the wires connecting to the strain gages on the lower half of the pile to prevent damage to the wires during expansion of the O-cell during testing.

Readings of the strain gages were taken before installing the cage in the drilled hole using a vibrating wire strain gage readout to ensure that the gages were properly functioning.

Pipes were also installed in the cage to allow for placement of the tell-tale rods after pouring of the pile. The ends of the pipes were sealed to prevent concrete from entering the pipes.

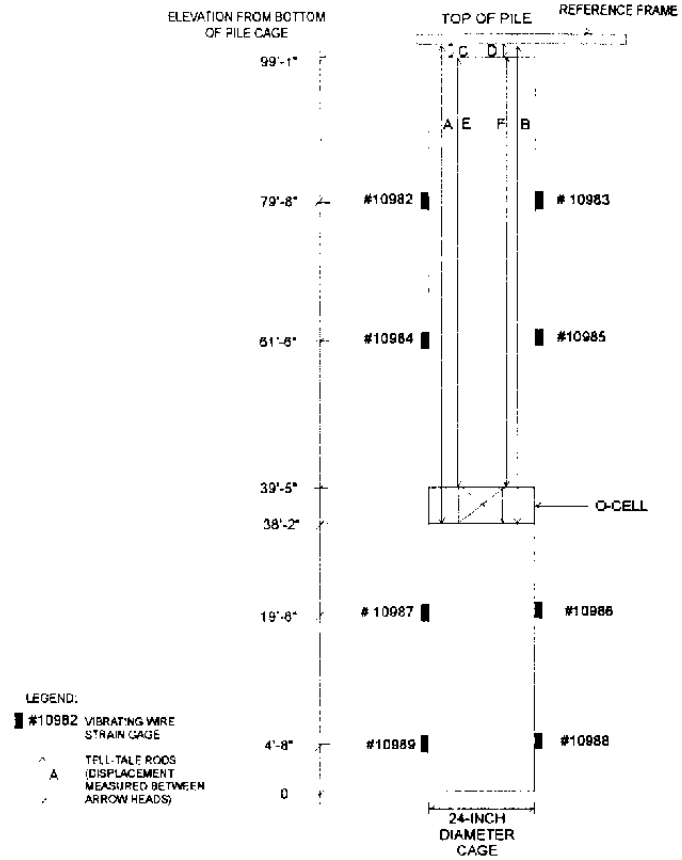

Fig. 1 Elevation of Pile Reinforcement Cage

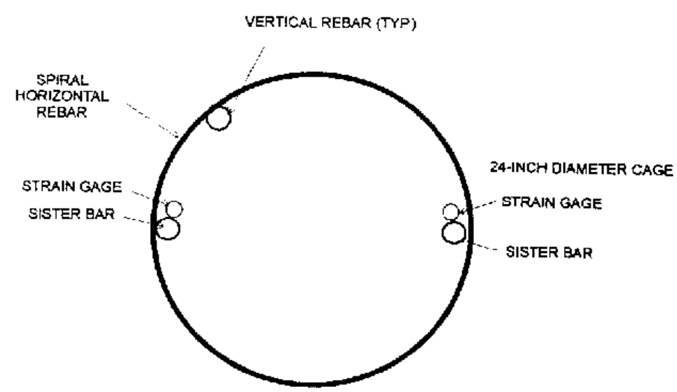

Fig. 2 Plan of Pile Reinforcement Cage

Pile Placement

The reinforcing cage was lifted and installed in the drilled hole using two cranes. As the cage was lowered into the hole, roller spacers were used to prevent the cage from damaging the sides of the hole and keep the cage relatively centered. Once the cage was set, concrete was pumped into the hole using the tremie method. The "Slurry Pro" mixture was displaced by the concrete and recycled. Measurements of the concrete depth and volume of concrete pumped were taken periodically and used to estimate the average diameter of the pile. The concrete was allowed to cure for about five days before the pile load test was conducted.

TEST AREA PREPARATION

A reference frame was constructed above the test pile in such a way that the frame would be negligibly affected by ground disturbances during the load test. The reference frame was assumed to be fixed with respect to the ground surface and, therefore, served as a benchmark for the displacement gages and for survey measurements of the pile during the load test. Scales were attached to the reference frame and a distant wall surface. The vertical movement of the scales was checked during testing by shooting the scales at the end of each pile load increment using a transit. These survey measurements were performed to verify that the reference frame moved negligibly during the test.

The tell-tale rods were inserted in the pipes attached to the cage after the concrete had set.

DATA ACQUISITION EQUIPMENT

The following data acquisition equipment was used in gathering data from the pile load test:

- ***Vibrating Wire Strain Gages***: eight gages were mounted to the inside of the reinforcing cage, used to measure the axial strain in the concrete pile during testing. The locations of the vibrating wire strain gages are shown in Figure 1.

- ***Electronic Displacement Gages***: six gages were attached to the tell-tale rods, which measured the movement of portions of the pile as follows:

  A and B: Movement of Bottom of load cell platen relative to reference frame.

  C and D: Movement of Top of pile relative to reference frame.

  E and F: Compression of upper portion of pile relative to top of the O-cell.

  The locations for displacement measurements using the tell-tale rods are shown on Figure 1.

- ***Vibrating Wire Strain Gage Readout***: Used to take zero readings and check the status of the strain gages mounted to the reinforcing cage.

- ***Multiplexer***: Multi-channel box to which all wires from all electronic strain and displacement gages were run.

- ***Data Logger***: Used to record and time stamp data from the strain gages mounted on the pile reinforcement cage and the eight electronic displacement gages.

PILE LOAD TEST PROCEDURE

All data acquisition equipment was installed and zero readings were established before the commencement of the load test. Once all instrumentation was in place and satisfactory zero baseline readings were established, the pile was loaded by applying pressure to the load cell. Load cell pressure increments of approximately 400 pounds per square inch (psi) were used, corresponding to load increments of 35 kips. Each load step was held for about 4 minutes while the data logger recorded eight readings per load step (one reading every 30 seconds). One manual reading was taken at the end of each load step and plotted as the test was performed. The pile was tested until failure (defined as excessive displacement) of the lower portion occurred; then the pile was unloaded in steps.

PILE LOAD TEST RESULTS AND ANALYSIS

The lower portion of the test pile failed at a load cell pressure of about 10,000 psi, corresponding to a load on the lower and upper portion of the pile of 884 kips. The failure load was held for about 15 minutes, and then the pile was unloaded in three decrements. The raw data recorded by the data logger was downloaded to a personal computer and plots of these data obtained by the electronic displacement and strain gages were made against the load cell pressure. The data obtained using the electronic displacement gages is shown in Figure 3. The average axial strain was computed at the instrumented depths using data from the vibrating wire strain gages. The strain was used to estimate the load at each depth (in-pile load), based on the estimated constructed pile diameter and estimated elastic properties of the pile. The in-pile load for the two upper gage levels were plotted against the top-of-pile displacement (shown in Figure 4 for gages 10984 and 10985), while the in-pile load for the two lower gage levels were plotted against the bottom platen displacement of the load cell (shown in Figure 5 for gages 10986 and 10987). These data were used to confirm that the behavior of the pile along its length was as expected: lower loads at the upper-most and lower-most portions of the pile, and higher loads toward the

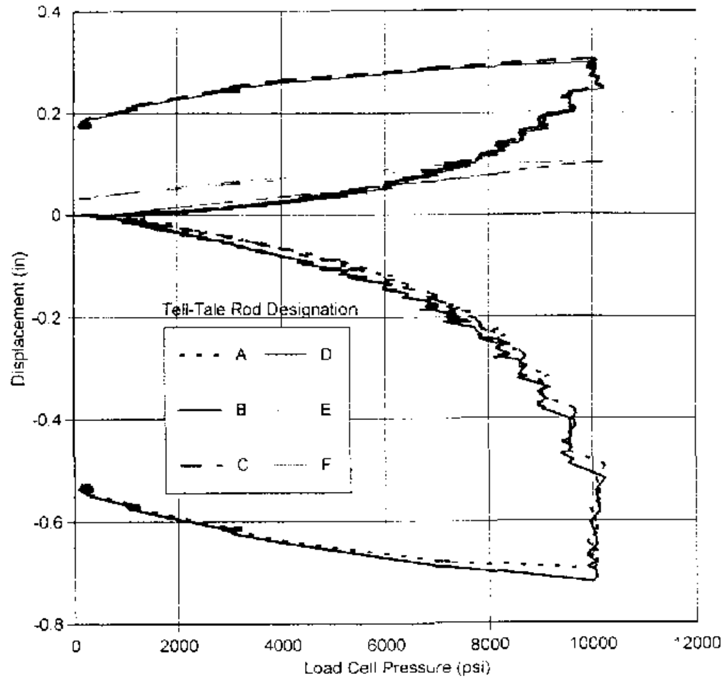

Fig. 3 Load Cell Pressure Vs. Displacement

middle of the pile. There were a few data points that were considered faulty, as shown on the figures, but the overall data appears to be reasonable.

CONCLUSION

The results from the Osterberg pile load test indicate that the ultimate capacity of the lower portion of the test pile was about 900 kips. The upper portion of the pile was nearing failure, and it was extrapolated that the ultimate capacity of the upper portion was about 1000 kips. Using the data obtained from the strain gages, it was estimated that the ultimate capacity of the lower portion of the 95-foot depth production piles in the non-liquefiable soils (below 72 feet) would be about 335 kips after subtracting 114 kips of anticipated liquefaction downdrag load. The results from the load test confirmed the computed estimates of pile capacities based on prior field explorations.

The Osterberg pile load test was economical for this situation. The O-cell test provided a means to isolate the lower portion of the pile to specifically test the downward capacity of that portion expected to support structural and downdrag loads in the event of liquefaction during an earthquake. The key to the success of the test was sufficient reaction capacity of the pile above the O-cell. The test pile could have been used as a production pile if circumstances had allowed it.

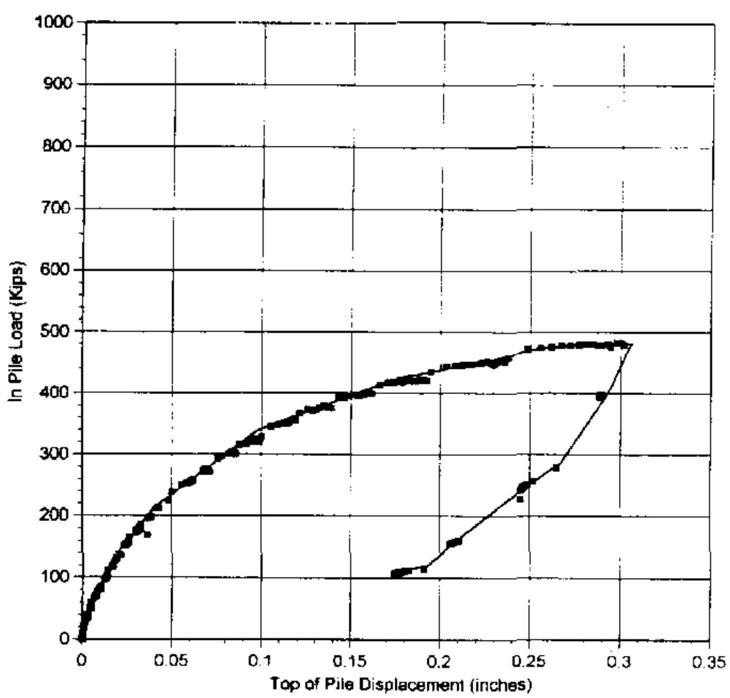

Fig. 4 Top of Pile Displacement Vs. In Pile Load Gages 10984 and 10985

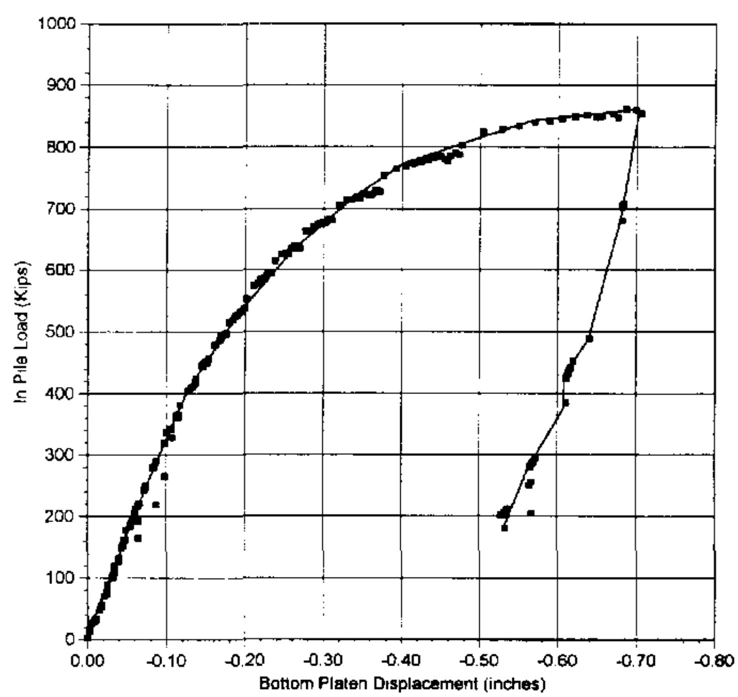

Fig. 5 Bottom Platen Displacement on Load Cell Vs. In Pile Load Gages 10986 and 10987