SUMMARY REPORT 31-1F(S)

TRANSDUCERS FOR MEASUREMENT OF PILE FORCES

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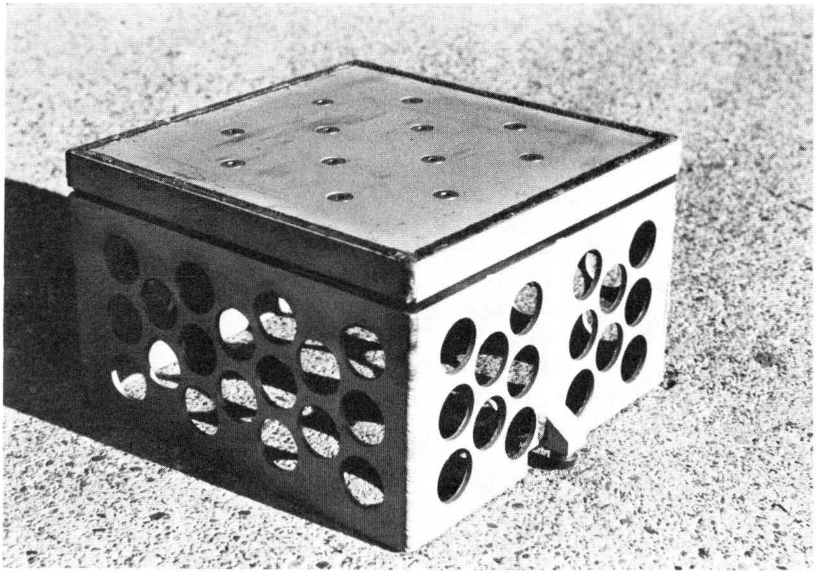

Load Cell for Measuring Dynamic Driving Forces on the Top of Concrete Piles

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Transducers for Measurement of Pile Forces

by

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Research Report 31-1F presents the results of a one-year Type B Study, entitled "Development of a Transducer for Use in Measuring Peak Forces on Piles During Driving," which was a cooperative research endeavor sponsored jointly by the State Department of Highways and Public Transportation and the U.S. Department of Transportation, Federal Highway Administration. The study was conducted during the period September 1975 through August 1976.

Historical Background — Beginning about 1961, the Texas Transportation Institute began the first of a series of research studies on driven piles. The second of the series, Study No. 125, was conducted to develop a method for using one dimensional wave equation theory and data obtained during driving to predict the static bearing capacity of a pile.

It was found that the accuracy of the wave equation method was improved if the peak value of the force on the head of the pile was incorporated into the analysis. To provide the means for measuring the peak force quickly and easily, two subsequent research studies were conducted to construct and field test an electronic readout unit.

The readout was designed to process an electrical input from a Wheatstone bridge circuit attached to the pile. Up to this time the Wheatstone bridges had been constructed by cementing strain gages to the wall of the pile with epoxy in the case of steel piles, and either cementing the gages to the prestress strands or embedding the gages directly in the concrete in the case of concrete piles. The gage installation process was time consuming and required trained technicians. The practicality of developing a load cell capable of generating the input required for operation of the electronic peak force readout unit was apparent.

Objective of the Study — The objective of Study 2-5-76-31 was to develop a lightweight portable load cell to be used in conjunction with the previously developed electronic readout in order to determine the peak force on the head of a pile during driving.

Accomplishments — Two methods of measuring the peak force on the head of a pile were researched and developed. The first method uses an aluminum load cell that was designed and constructed during the study. The second method uses strain gages that are epoxied to the exterior of square concrete piles.

The external dimensions of the load cell are approximately 17-1/8-in. × 17-1/8-in. × 10-3/4-in. (435 mm × 435 mm × 273 mm), and the weight of the cell is approximately 88 lb (392 N). The load cell was designed to be used on square concrete piles that do not exceed 16-in. (406 mm) per side. The instrumented portion of the load cell is a 16-in. × 16-in. × 1.9-in. (406 mm × 406 mm × 48 mm) block of aluminum that contains nine sensing elements. The sensing elements are arranged in a 3 × 3 square grid over the entire surface. With the exception of the strain gages, the entire instrumented component of the load cell was machined from a single block of aluminum.

Each element is composed of four small flexural members that are subjected to a state of pure shear during loading. Two electrical resistance type strain gages in series are attached to each flexural member, which gives a total of eight gages in each sensing element. The eight gages constitute a complete Wheatstone bridge in each of the nine sensing elements. The nine individual bridges are wired in parallel, and the entire gage installation terminates in a four-wire harness that attaches to an interconnect cable through a multipin connector on the outside of the load cell. The interconnect cable provides a hardwire link between the load cell and the readout unit.

In ordinary use, the load cell is placed directly on top of the pile with not more than 1/2-in. (13 mm) of cushion material between the cell and the pile to prevent the occurrence of extremely high contact stresses due to surface irregularities at the pile head. Normal thicknesses of cushion are placed between the load cell and the hammer, just as if no load cell were present.

Static evaluation tests were conducted on the load cell before final assembly, but the cell was never fully tested under field conditions.

The second method of determining a peak force involves the use of electrical resistance strain gages encased in plastic and rigidly attached to exterior pile surfaces. The method was evaluated by conducting tests in the laboratory and field. Laboratory tests were conducted on 4-in. × 4-in. × 13-in. (100 mm × 100 mm × 330 mm) concrete specimens to determine the correspondence between the strains measured by gages attached to the exteriors of the specimens and gages embedded inside the specimens.

Two types of bonding material for attaching gages to exterior concrete surfaces were tested. One type was a rapid setting, "five-minute" two-part epoxy; the other was a cement-like grout requiring approximately 24-hours for full curing. Overall the results indicated no significant differences in measured strains due to the different bonding materials. The gages attached with epoxy gave slightly lower indicated strains.

The field tests were conducted at a bridge construction site on SH 124 at the Intracoastal Canal, approximately one mile north of High Island, Texas. Soils at the test site were primarily soft silty clays with liquid limits ranging between 27 and 81; plasticity indices ranged between 7 and 56. Average values were 62 and 40 respectively. Four 18-in. square × 55-ft (460 mm square × 17 m) concrete piles were instrumented by attaching one strain gage on each of two opposite sides, three ft below the pile top, with rapid-setting epoxy.

Continuous records of force at the pile top versus time for several hammer blows during the final 10 ft (3 m) of penetration were obtained with a recorder utilizing direct print photographic paper. Also during the final 10 ft (3 m) of penetration the peak force at the pile top was measured with the DHT peak force readout unit.

The peak forces were measured and recorded for every third hammer blow. All piles were driven with a Delmag D46-02 hammer. The average blow count at the end of driving was approximately 12 blows per ft (39 blows per m). The peak forces measured by the continuous force-time recorder ranged from approximately 6% lower to 18% higher than values obtained with the DHT readout at the same pile penetration.

The field test data were used to perform a wave equation analysis of the High Island pile driving. Results of the analysis were used to plot static soil resistance versus pile driving blow count. This graph, along with the measured blow count, was used to estimate the static bearing capacity of the piles. The analysis was made by selecting values of certain input variables such that the computed peak force was in agreement with the measured value.

Summary and Conclusions — The primary objective of the study was to develop instrumentation which would allow the peak force at the top of a pile to be easily measured during driving, without recourse to complicated cumbersome equipment. A load cell was developed specifically for this purpose. Advantages of the load cell are its simplicity of operation, moderate weight, and the fact that the modulus of elasticity of the concrete pile need not be known. The disadvantage of the load cell is that it can be used only on square concrete piles measuring 16-in. (406 mm) or less per side. The load cell has not been field tested.

Another method for measuring the peak force is by means of strain gages attached directly to the side of the pile. The disadvantages of this method are (1) the time required to install the gages, and (2) the modulus of elasticity of the pile material must be known. The advantage of this method is that it can be used on any size or shape of pile and any kind of pile material. This method has been used successfully on steel piles (not as a part of this study) and concrete piles.

The published version of report 31-1F contains data on laboratory and field tests for strain gages attached to pile sides. Soil profiles, driving records, and other pertinent data are given for the field test site. Machine drawings for the various parts of the load cell are contained in the report.

The published version of this report may be obtained by addressing your request as follows:

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