Title
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A symposium on Recent Advances in Geotechnical Centrifuge Modeling was held on July 18-20, 1984 at the University of California at Davis. The symposium was sponsored by the National Science Foundation's Geotechnical Engineering Program and the Center for Geotechnical Modeling at the University of California at Davis.

The symposium offered an opportunity for a meeting of the International Committee on Centrifuges of the International Society for Soil Mechanics and Foundation Engineering. The U.S. participants also met to discuss the advancement of the centrifuge modeling technique in the U.S. A request is being transmitted to the American Society of Civil Engineers to establish a subcommittee on centrifuges within the Geotechnical Engineering Division.

TESTS ON PILES INSTALLED IN FLIGHT ON THE CENTRIFUGE

by M. A. ALLARD*

INTRODUCTION

With the development of much larger piles up to three meters diameter and one hundred and fifty meters in length, simple extension of empirical rules has been difficult and engineers have been forced into studying the mechanics of pile-soil interaction, during driving and under static load.

Prototype scale field experiments on the stress field around driven piles are difficult to carry out because of the variability of soil, and problems of installation of pressure transducers near the pile. In consequence, the few results available are inconclusive or unsatisfactory as a basis for theoretical comparisons. It has therefore been proposed to perform a number of pile experiments in the Caltech centrifuge.

For this investigation, an apparatus capable of driving or pushing a pile in flight on the centrifuge had to be designed and built. Several bearing capacity tests were then made with the pile driven in flight to compare with tests done with the pile driven at 1g.

The pile driving and pile pushing mechanisms designed at Caltech are described, and some results of bearing capacity tests are presented in this report.

THE PILE DRIVING MECHANISM

This mechanism has been specially designed to fit into the pile test container which consists of a long cylindrical vessel, 22 in. high and 6 in. diameter, directly mounted on the centrifuge arm.

Its structure is in two parts.
The first part, **the frame**, consists of two columns held together by two circular plates. One plate of aluminum is fixed at the base of the columns, the other of lucite is near the top (its height is adjustable). The plates' diameter is slightly smaller than 6 in.. Each column has two diametrically opposite rows of notches equally spaced (1/8 in.), over a length of 8 in., which is the driving length. The second part, **the carriage**, consists of a horizontal beam that slides up and down the columns. Ratchets are placed on the carriage such that when in position they fit into the notches of the columns and prevent upward movement of the carriage relative to the frame.

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The mechanism is suspended by its columns to two horizontal rods connected together above the container (see Fig.1). The frame is fixed inside the container. A small air-driven piston ("Tiny Tim") is attached on top of the carriage. The pile is placed underneath the carriage and will be forced down into the soil by the piston, as shown in Fig.2.

1st sketch: the stroke of the piston is near its minimum, the pile is resting in the soil and supports the carriage.

2nd sketch: the stroke is at its maximum, the pile is hit, and by the impact given by the hammer the pile is forced down into the soil. The teflon sleeve slides along the guide, therefore preserving a connection between the pile and the carriage to maintain good alignment.

3rd sketch: due to the effect of gravity the carriage slides down until it rests on the pile again. Because of the ratchets, upward movement is prevented and only downward motion of the pile is permitted.

These sequences are repeated and the pile is driven into the soil. The frequency of the piston strokes is 4Hz.

To prevent tilting of the pile during its driving a teflon guide is placed in the bottom circular plate.

THE PILE PUSHING MECHANISM

This is the same overall mechanism as for the pile driving one. The "Tiny Tim" is removed and the pile is fixed to the carriage. The frame is suspended by its two columns to the two horizontal rods that hinge from a fulcrum bolted to the lip of the container. The outer hydraulic piston alternately pushes and pulls on the two rods. It then transmits an up and down translation to the frame with respect to the container. As before the carriage will undergo only downward movement relative to the frame. See Fig.3.

1st sketch: reference configuration; the piston is in the lower position.

2nd sketch: the piston is going up, pushing the frame up. It can be seen that only the frame undergoes an upward movement. The carriage subjected to the centrifuge acceleration will slide down the frame, and the ratchets will occupy a new position further down the colomns.

3rd sketch: upper position of the piston; the pile is still at the same level.

4th sketch: the piston is going down, pulling the frame down. Because the ratchets prevent upward motion of the carriage relative to the frame, the whole mechanism is forced down. Hence the pile attached beneath the carriage is forced down into the soil.

5th sketch: final configuration after one complete cycle of the piston.

These sequences are repeated and the pile is driven into the soil once every cycle of the piston.

The downward movement of the pile is controlled by regulating the stroke of the piston.

BEARING CAPACITY TESTS

Several bearing capacity tests on piles driven in flight were done using the pile pushing mechanism.

The model pile (a 3/8 in. diameter, 10 in. long, and 0.03 in. thickness aluminum tube with a bottom cap) was driven at 50g in a dry fine Nevada sand with a unit weight of 105 pcf.

Instrumentation

The carriage is instrumented with strain gauges connected to form a Wheatstone bridge. This then constitutes a load cell with which to measure the load applied to the pile during and after driving.

The depth of the pile is calculated from the output of a rotary potentiometer which is fixed to the upper circular plate and connected to the carriage by a string and pulley system . A soft spring is used to maintain continuous tension of the string.

A Linear Variable Differential Transformer (LVDT), connected between the upper circular plate and the top of the container, is used to indicate the movement of the piston, and therefore of the driving mechanism.

Test procedure

The test proceeds in two parts:

1) The centrifuge is spun up to the test acceleration of 50g. The pile is then driven into the soil, to a given depth, where a bearing capacity test is performed. This test is named type (A).

2) The centrifuge is stopped so that relaxation of the soil occurs, but all other conditions are preserved. The centrifuge is then brought up to 50g again, and a second bearing capacity test is done on the pile at essentially the same depth as before. This test is named type (B).

Preliminary results

Bearing capacity tests have been done in the past in the centrifuge with the pile driven into the soil at 1g and the test itself performed at Ng. The present test procedure is such that by stopping the centrifuge and allowing relaxation of the soil, the conditions of the pile driven at 1g are recreated. By preserving the other conditions, namely the soil and position of the pile, the two type of tests can be compared. The only difference between the two tests lies in the stress conditions around the pile.

Figure 4 is a comparison of typical load versus penetration curves for tests A and B. The results obtained show that in the second procedure the bearing load of the pile is smaller. The values are about 75% of the actual values obtained from the first procedure.

Conclusion

From these tests it is apparent that the pile must be driven in flight in the centrifuge to correctly represent the stress distribution around it.

Experiments are in progress at Caltech to investigate the stress field around a pile during driving.

ACKNOWLEDGMENTS

John Lee, research engineer at Caltech, and Mike Becker, former Caltech student, contributed significantly to the design and construction of the mechanisms.

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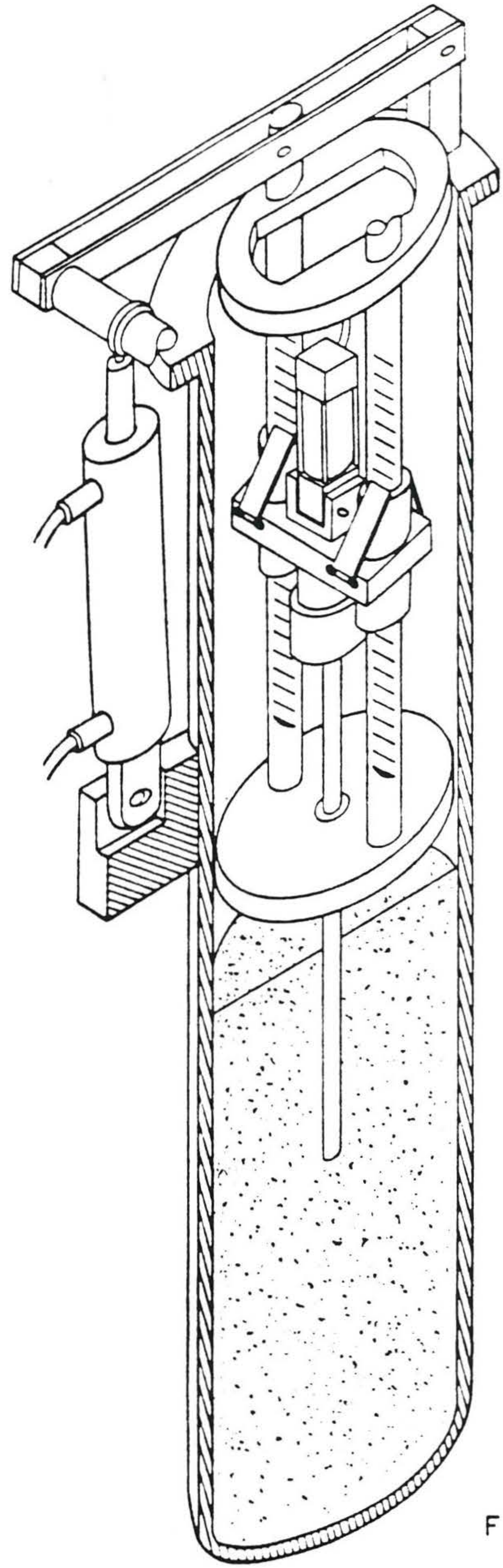

FIGURE I

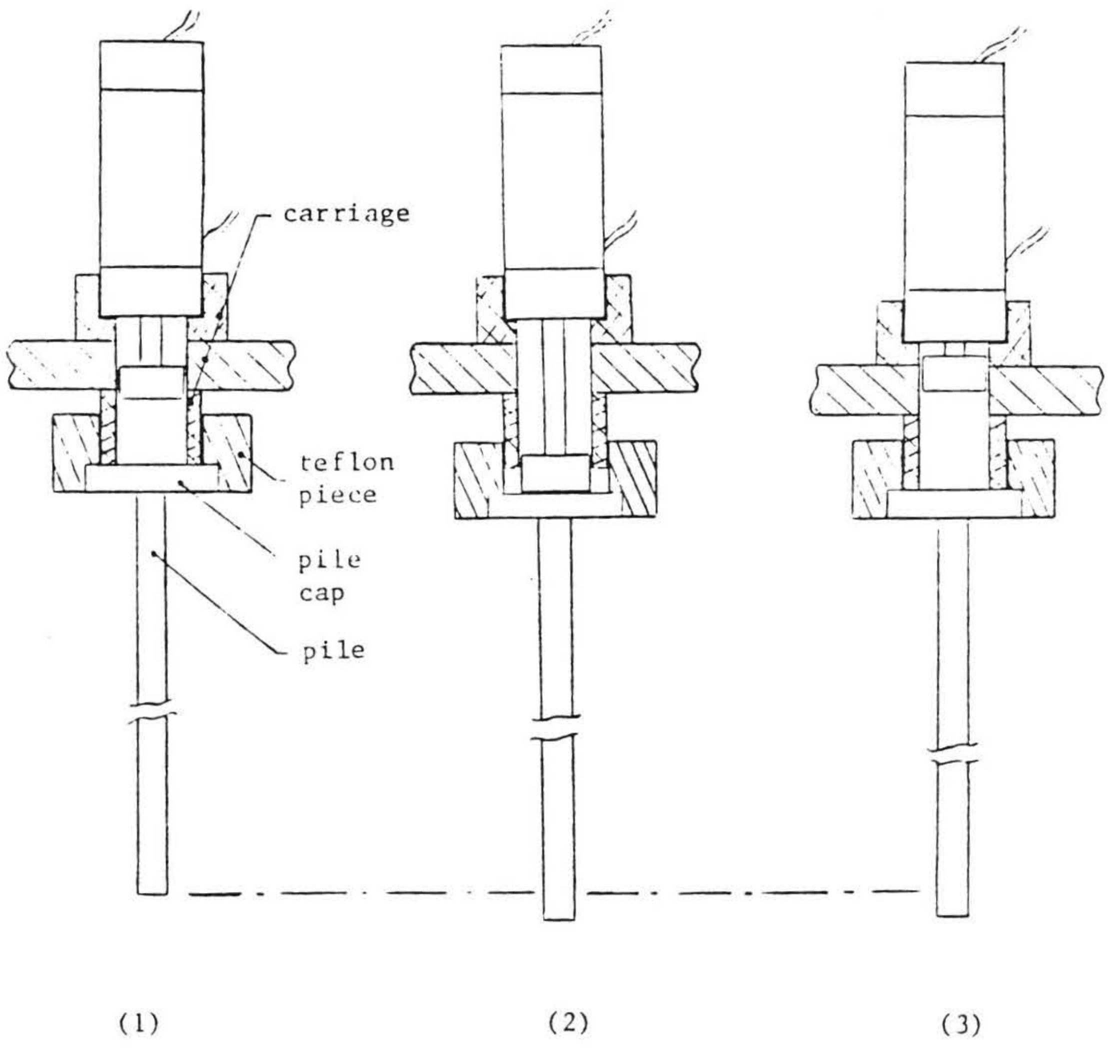

FIGURE 2

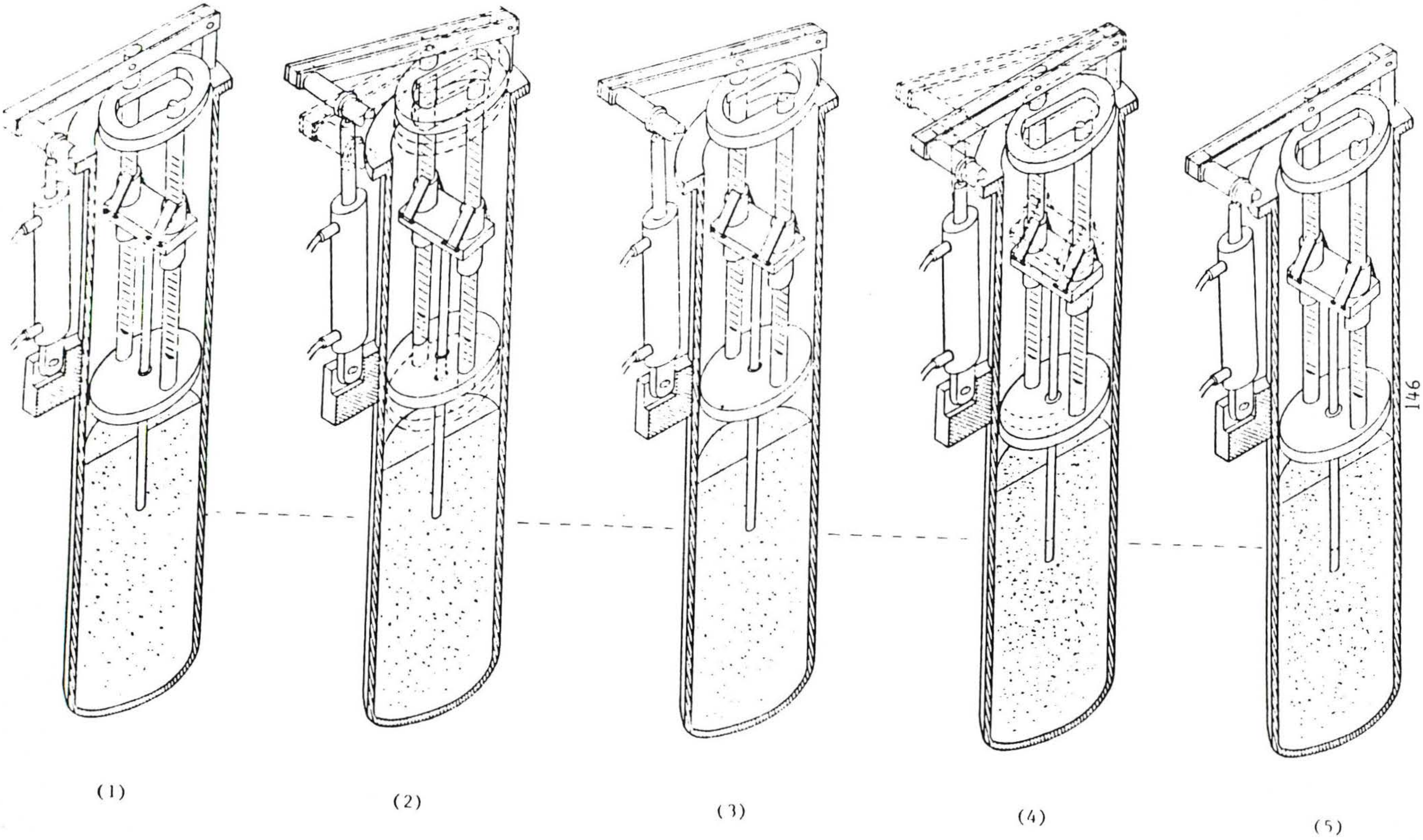

FIGURE 3

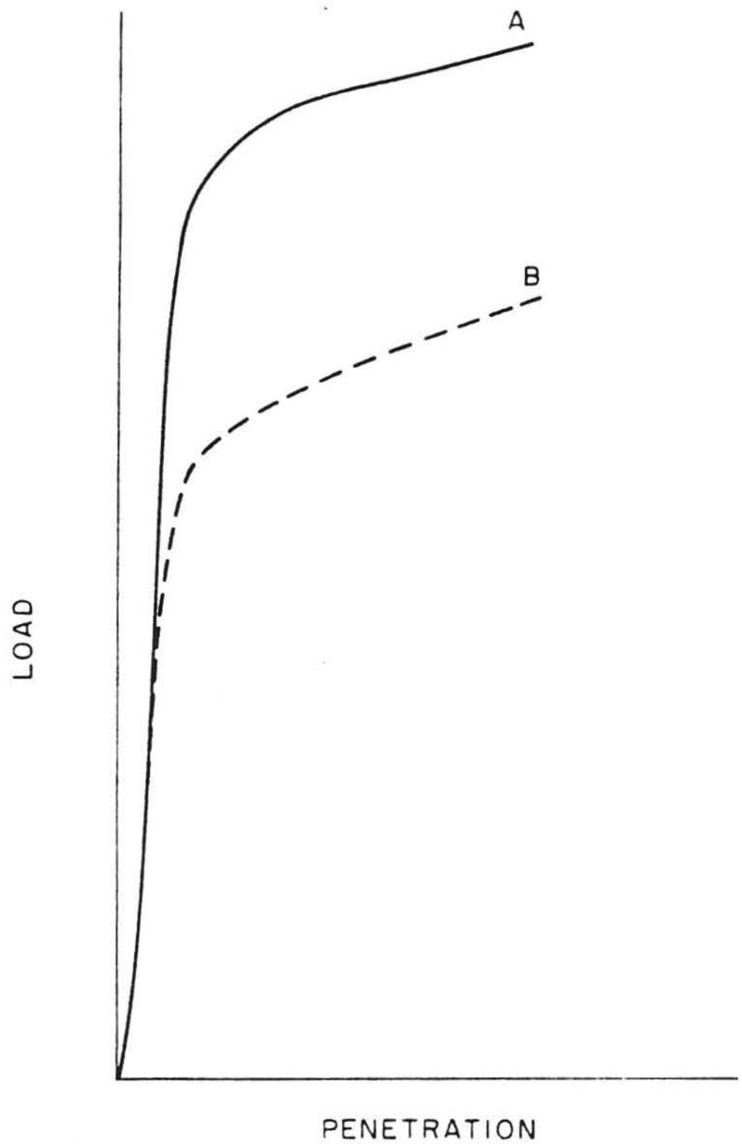

FIGURE 4: Comparison Between Capacity Tests (A) and (B)