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CENTRIFUGE PREDICTION OF EGRESS SYSTEM PERFORMANCE

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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.

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CENTRIFUGE PREDICTION OF EGRESS SYSTEM PERFORMANCE

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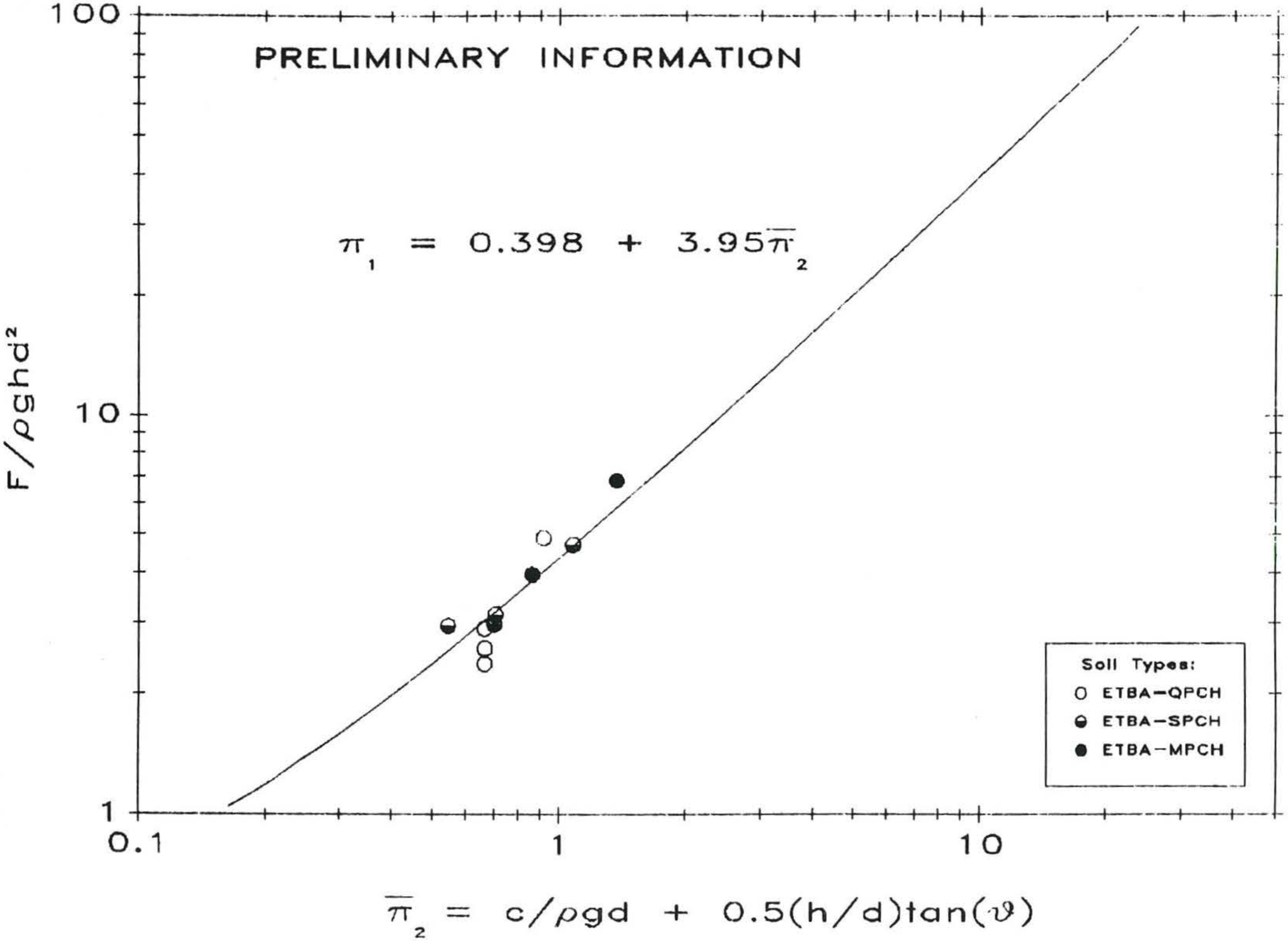
Hard silo basing requires missile canister egress through a layer of blast-compacted soil debris on the order of 15 to 20 feet thick. This is analogous to the pull out of a shallow soil-anchor for the 16-foot canister closure under consideration. Anchor design formulae have been developed by numerous investigators over the past 25 years; see attached references, especially the literature search by Gurtowski (1984). All of these results are based upon laboratory model test data and in some cases are supported with finite element code analysis. A common conclusion is that break-out mode and maximum load depend greatly upon soil strength properties. Recently, Ko (1982) suggested that the modeling fidelity of subscale egress could be improved by conducting laboratory tests on a centrifuge, and performed a suite of tests using a typical Yuma desert soil.

The work described here is an application of the centrifuge technique as a prediction method in the design of a full-scale field demonstration test to be conducted in March of 1985. Two approaches to the egress problem were employed.

In the first approach, five generic soil types were used in an attempt to determine egress load in terms of soil properties. For each soil type, direct shear tests were conducted to estimate strength properties, as a function of dry density and moisture content (Godlewski, 1984). Maximum loads required for egress were measured for various scaled debris depths. The centrifuge data were cast in nondimensional form and used in a step-wise second order polynomial regression analysis. This provided a design prediction equation in terms of measured or estimated soil properties, which can be used for system studies. This equation is still under development; however a preliminary version based upon specific results (discussed below) of just three density variations of the Engineering Test Bed (ETB) soil is shown in Fig. 1. Here, F is the peak load observed during egress; ρ, c and ϕ are the soil density, cohesion and friction angle; g is gravitational acceleration; h is debris depth and d is closure diameter.

FIGURE 1
CORRELATION OF LOAD COEFFICIENT WITH AVE SHEAR STRESS



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The second approach was to use the centrifuge model to directly simulate the anticipated field event using an "identical" soil. The success of this method depends upon the fidelity of the soil model representing the debris embankment to be placed in field. Here, samples of the actual ETB soil were obtained from DOE pit 400. The nominal field condition is to place this soil at a density corresponding to the standard Proctor (ASTM D698-78).

Load histories from a model of the model test are compared in Fig. 2. The result from test 37A-9ED is for a 4-inch diameter model closure run at 64G. It can be compared to the result from test 43A-OED, which is for a 2-inch diameter model run at 128G. Peak scaled loads are in good agreement, however load decay with time is more rapid for the larger closure. This is attributed to a grain-size effect that governs the rate at which material falls through the emerging rupture gap in the soil around the closure. Both models were run at a constant strain rate corresponding to a full scale velocity of 12 inches/second.

To examine the range of loads that can be expected due to extremes in soil placement, centrifuge tests were conducted at three different densities, all at the same moisture content, nominally 5%. The three curves shown in Fig. 3 are for soil densities that correspond to modified Proctor (MP) compaction (ASTM D1557-78), standard Proctor (SP), and "quarter" Proctor (QP) using an energy of compaction equal to 25% of the standard Proctor. The left ordinate shows the pressure in the actuator corresponding to the total load as shown on the right. The curves are based upon a least squares fit to the ETB data using the values for soil mechanical properties measured by Godlewski (1984). A typical value for one standard deviation in the region of 15-foot debris depth is approximately 50 psi. Reproducibility of the centrifuge results is on the order of 5%. This plot provides the current best estimate for the upcoming full-scale field test.

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FIGURE 2: MODEL-OF-MODEL LOAD HISTORIES
(Closure Tare Weight Excluded)

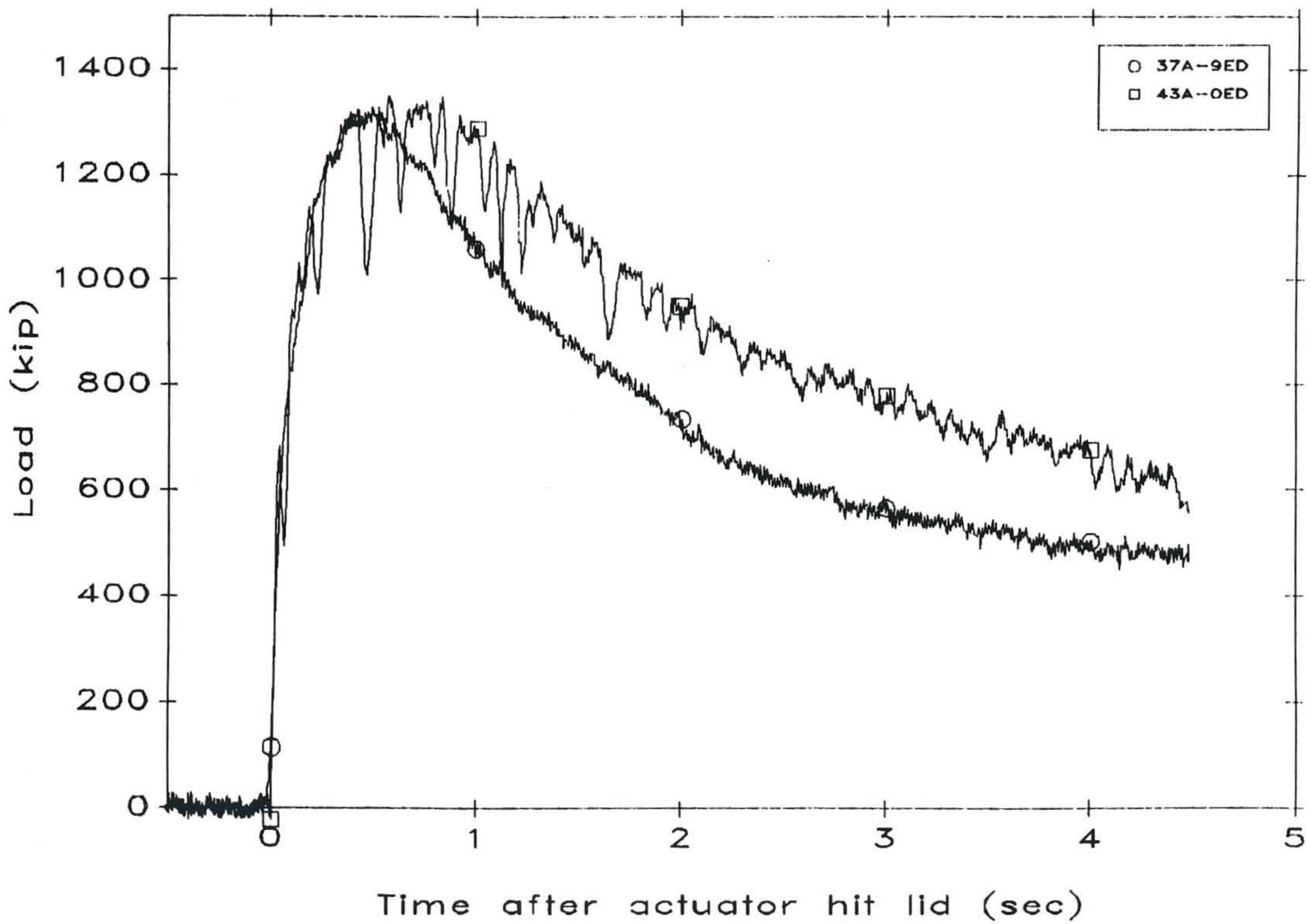
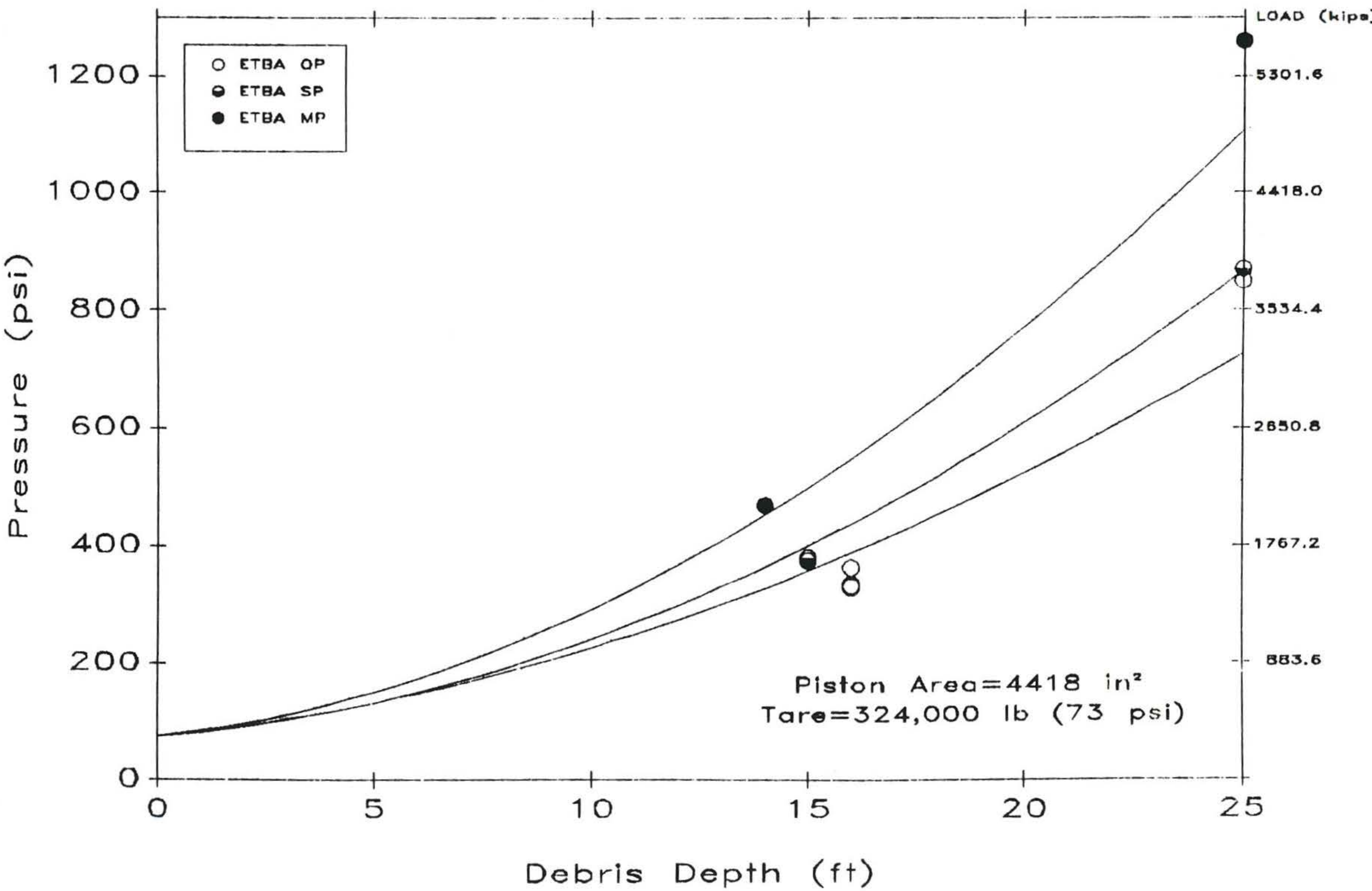


FIGURE 3

CENTRIFUGE PREDICTION OF ETB EGRESS LOADS VS DEPTH



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