CAPWAPC CAPABILITIES AND BORED PILE TESTING

PDA USERS DAY
CLEVELAND 1989

by

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NEW SOIL MODEL FOR BORED PILE ANALYSIS

Bored pile dynamic pile testing is generally more difficult than driven pile testing for the following reasons.

- Large energies are required to mobilize the end bearing of the piles, particularly, when piles are cast in a "relaxed" condition (soil is unstressed during casting). High energies only can be generated with large ram weights since high strokes produce potentially unsafe tension stresses.

- The very close bond of skin friction and end bearing produces - among other undesirable situations - acceleration (inertia) dependent resistance forces and soil motions before a complete pile-soil or soil-soil failure occurs. Thus impact energy is lost into the surrounding soil and the soil resistance-pile motion relationship is not as simple as for driven piles.

The first test complication can be overcome by sufficient ram mass. For the second difficulty an improved soil model must be created. The following examples demonstrate both test set-ups and soil model modifications for better matching of bored pile records.

The 1989 CAPWAPC Model

In order to match measured bored pile records, CAPWAPC was modified to include "Soil Support Dashpots" underneath the standard soil model. The SSD is also separated from the standard soil model by a mass which may be thought of representing the soil. For the toe the SSD has been used for several years. Only the soil mass has lately been added.

Intuitively (see also a schematic of the new soil model on the next page) it is clear that the SSD starts to move as soon as a soil resistance builds up in the pile-soil interface. Thus, unloading occurs already during the loading process. If the soil mass is large then the initial movement will be delayed because of inertia. The soil mass of course, will continue to move even after the interface forces have disappeared.

The 1989 CAPWAPC soil model includes the following unknowns.

A. On Each Shaft Segment (N_s values)

R_{ui} ultimate resistance
q_i quake
J_s damping

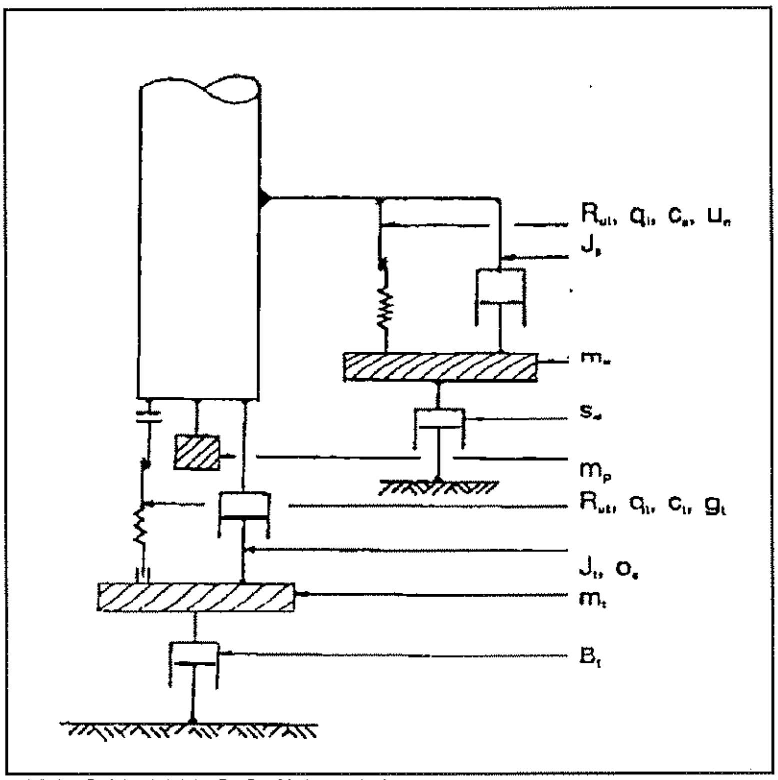
B. Globally on the Shaft

c_s unloading quake ratio
u_n unloading level

m_s	soil mass
s_d	soil support dashpot

C. At the Toe

R_{ut}	toe ultimate resistance (n_t values)
J_t	toe damping
q_t	toe quake (n_t values)
c_t	toe unloading quake ratio
g_t	toe gap
m_p	mass of soil plug
m_t	toe soil mass
b_d	toe soil support dashpot
o_s	Smith damping option



1989 CAPWAPC Soil Model

Examples

During the past few months, GRL had an opportunity to study the high strain test records of several different projects. Only with the improved model did it become possible to match the records on two projects.

Data was obtained or analyzed from the following sites.

- 4-ft dia. postgrouted shafts with up to 55 ft length in sand.
- 16-in. dia. auger cast shafts of 28 and 32 ft length in silty and clayey soils.
- 1.5 m dia. drilled shafts of up to 60 m length in variable soil conditions.
- 1.05 m dia. drilled shafts of 30 m length in generally stiff clay.

First Case

This was the first dynamic test series on large diameter piles in the US with a carefully and specifically designed test system. Wave equation analyses were run for an estimate of the necessary ram weight, drop heights and cushions. Particular attention was paid to stresses under energies which were sufficient to activate capacities of up to 2000 kips. Since the soil consisted of sand, it was anticipated that the toe quakes would be rather large.

The test was conducted using a 16 ton ram consisting of four steel cubes 1x1x4 ft in size. Thus, the ram length was 16 ft. The ram was guided by conventional box leads. The impact energy was transferred through 2 pieces of plywood on a six inch steel plate over two more sheets plywood (Figure 1.1). Fall heights were raised from 3 ft in the beginning to as much as 12 ft. such high fall heights were necessary because of a two-line ram rigging. On one of the piles a maximum set of 17 mm was achieved (Figure 1.2).

Typically 10 blows were available for analyses. At first it was decided to analyze only early blows with 3 mm set. However, since static load tests were apparently run to sets as large as 75 mm CAPWAPC analyses were also run for late high energy blows (Figure 1.5). The enclosure shows the potential and transferred energies and the CAPWAPC capacities. The important finding was that a realistic CAPWAPC modeling was not possible without the "soil support dashpot" which may also be thought of representing "dissipation damping". Note the large tension waves after relatively high friction (Figures 1.3 and 1.4).

One remaining cause for concern was the unusual resistance distribution. Apparently too much friction was calculated the upper soil layers and too little near the toe. One of the next CAPWAPC development tasks will be a residual stress analysis since residual stresses could be responsible for the unusual soil resistance prediction. Furthermore, a correlation with the static test results is yet to be made.

Second Case

Static tests were not run on the auger cast piles. However, the matching process was simple and reasonable bearing capacities resulted. It may be argued that a true shear occurred without much soil motion in the silty clayey soil at the Cleveland site. The end bearing values were small and therefore easily activated (Figure 2.1). Also for the relatively small pile diameter toe quakes were small.

For this type of test the main concern is the integrity of the test pile, i.e., particular care has to be taken during testing to protect the pile top. In the present case, a 3000 pound weight was dropped 1 or 2 ft. The weight, a wrecking ball, was suspended from the bucket of a front loader. A 2-inch steel plate and 2 sheets of plywood were used to protect the pile top.

Third Case

GRL was not involved in the actual testing of these large piles using a 10 ton ram with free fall (cut cable). The piles were bored into a variable mixture of soils, including sands of relatively low strength. Dissipation damping appeared <u>not</u> to be necessary for matching.

Initial correlations with static load tests showed good agreement (within 200 tons of test loads up to 1600 tons). Later results from production piles sometimes gave lower than anticipated predictions. It is not clear whether the standard soil model was sufficient to represent the soil behavior. Results from high and low end bearing piles are shown in Figures 3.1 and 3.2, respectively.

Fourth Case

The last case was reanalyzed for a Far East User. A few records were submitted (Figure 4.2). The pile had been bored in soft and stiff clays. The static load test plunged at 800 tons (Figure 4.3). CAPWAPC matching was only possible with dissipation damping. However, the predicted capacity did not exceed 50% of the static result. It is possible that the pile did not completely shear during the test blow with the 6.5 ton ram. Note the good match but low prediction and the poor match with the correct (i.e., static) soil resistance from GRL and the Far East User, respectively (Figure 4.2).

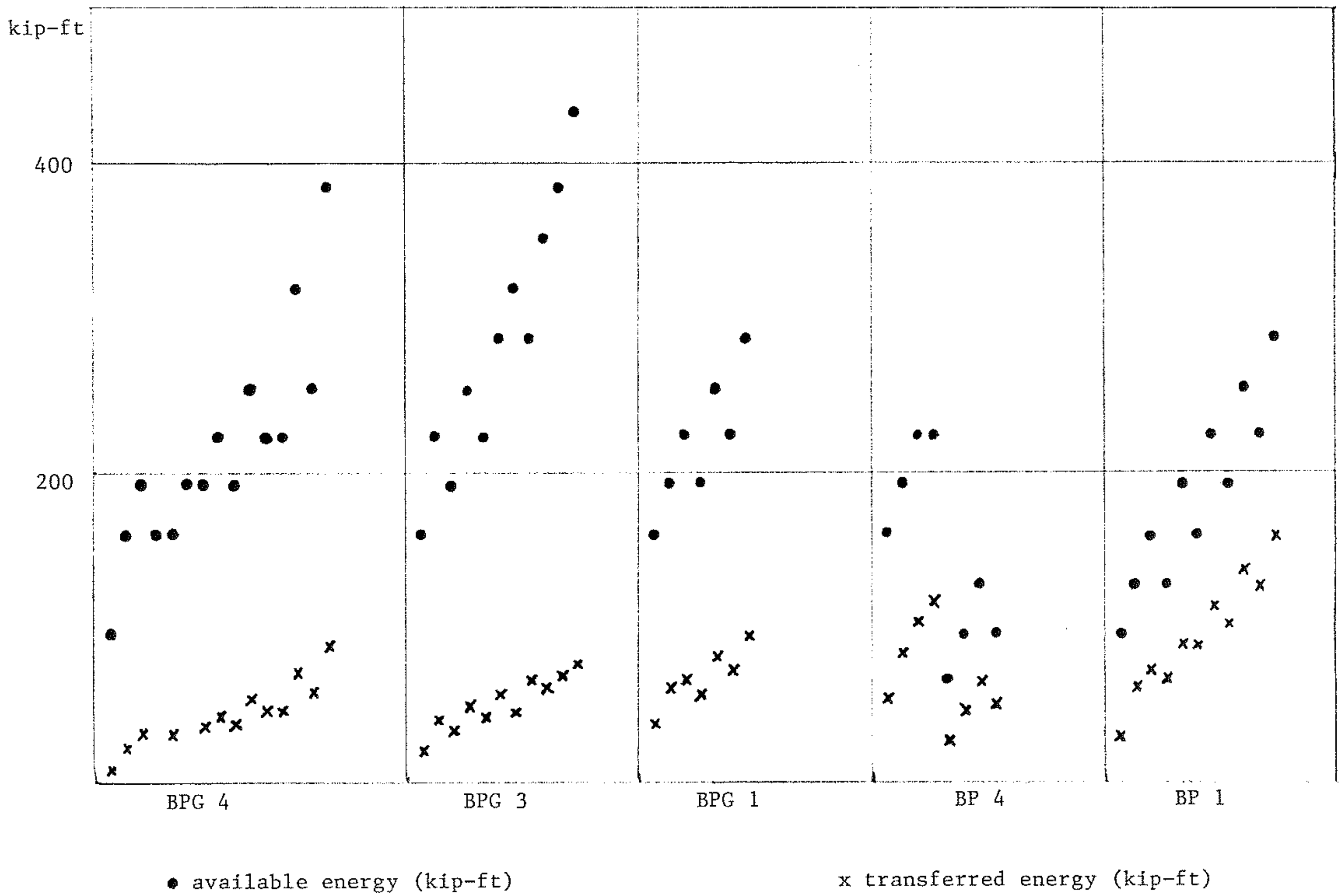


Figure 1.1: Available and Transferred Energy for Case 1 Piles

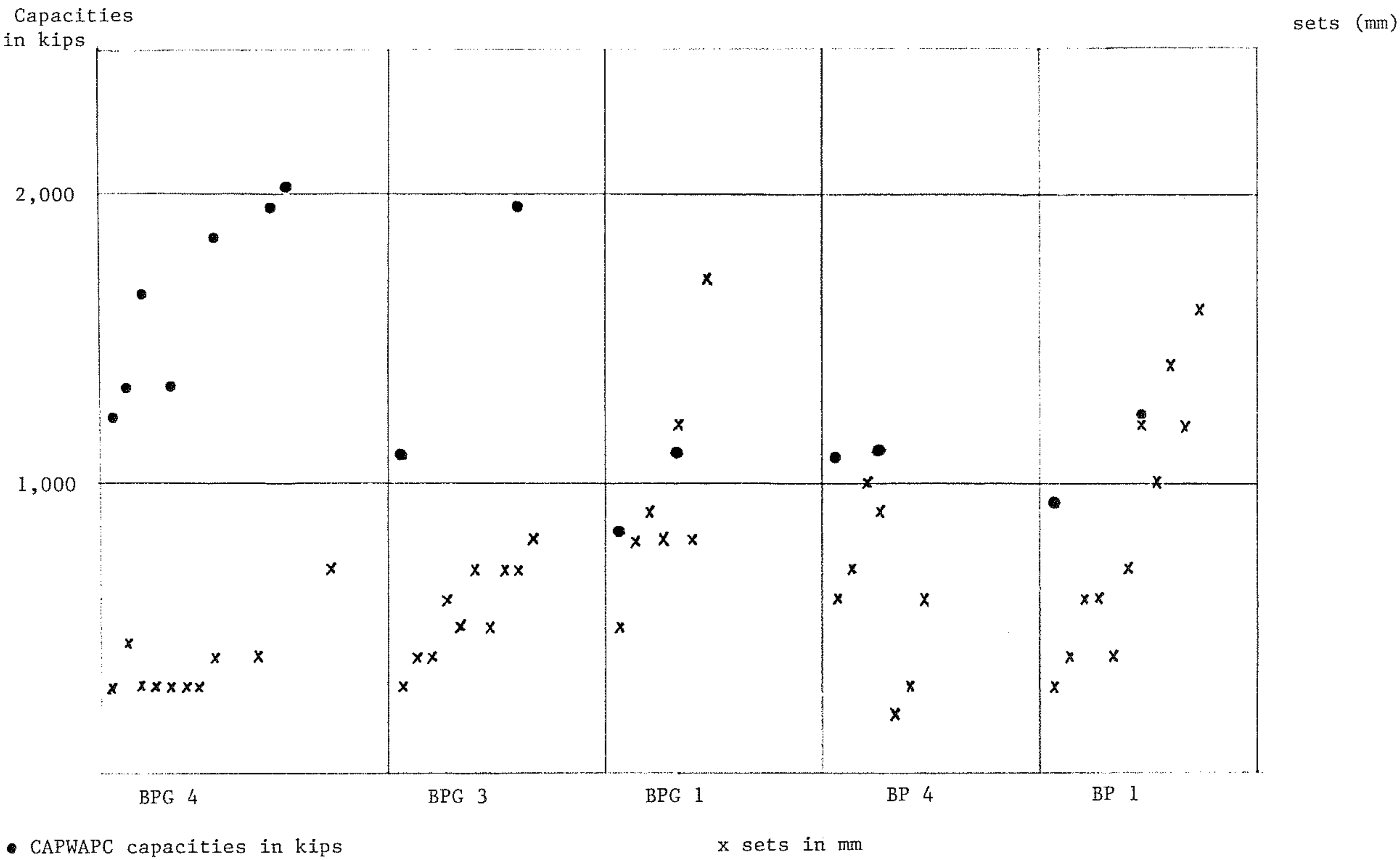


Figure 1.2: Predicted Capacities and Pile Sets for Case 1 Piles

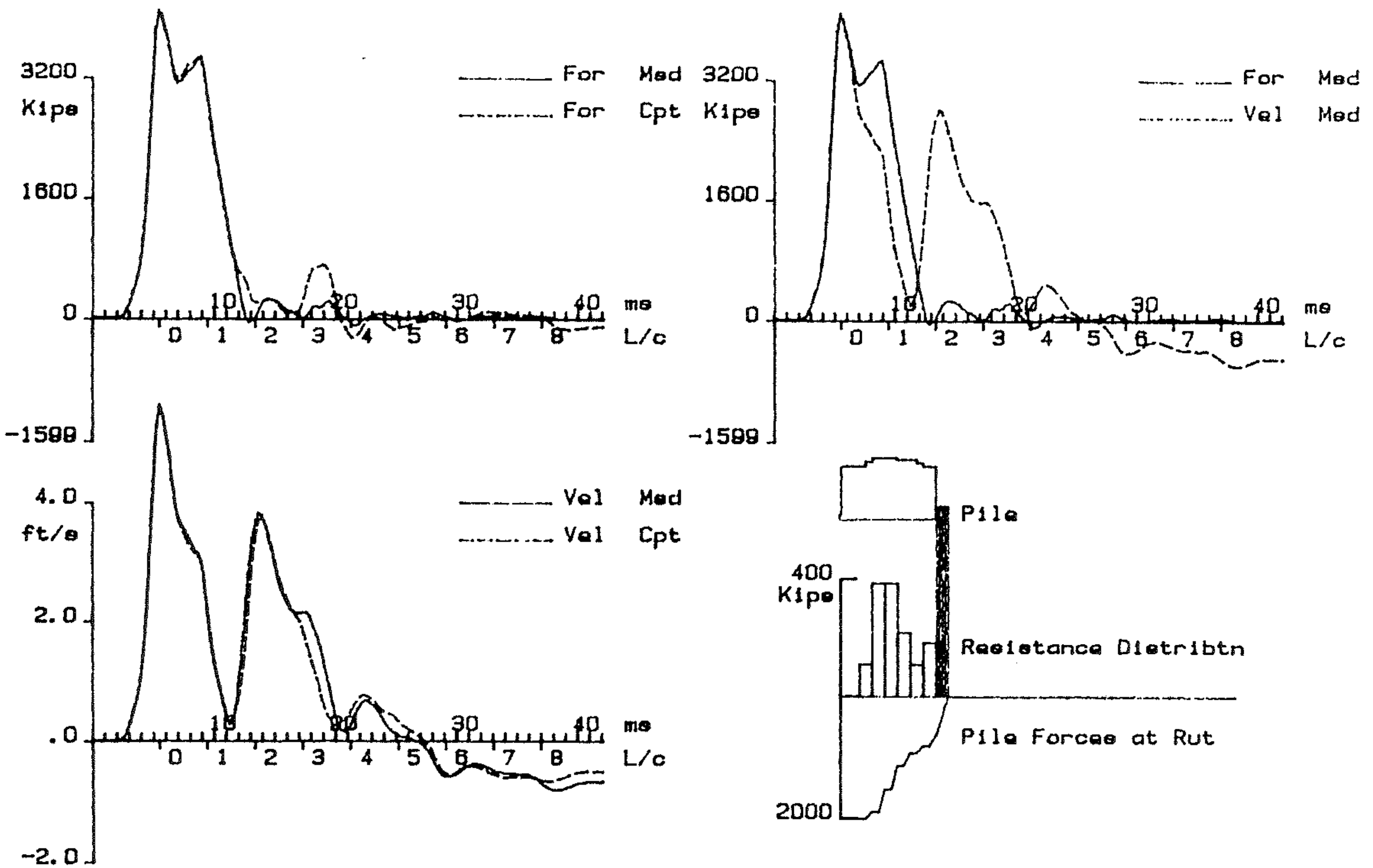


Figure 1.3: CAPWAPC Results for Postgrouted 4 ft dia. pile from High Energy Blow-using Dissipation Damping.

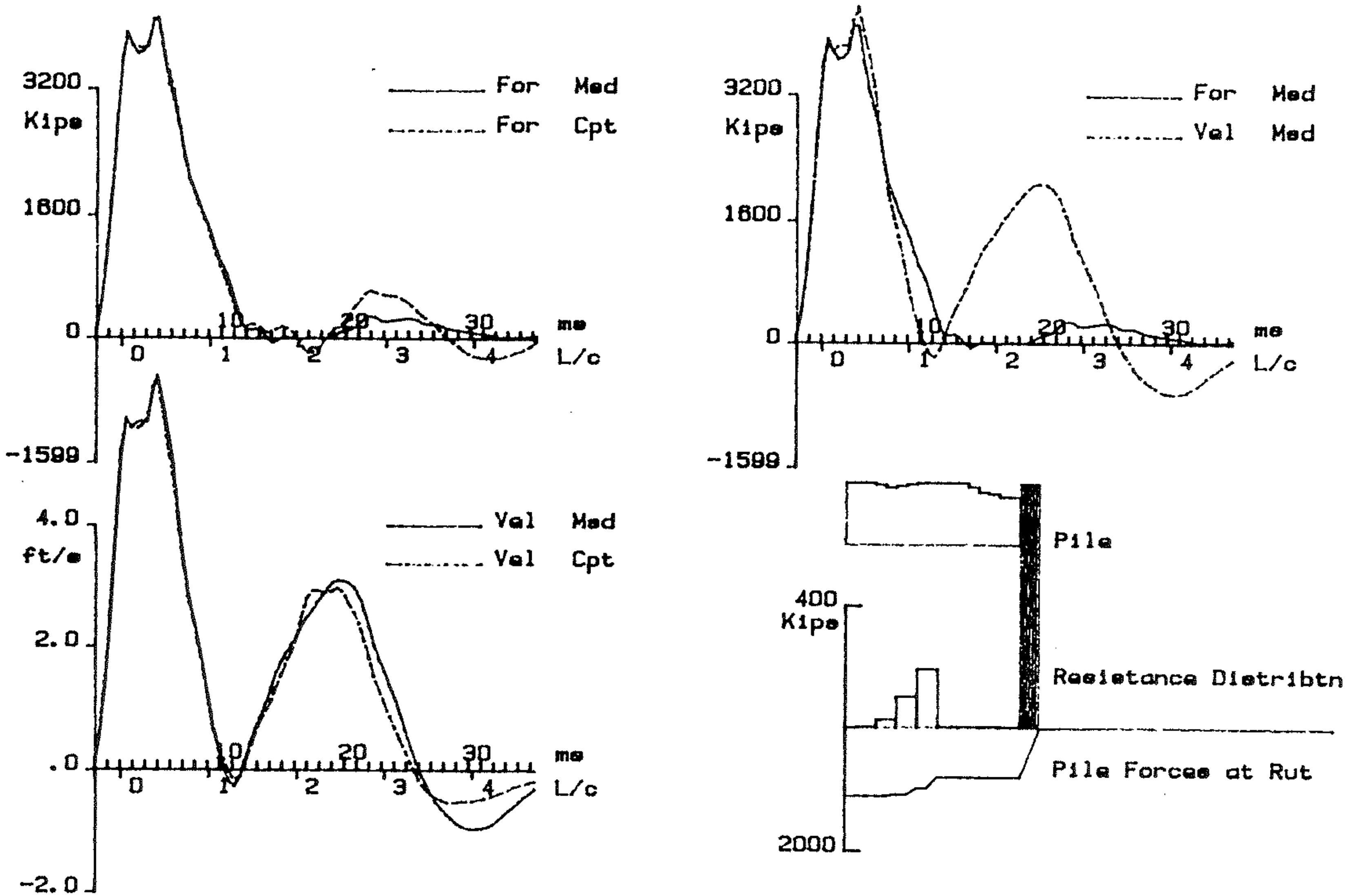


Figure 1.4: CAPWAPC Results for Regular Drilled Shaft using Dissipation Damping

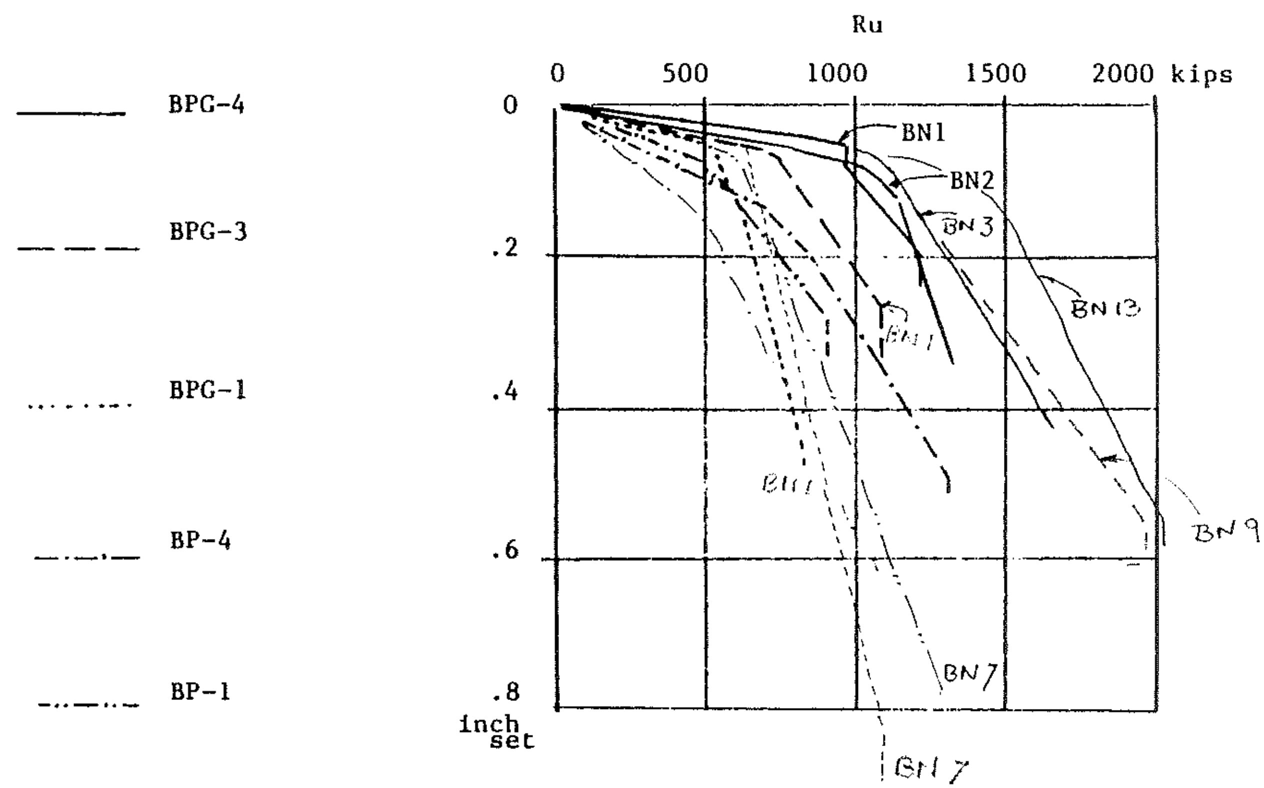


Figure 1.5: Simulated Load Test Results from Case 1 Piles

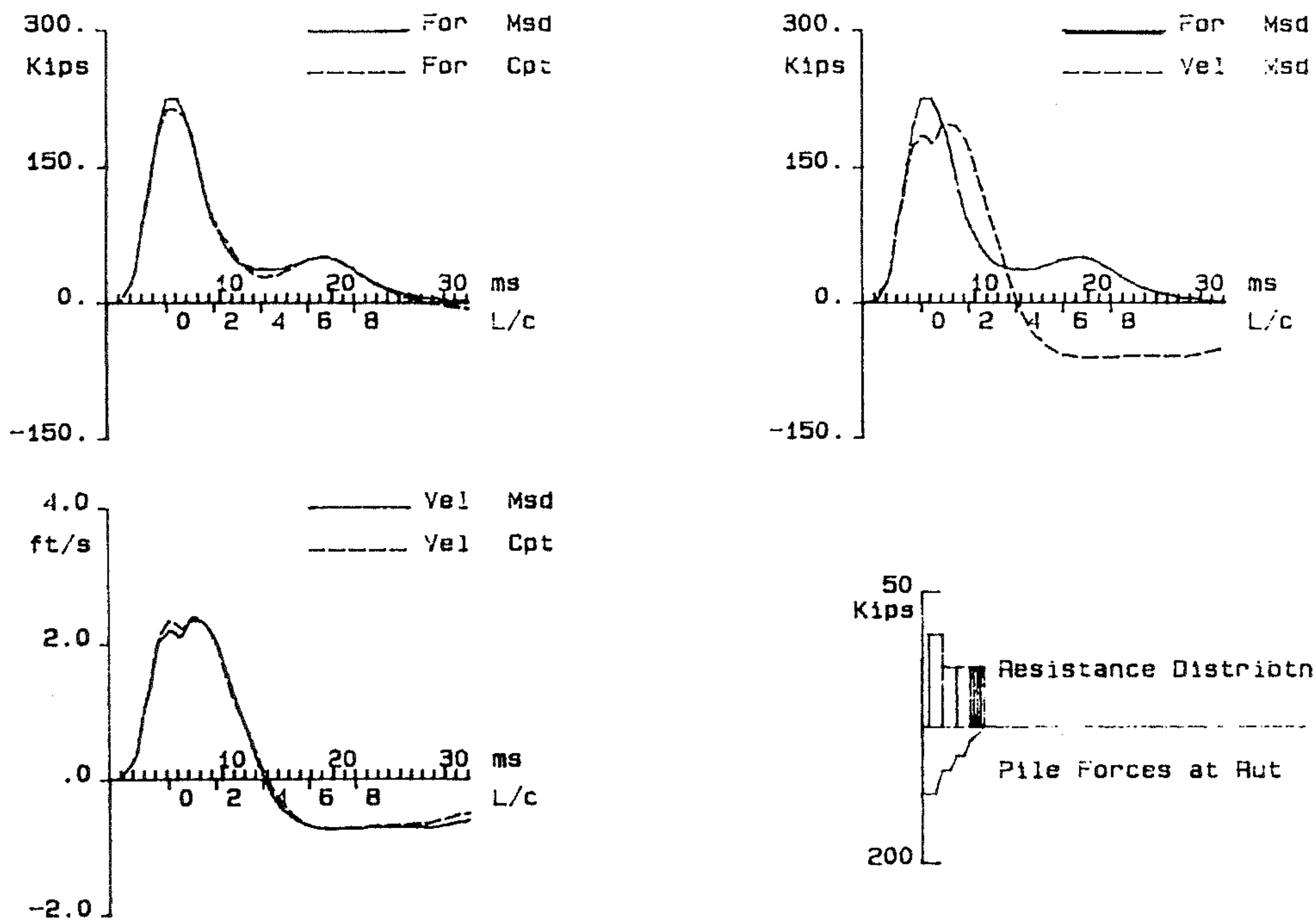


Figure 2.1: CAPWAPC Results for a 16 inch auger pile of 30 ft length

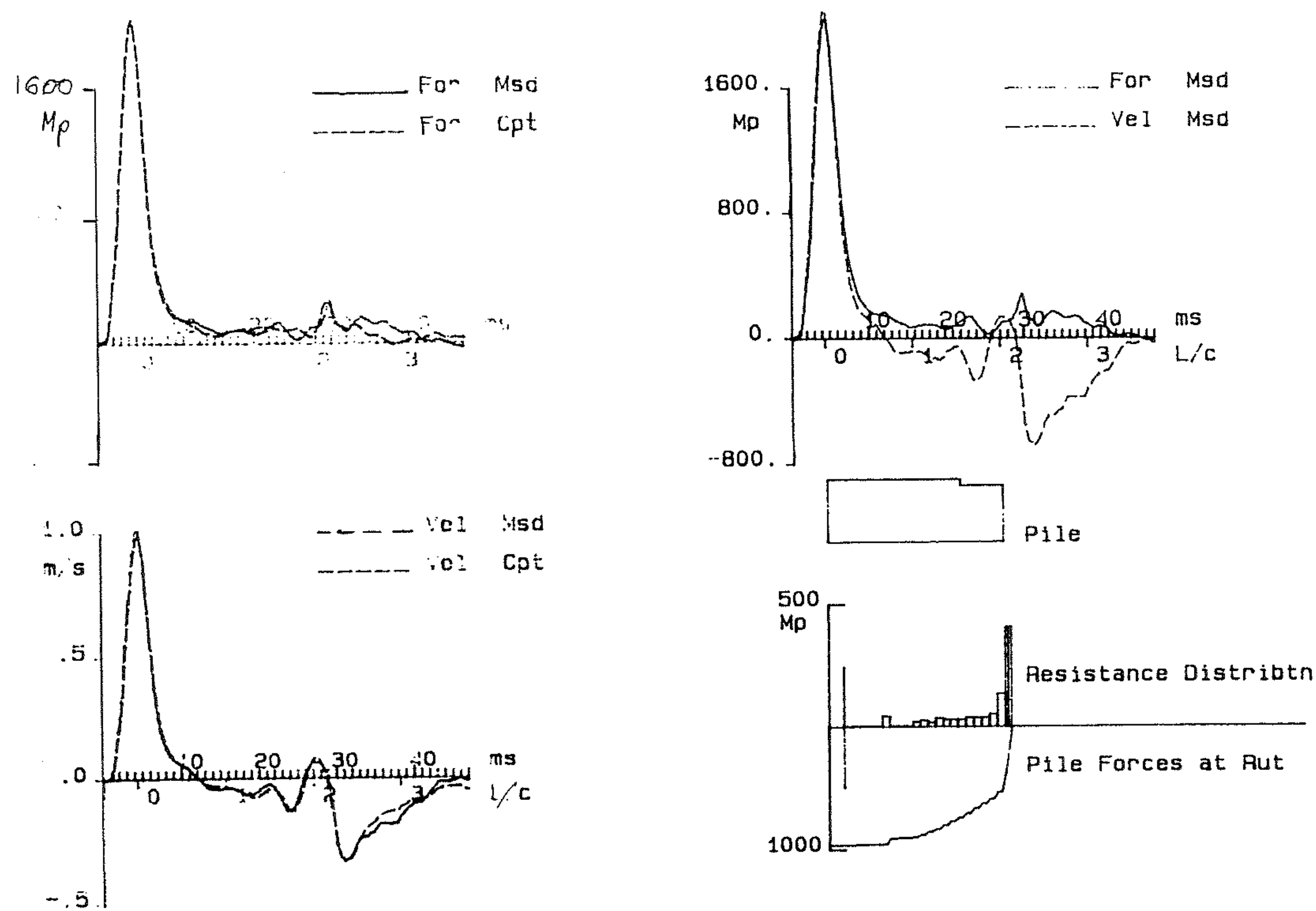


Figure 3.1: CAPWAPC Results for Large Diameter Drilled Shaft with High End Bearing (no Dissipation Damping)

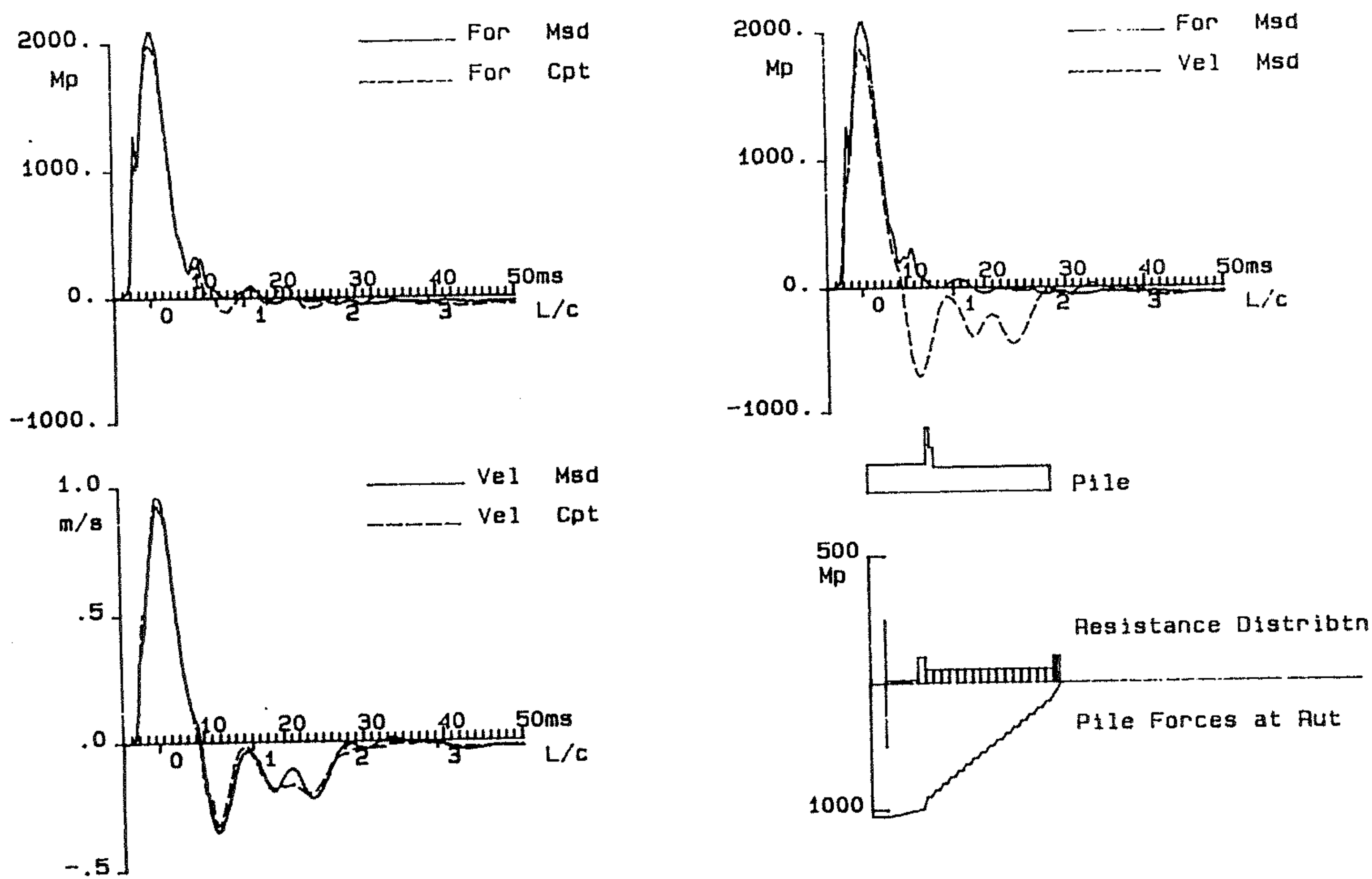


Figure 3.2: CAPWAPC Results for Large Diameter Drilled Shaft with Low End Bearing (No Dissipation Damping)

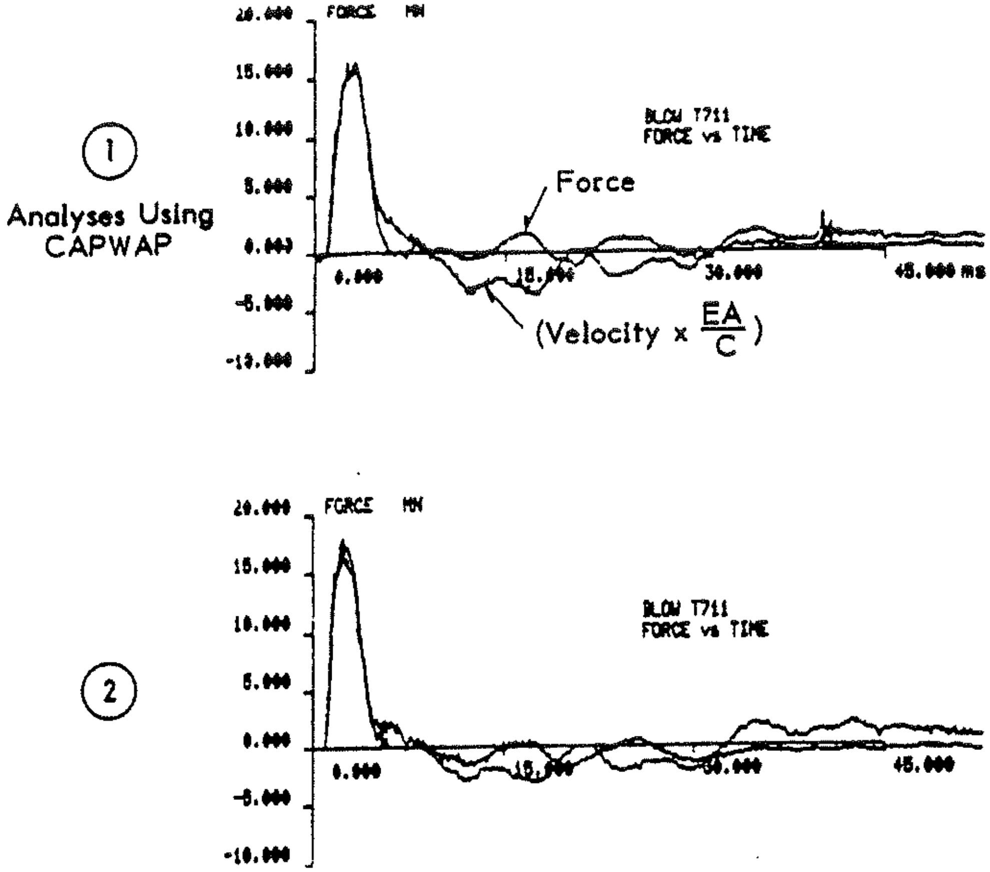


Figure 4.1: Records Obtained from 6.5 ton Ram Impact on
1 m Diameter, Pile Bored

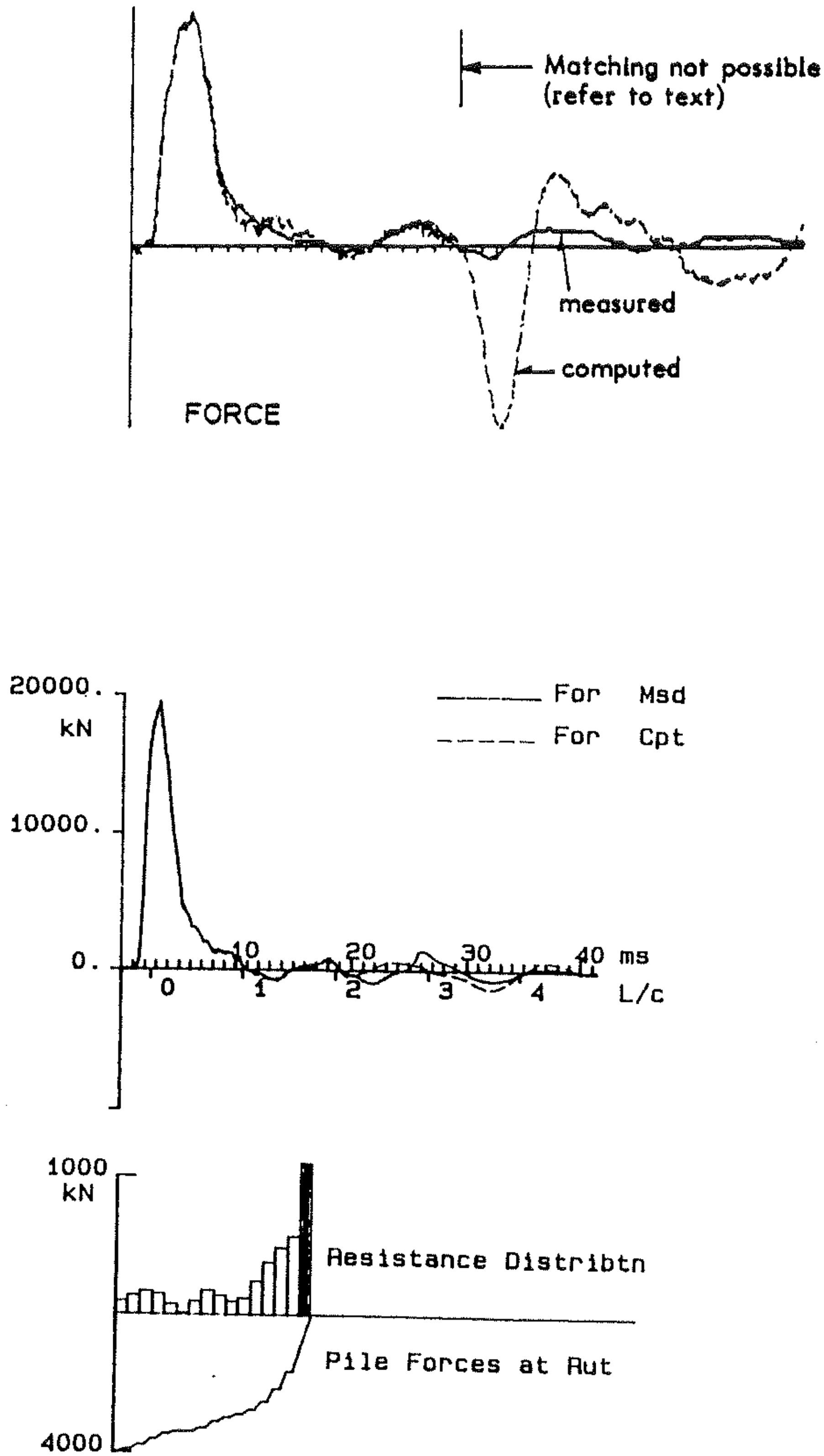


Figure 4.2: CAPWAPC Results, Case 4
Top: Match with High Friction, no Dissipation Damping
Middle: Match with Low Friction (see bottom) and Dissipation Damping

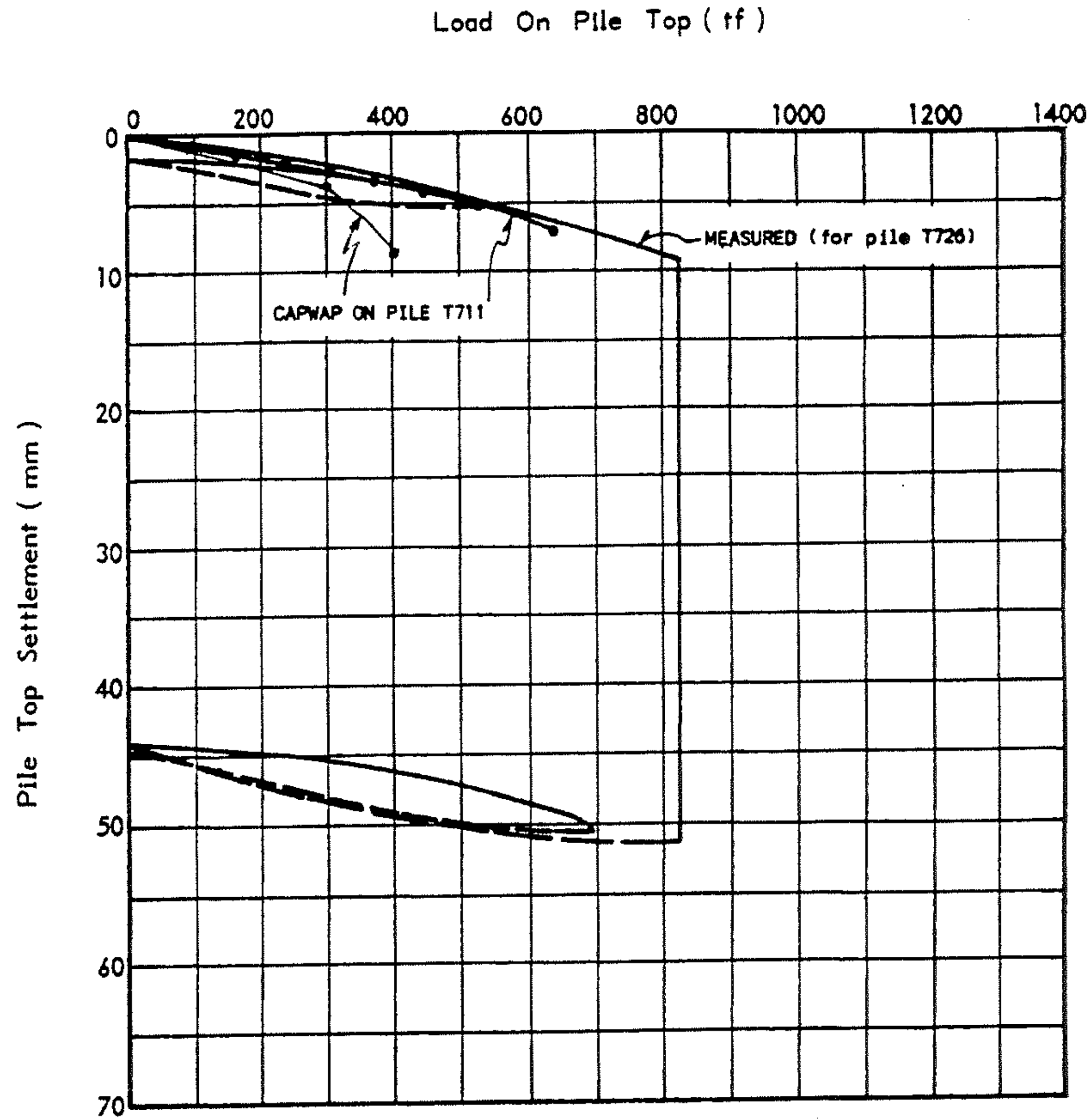


Figure 4.3: Static Results from both CAPWAP analysis and actual test

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