Dynamic pile instrumentation in a calcareous sand close to PCR-2 platform, Brazil

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SUMMARY

In preparation of the PCR 1 platform installations, 60 km north of Fortaleza, Brazil, an extensive test program was conducted in 1981 by Petrobrás. The test pile location was in close proximity to PCR 1 near a single well platform referred to as PCR 2.

The pile was instrumented at some locations with strain gages and accelerometers. In addition, pile top strain and accelerations measurements were taken and field processed by a Pile Driving Analyzer. The dynamic data was recorded on tape and reanalyzed in the laboratory by the CAPWAP method.

Results from measurements are presented and conclusions are drawn as to the hammer performance, the pile structural integrity and the soil driving and set up resistance. Comparisons of computed and measured quantities were made. The calcareous sandy soil exhibited a loss of lateral skin friction during the driving. Furthermore, tensile reflections from a few locations on the pile were interpreted as pile damage.

INTRODUCTION

The pile tested was a 0,86 m diameter open-end pipe. The bottom 50 m had a wall thickness of 0,045 m. All sections above this length had a wall thickness of 0,05 m. It was instrumented along the depth, as shown in figure 1. The length below the top gages varied from 70 m to 137 m during the test.

The reference for all penetrations was 52 m above the mudline. The pile was tested between penetration depth of 56 m and 137 m. A calcareous layer was supposed to exist approximately 25 m below the mudline and approximately 60 m was a coral layer. Other soils were basically calcareous silty sand.

The Vulcan 340 was used to install the test pile. This unit is a single acting air steam hammer and was run on an air compressor source.

TEST PROCEDURE

Besides the instrumentation along the length, two accelerometers and two strain transducers, from Pile Dynamics, were attached to the pile at a distance of approximately 7,5 m from the pile top. The signals were conditioned, amplified and calibrated by a Pile

Driving Analyzer. Further details on instrumentation and interpretative techniques of the data is presented by Goble et alli (1980). Also, the prototype of strain transducers and accelerometers, both based on strain gages, made by IPT, were used to verify its performance, and some results are presented.

Thus, as observed in figure 1, two data aquisition systems were used, one set up by IPT and the other by Pile Dynamics.

RESULTS

Data processing was accomplished by converting the analog tape records to digital form using a 32 K word Varian 72 minicomputer. The laboratory processing was used to produce plots of the measured data, provide Case Method capacity and provide data in digital form for the CAPWAP analysis.

A record of the blow count log with the measured energies determined in the field by the Pile Driving Analyzer is given in figure 2.

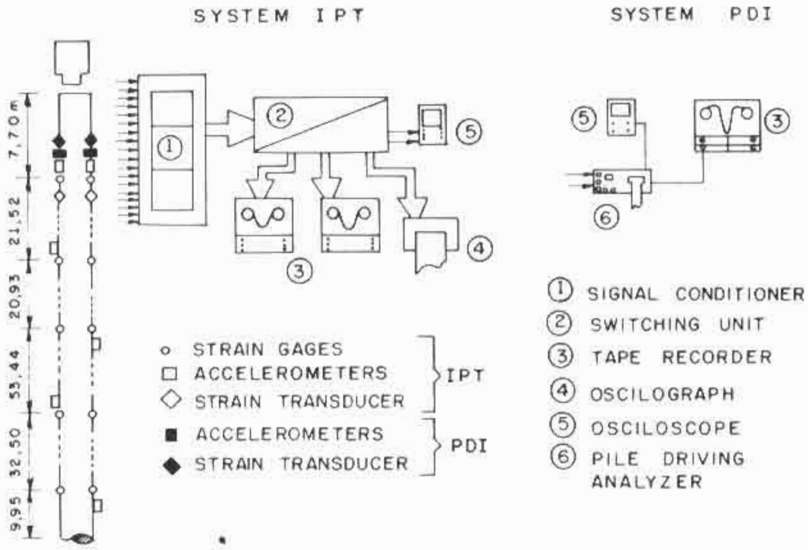
Capacities determined by CAPWAP compare very favorably with capacities determined by the Case Method with a J = 0,4 damping factor. These results are summarized in table 1 and also in figure 2. The highest capacity of 11,5 MN was achieved at the 63 m (fig.2) level below mud line. Typically, capacities were 6,0 MN. Skin friction and bearing capacity are summarized in table 1. Skin damping constants obtained were larger than would usually be assumed for sandy soils. The distribution was not extremely sensitive to the quake values. All further details are in Reference 1.

TABLE 1 - CAPWAP SUMMARY

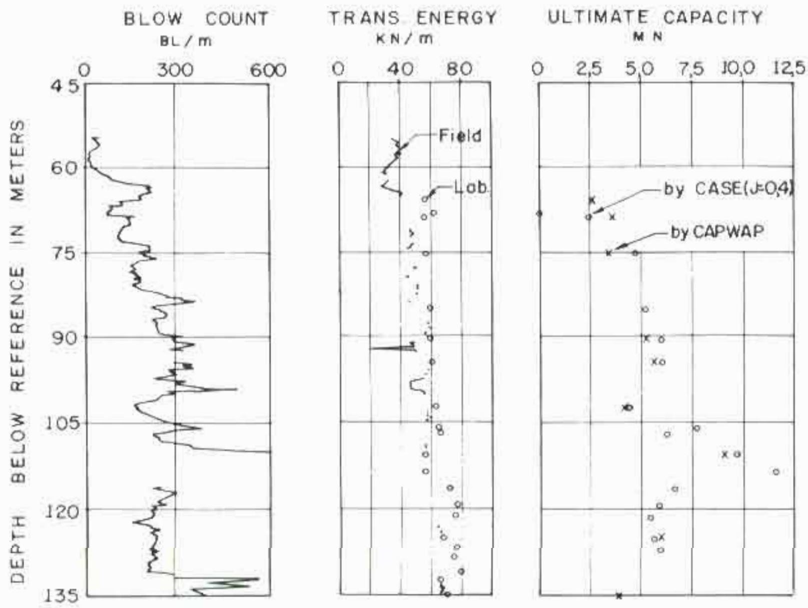
Below Mud Line (m)	Capacity			Damping Case		Quake	
	Skin (MN)	Toe[1] (MN)	Total (MN)	Skin	Toe[1]	Skin (10^{-3}m)	Toe (10^{-3}m)
13,7	1,15	1,47	2,62	0,41	0,06	3,8	3,8
16,8	2,06	1,58	3,64	0,35	0,03	3,8	3,8
23,5	1,76	1,65	3,51	0,55	0,15	3,8	6,3
39,0	2,75	2,47	5,22	0,50	0,15	2,5	2,5
42,8	2,42	3,25	5,67	0,32	0,21	3,5	3,5
50,9	2,83	1,37	4,20	0,47	0,07	2,0	2,0
59,1	1,97	7,14	9,11	0,27	0,75	2,0	1,5
74,1	3,59	2,32	5,91	0,55	0,20	2,5	4,0[3]
83,9	2,85	1,04[2]	3,89	0,69	0,22[2]	2,5	2,5[4]

[1] includes "Pile Toe" plus last two skin frictions
[2] from new pile toe at last undamaged element
[3] reduce stiffness to half at element 65 of 69
[4] extreme damage at and below element 59 (of 69) rendering bottom section useless

cont.



. 1 - DATA ACQUISITION SYSTEMS



. 2 - DRIVING CHARACTERISTICS SUMMARY

cont. Table 1.	SKIN FRICTION LOSS						
Penetration (m)	13,7	16,8	23,5	39,0	42,8	50,9	59,1
Skin friction(MN)	1,15	2,06	1,76	2,75	2,42	2,83	1,97
Trace in Figure 3	1	2	3	4	5	6	7

SOIL BEHAVIOUR DURING THE DRIVING

Using the CAPWAP results, it was possible to draw the unitary skin friction variation during the driving of the pile, as shown in figure 3. This decreasing of the lateral skin friction with the continuous driving was interpreted as a calcareous soil property, explained by cracking of the cemented structure. Further investigations during the installation of the main PCR-1 Platform, 8 months after the test, showed that this type of soil regains this loss of resistance, with a set up factor around 2,5.

PILE INTEGRITY

Although the pile had rather thick wall sections and relatively low stresses (typically 90 MPa or less), pile structural damages were observed during the field monitoring. After the tip had penetrated 82,4 m below mud line, the damages did not grow larger. A crude estimate of 25 m above the tip was given for the major damage location in the field.

Using the plots in figure 4, structural weaknesses were definitely detected in the recording when the tip was at 66,3 m below mud line, at 14 meters above the tip. From the time between impact and damage reflection (relative force decrease and velocity increase) the stiffness reduction location is computed. During the 15 meter span of testing, the time of the damage reflection did not change relative impact, suggesting that "damage" was definitely in the pile section and not a soil effect (such as the coral layer presence).

At 76,9 m below, a second weakness was observed approximately 21 m above the tip. At 82,4 m below mud line, this damage had become essentially complete.

The values for the "pile toe" in table 1 are therefore given from the last undamaged element. It is thought that high toe damping is due to the energy required to cause further distortion of the pile section (bending, buckling or tearing of weld).

MEASURED AND COMPUTED FORCE COMPARISONS

Some measured forces obtained by strain gages located along the length of the pile are presented in figure 5, where the penetration was about 60 m these measured curves were compared force curves by CAPWAP method, after considering soil resistances. As can be seen an excellent agreement was verified.

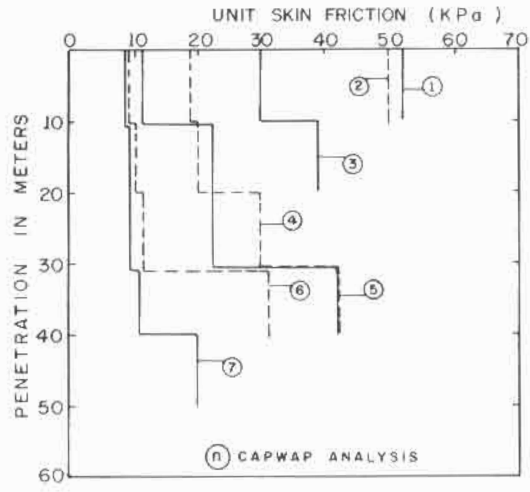


FIG. 3 - SKIN FRICTION COMPUTED DURING DRIVING

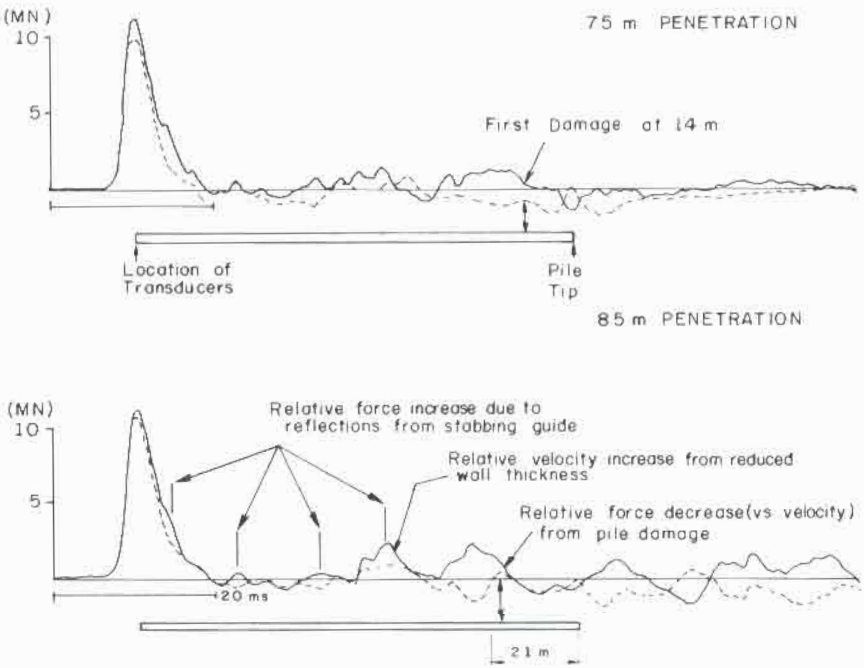


FIG. 4 - DYNAMIC DATA INTERPRETATION

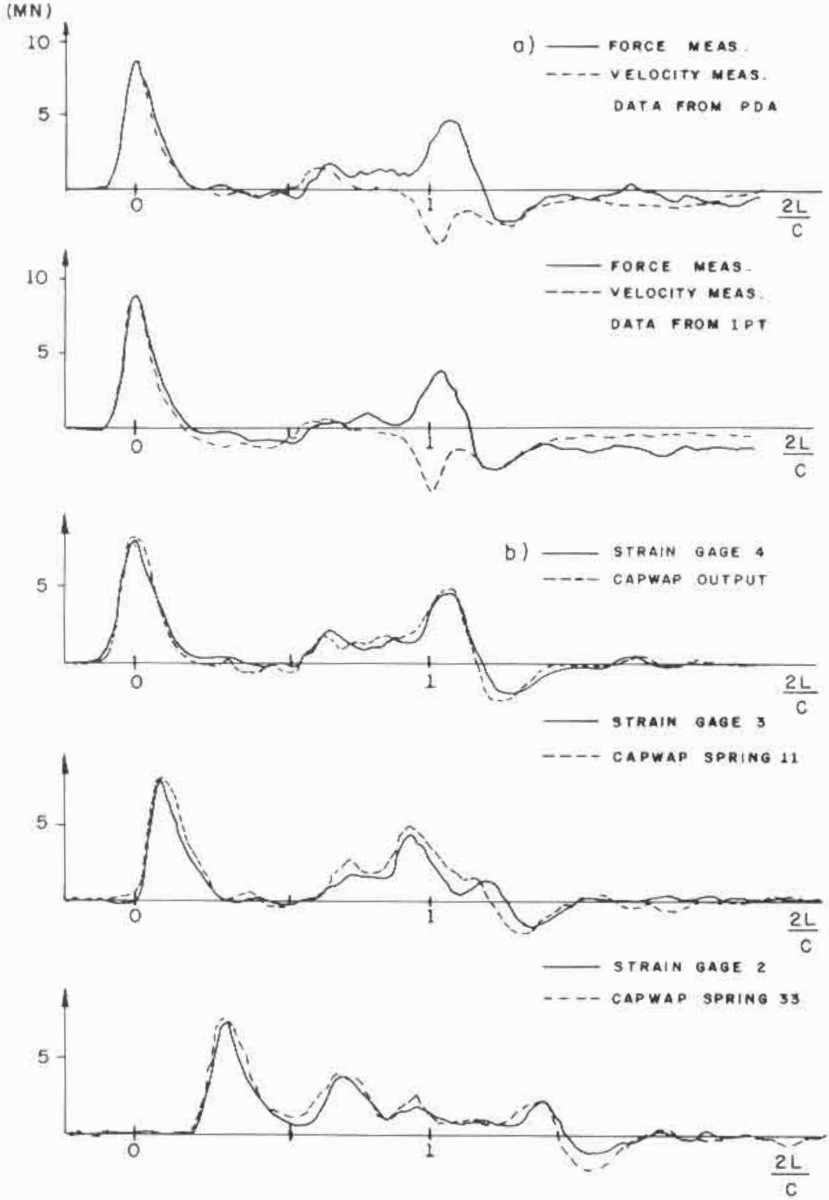


FIG. 5 - DATA COMPARISONS. a) FORCE AND VELOCITY MEASURED BY PDA AND BY IPT. b) MEASURED AND COMPUTED FORCE ALONG THE LENGTH OF THE PILE.

In the upper portion of the same figure the force and velocity measurements obtained at the top of the pile by Pile Dynamic's transducers and by IPT's prototype transducers are presented. Both pairs of curves well resemble each other, suggesting satisfactory performance of prototypes.

CONCLUSIONS

The test performed proved to be of great validity, considering the large amount of information obtained by the instrumentation. This program made it possible to determine soil parameters (using CAPWAP) useful for for further studies (such as driveability analysis by the wave equation).

Although pile stresses were low, major structural damage was observed approximately 21 m above the tip.

Maximum bearing capacity by Case (J=0,4)(11,5MN) was reached, when the high end bearing condition was encountered at 63 m below mudline due to hard coral layer. Skin friction value could not be determined for the lower elevations at final depth due to the damage.

By the CAPWAP analysis it was possible to observe particular behaviour of the calcareous sandy soil,exibiting a loss of lateral skin friction, explained by the cracking of the cemented structure.

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