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 Petrolbras. 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 File Driving Analyzer. The dynamic data was recorded on tape and realigned in the laboratory by the LAMAP 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 0.03 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 50 m above the mudline. The pile was tested between penetration depth of 55 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 wells were basically calcareous and silty sand.

The vibro 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 File 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 are presented by Goble et al. (1982). Also, the prototype of strain transducers and accelerometers, both based on strain gages, made by JMI, were used to verify its performance, and some results are presented.

Thus, as observed in figure 1, two data acquisition systems were used, one set up by JMI and the other by File Dynamics.

RESULTS

Data processing was accomplished by converting the analog tape records to digital form using a 32 k word custom 7090 minicomputer. The laboratory processing was used to produce plots of the measured data, provide least 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 File Driving Analyzer is given in figure 2.

Capacities determined by CAPWAP compare very favorably with capacities determined by the Cape Method with a J = 0.4 damping factor. These results are summarized in Table 1 and also in figure 2. The highest capacity of 11.6 MN was achieved at the 85 m level (fig. 2). Level below mud line, typically, capacities were 6.0 MN. Skin friction and bearing capacity are summarized in Table 1. Skin friction 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

<table>
<thead>
<tr>
<th>Depth Must Line [m]</th>
<th>Capacity</th>
<th>Casing Cap.</th>
<th>Quake Top</th>
<th>% Thr.</th>
</tr>
</thead>
<tbody>
<tr>
<td>53.9</td>
<td>3.59</td>
<td>1.57</td>
<td>0.68</td>
<td>2.5</td>
</tr>
<tr>
<td>59.1</td>
<td>3.33</td>
<td>1.84</td>
<td>0.86</td>
<td>3.8</td>
</tr>
<tr>
<td>64.7</td>
<td>3.09</td>
<td>1.94</td>
<td>0.78</td>
<td>2.0</td>
</tr>
<tr>
<td>69.6</td>
<td>3.02</td>
<td>1.91</td>
<td>0.76</td>
<td>2.9</td>
</tr>
<tr>
<td>74.4</td>
<td>3.01</td>
<td>1.90</td>
<td>0.75</td>
<td>3.0</td>
</tr>
<tr>
<td>79.1</td>
<td>3.00</td>
<td>1.89</td>
<td>0.74</td>
<td>3.1</td>
</tr>
<tr>
<td>83.9</td>
<td>3.00</td>
<td>1.88</td>
<td>0.73</td>
<td>3.2</td>
</tr>
<tr>
<td>88.5</td>
<td>3.00</td>
<td>1.87</td>
<td>0.72</td>
<td>3.3</td>
</tr>
</tbody>
</table>

1. Includes "Pipe Tow" plus last two skin frictions
2. From new pile toe at least underpinning element
3.схна skifness to half an element 85 of 69 rendering bottom section useless.
1. DATA ACQUISITION SYSTEMS

<table>
<thead>
<tr>
<th>BLOW COUNT</th>
<th>TRANS ENERGY</th>
<th>ULTIMATE CAPACITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>N/m</td>
<td>kJ/m²</td>
<td>kN/m</td>
</tr>
<tr>
<td>300</td>
<td>0-30</td>
<td>25-50</td>
</tr>
<tr>
<td>600</td>
<td>40-80</td>
<td>75-125</td>
</tr>
</tbody>
</table>

2. TRAVERSE CHARACTERISTICS OF MARTY

- Three systems were used:
  - Strain gauges
  - Accelerometers
  - Strain transducers
  - Dynamometers

- Data were acquired using an analog tape recorder connected to a computer.

- The results were given in graphs showing blow count, trans energy, and ultimate capacity.

- Strain gauges, accelerometers, and strain transducers were used in the acquisition system.

- The signal conditioner and switching unit were also employed.

- The data in Figure 25 show the energy levels at different depths.

- The blow count varies from 300 to 600, and the trans energy from 0 to 80 kJ/m².

- The ultimate capacity ranges from 25 to 125 kN/m.

- The traverse characteristics of Marty are presented in the graph.
SOIL BEHAVIOR DURING THE DRIVING

Using the DIC data results, it was possible to draw the typical skin friction variation during the driving of the pile, as shown in Figure 3. The decreasing of the lateral skin friction with the continued driving was interpreted as a self-induced soil property, explained by cracking of the cemented structure. Further investigations during the installation of the main PCH-1 platform, a month after the test, showed that this type of soil retains this loss of resistance, with a set-up factor around 70%.

PILE INTEGRITY

Although the pile had rather thick wall sections and relatively low stresses (typically 85 MPa or less), pile structural damages were observed during the final monitoring. After the tip had penetrated 66.3 m below sea line, the damages did not grow larger, a crude estimate at 2/3 above the VB 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 and line-caused meters above the VB. From the time between impact and damage reflection (negative force decreased and velocity increased), the stiffness reduction location is compared. During the 35 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 present).

At 76.8 m below, a second weakness was observed approximately 2/3 above the VB. At 102.4 m below line, this damage then became essentially complete.

The values for the “pile tip” in Table 1 are therefore given from the last damaged element. It is thought that high force damping is due to the energy required to cause further distortion of the pile section (bending, buckling or tearing of walls).

MEASURED AND COMPUTED FORCE COMPARISON

Some measured forces obtained by strain gages located along the length of the pile are presented in Figure 5, where the penetration was about 80 m. These measured curves were compared force curves by FINMAP method, after considering soil resistance. As can be seen an excellent agreement was verified.
Raw the unitary skin pile, as shown to friction with the soil stresses.

Further depth of pile, of soil engaged around 2.5.

The relatively low friction

structural damages

the tip had
did not grow larger,
given for the major

assess were definitely
18,3 m
below
the line between
creep and velocity
computed. During
damage reflection
the "damage" was
beneficial (such as the

and approximately
this damage had

therefore given from
high for damping in
sufficient of the pile

located along the
1, where the
were compared
velocity was
wastage.

UNIT SKIN FRICTION (kPa)

PENETRATION IN METERS

FIG. 1 - SKIN FRICTION INITIAL DEVELOPMENT

75 m PENETRATION

First Damage at 18 m
Location of Transducers

75 m PENETRATION

Effective force change due to reflections from steeling guide

Relative stress increase from reduced

Wave height

Relative stress decrease/gain velocity

from pile damage

H. 1 - SKN FRICTION INITIAL DEVELOPMENT

311
Correlation of force on large diameter

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President, Gobe &

1. INTRODUCTION

The West Gate Freeway in the city’s west, was the city’s next large diameter construction.

When doubts about the strength and stability of the construction were developed, dynamic tests were performed.

A total of twelve piles were tested into basalt. A construction site discussion (on piles) was necessary.

The results from this paper. On prediction and testing at the dynamic site knowledge of both prior to and post construction, discussions on pile design and dynamic.

2. MEASUREMENTS

Testing was performed tops with fall. Pile was subjected to several drop height waves.

Method bearing

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*Quoted from Australian Council
**President, Gobe
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 IIT's prototypes 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 CAVAP) useful for further studies such as drivability 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 Cote (340,411kN) was reached, when the high and 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 CAVAP analysis it was possible to observe particular behaviour of the calcareous sandy soil, exhibiting a loss of lateral skin friction, explained by the cracking of the cemented structure.

ACKNOWLEDGEMENT

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REFERENCES
