Cyclic Pressuremeter Tests Dedicated to Study the Behavior of Piles Under Cyclic Transverse Loads

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Abstract

We propose a cyclic pressuremeter (CPM) test protocol deduced from the reaction of the soil-pile values derived from tests of cyclic transverse loads on pile. The relative displacements issued from CPM tests are compared to the relative displacements of the pile under cyclic transverse loads.

Keywords

Pile • Pressuremeter • Transverse • Cyclic • Load

1 Introduction

For some structures such as onshore and offshore wind turbines and oil platforms, which are supported by piles, cyclic transverse loads are very significant due to the wind and waves. Several previous studies were interested in the action of piles under cyclic transverse loads [1–3]. The pressuremeter is a widely used tool in the prediction of the behavior of a transversely loaded pile in the case of a static load [4–6]. In fact, as an application of a cavity expansion, the pressuremeter test is comparable to the soil-pile reaction under transverse loads. In the present paper, we proposed to use the results of a cyclic pressuremeter (CPM) test program to predict the behavior of a pile subjected to cyclic loading tests. The experimental site is in Plancoët (Côtes-d'Armor, France).

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2 Materials and Methods

The pressuremeter test is an in situ test consisting in the radial expansion of a cylindrical probe on the wall of a borehole. This probe was introduced into the borehole until reaching the desired depth of the test. Then, equal increments of pressure were applied with the control unit, transferred with a tubular system to the probe [7]. For *CPM* tests, the applied pressure was in loops of loading and unloading [8]. The volume variation was measured as an out-put of the test. The used material consisted of a control unit able to control electro valves by means of a computer. The borehole was drilled until 5 m of depth by hand auger and the probe was manually introduced into the soil until the required depth. The CPM tests were stopped when a stabilization of the volume variation was observed.

The CPM test program was adapted to the cyclic loading tests on a pile carried out in Plancoët [9]. The pile subjected to cyclic loading tests was an HEA28A embedded to 6.1 m. The pile was instrumented by 28 couples of strain gauges from which the moment was directly deduced. The main experimental result in this study was the reaction of the soil-pile P. P was obtained by a double differentiation of the recorded moment curve. The maximum and the minimum reactions (P_{max} and P_{min}, respectively) were measured on different depths during the cyclic loads under the maximum and the minimum applied loads (H_{max} and H_{min}, respectively). The pressures applied by the pressuremeter were deduced from the soil reactions P recorded during the first cycle of the loading tests on pile. The pressure of the start of the cyclic load on the CPM, also called average pressure p^*_{av}, at a given depth, was determined as follows.

$$p^*_{av} = \frac{P_{max} + P_{min}}{2 \times B} \quad (1)$$

B is the width of the pile. The pressure of the half-amplitude $p^*_{1/2}$ is given by:

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$$p^*_{1/2} = \frac{\max(|P_{max}|, |P_{min}|)}{B} \quad (2)$$

In order to ensure the contact between the probe and the soil, both p_{aver} and $p_{1/2}$ were increased by the pressure of soil at rest p_0, deduced from static pressuremeter tests. Also, inversed corrections were taken into consideration, like the pressure loss p_{loss} due to the hydraulic system and to the membrane rigidity p_{mr}.

$$p_i = p^*_i + p_{loss} + p_{mr} \quad with \quad i = av, 1/2 \quad (3)$$

The frequencies of the CPM tests and the tests on pile were kept identical. The two CPM test programs, PCCH1 and PCCH2 are related to the average of the results of the pile tests CH1 and CH2 respectively. CH1 is the cyclic loading test with a maximum load of H_{max} = 13.3 kN. This test consisted of three series. The first and the second series are identical, with a number of cycles NC = 1000 (3.9 h). The third one is performed with NC = 10,000 (39 h). CH2 is the cyclic loading test with H_{max} = 20 kN and was conducted twice, identically as NC = 10,000 (39 h). For all the tests, a minimum load H_{min} = 6.7 kN was maintained. Table 1 sums up all undertaken parameters for the CPM tests in Plancoët.

3 Results and Interpretation

The pressure-volume curves represent the evolution of the applied pressure as a function of the observed volume change during the CPM tests (example from the PCCH2 at 2 m of depth in Fig. 1).

The cyclic loads started when the volume was about 70 ml. The accumulation of volume was relatively important in the first cycles (distant loops), when it started to stabilize in the last part of the curve (condensed loops).

Relative displacement from the results of tests performed on pile is defined as the ratio of the displacement during cyclic loads to the first value of the measured displacement derived from the first cycle y_{0i} and from the CPM tests as follows.

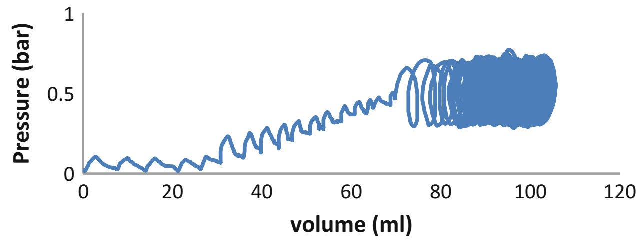

Fig. 1 Pressure-volume curve from PCCH2 at 2 m of depth

$$y^{Pile}_{Re,i} = \frac{y_i}{y_{0i}} i = max, min \quad (4)$$

$$y^{CPM}_{Re} = \frac{\Delta V}{\Delta V_0} \quad (5)$$

ΔV_0 and ΔV are the evolution of the volume measured in the first average pressure and during cyclic pressure, respectively.

Figures 2 and 3 show the results of the relative displacements for CH1 compared to PCCH1, and CH2 compared to PCCH2 at different depths.

At 1 and 2 m of depth, the accumulation of the horizontal displacement for both pile and CPM tests are less than 150%. At 3 and 4 m, the relative displacement is more important. The accumulation of the displacement under minimum loads is more important than the accumulation of the displacement under maximum loads. The area of soil between y_{min} and y_{max} is in fact the most disturbed by the cyclic loadings.

After an important number of cycles, the curves of are included between the curves of and at the first 3 m. CPM test curves and tests on pile curves have the same trend. The CPM test results are able to predict the pile displacements under cyclic loads.

Table 1 Values of CPM tests parameters (Plancoët site)

Depth (m)	PCCH1				PCCH2			
	p_{aver} (kPa)	$p_{1/2}$ (kPa)	Duration (h)	NC	p_{aver} (kPa)	$p_{1/2}$ (kPa)	Duration (h)	NC
1	37.7	13.6	1.27	287	50.5	26.6	0.85	234
2	29	9.4	1.28	332	37.5	20	0.85	220
3	19	5.2	0.93	224	30	12	0.85	225
4	17	5	1.24	317	25	11	0.85	211
5	–	–	–	–	21	10	0.88	207

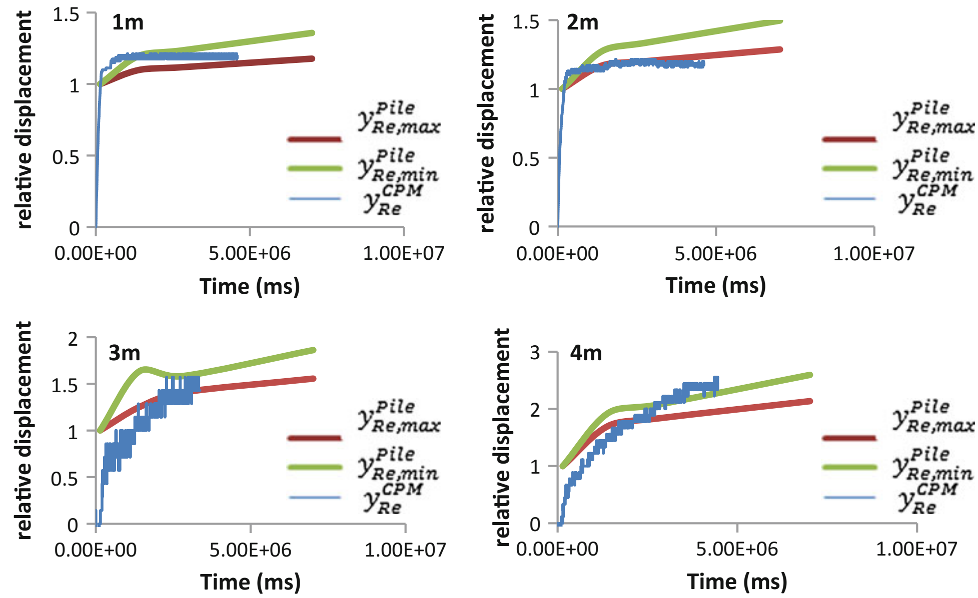

Fig. 2 Comparison of relative displacements for CH1 and PCCH1

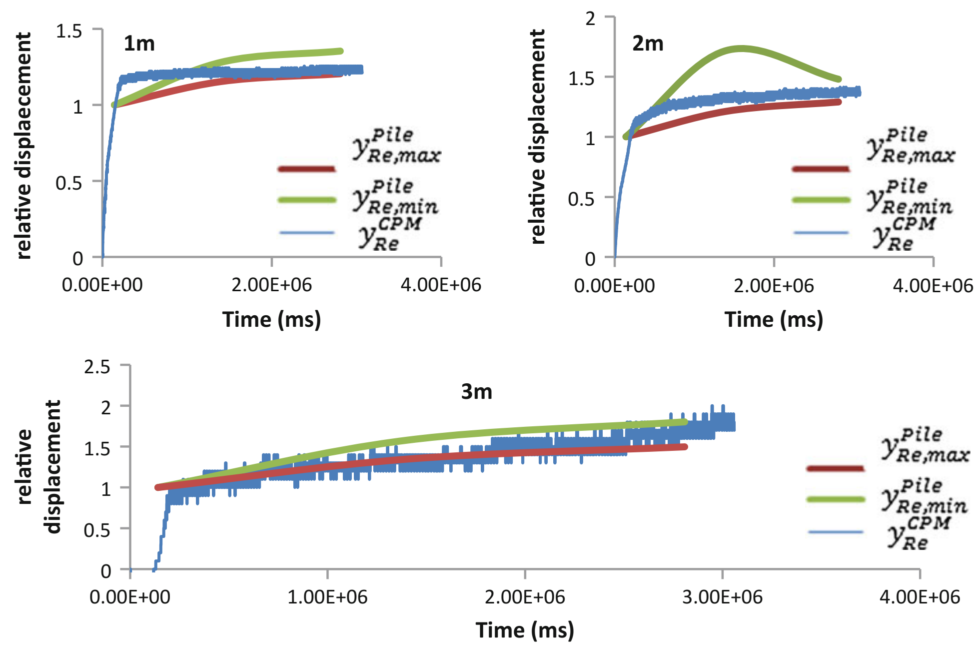

Fig. 3 Comparison of relative displacements for CH2 and PCCH2

4 Conclusion

In this paper, we presented the cyclic loading tests on a pile carried out at the site of Plancoët. Then, CPM test program deduced from the soil-pile reaction, an experimental result from the tests on pile, were developed and exerted on the same experimental site. Afterwards, a relative displacement, derived from CPM tests, was compared to the relative displacement from tests on pile. The results show that CPM tests are able to describe the behavior of the pile under cyclic transverse loads and to predict the horizontal displacement of the pile.

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