View metadata, citation and similar papers at core.ac.uk

brought to you by CORE

provided by Missouri University of Science and Technology (Missouri S&T): Scholars' Mine

Missouri S&T

Missouri University of Science and Technology

Scholars' Mine

International Conferences on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics

1991 - Second International Conference on Recent Advances in Geotechnical Earthquake Engineering & Soil Dynamics

10 Mar 1991, 1:00 pm - 3:00 pm

Validation of a Piles Dynamic Analysis Computer Code Through In Situ Tests

R. Bonaz
Geodynamic et Structures, Paris, France

A. Pecker
Geodynamic et Structures, Paris, France

T. Duroy
Électricité de France, Septen, Villeurbanne, France

M. Ralljaona
Électricité de France, Septen, Villeurbanne, France

J. P. Touret
Électricité de France, Septen, Villeurbanne, France

Follow this and additional works at: https://scholarsmine.mst.edu/icrageesd

Part of the Geotechnical Engineering Commons

Recommended Citation

Bonaz, R.; Pecker, A.; Duroy, T.; Ralljaona, M.; and Touret, J. P., "Validation of a Piles Dynamic Analysis Computer Code Through In Situ Tests" (1991). *International Conferences on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics*. 20.
https://scholarsmine.mst.edu/icrageesd/02icrageesd/session13/20

This Article - Conference proceedings is brought to you for free and open access by Scholars' Mine. It has been accepted for inclusion in International Conferences on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics by an authorized administrator of Scholars' Mine. This work is protected by U. S. Copyright Law. Unauthorized use including reproduction for redistribution requires the permission of the copyright holder. For more information, please contact scholarsmine@mst.edu.

Proceedings: Second International Conference on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics, March 11-15, 1991 St. Louis, Missouri, Paper No. 5.27

Validation of a Piles Dynamic Analysis Computer Code Through In Situ Tests

R. Bonaz and A. Pecker
Geodynamic et Structures, Paris, (France)

T. Duroy, M. Ralijaona, and J. P. Touret
Electricite de France, Septen, Villeurbanne (France)

SUMMARY : In order to qualify the CLAPIFOU code, which computes the dynamic response of a pile foundation subjected to earthquake or harmonic forces, a test campaign was carried out on piles, to full scale, on pile groups of 2 x 1 piles and 2 x 3 piles on the Plancoët site. The purpose of the study is to compare the results of the experiments and the digital simulations with the computer code. The comparison is good but confirms the need for a good knowledge of the soil's characteristics.

I. INTRODUCTION

Since 1975, the EDF has been studying the possibility of using deep foundations for nuclear power plants located in seismic zones. In March 1979, tests, at Nice airport, were carried out on mock-up reactor buildings, whose foundations were on piles, during the dynamic compacting stage of the works-site, using the Ménard method. Not being able to interpret the tests correctly, lacking the appropriate method, the GEFOP (the study group on deep foundations) made up of the main SOIL Mechanics engineering company,of universities, and the EDF-SEPTEN, was set up at this time. A code was written to analyse the dynamic response of foundations on piles. The Ecole Centrale de Paris was the kingpin of this project.

Lead by D. AUBRY, 3 theories were produced, resulting in the writing of a code to calculate the dynamic response of foundations on piles.

The problem is to evaluate the effects of the soil-structure interaction , that is, to calculate the dynamic impedance matrix of the building-soil-pile(s) system.

We can use several different methods to solve this problem, from analytical methods, which are interesting because they take into account the non-linear nature of the soil around the pile (but not the dynamic group effect), to finite element methods but which are heavy and difficult to use because they need direct time history response calculations.

Integral equations are the most up-to-date method and are interesting as they account for the group effect and particularly, the wave diffraction effect between the piles and the different soil layers. Moreover, they limit the cost of calculation. This is the method that was chosen for the CLAPIFOU code.

II. PRESENTATION OF THE CLAPIFOU CODE

The function of the CLAPIFOU (Continuum Linear Analysis of Pile Foundations) code is to analyse the stationary wave response of a foundation on a group of piles. The code was written at the Ecole Centrale de Paris by D. AUBRY, F. CHAPEL, J.M. CREPEL and C.C. TSAKALIDIS, and is now maintained by the engineering company COYNE ET BELLIER. The code is made up of three parts DOS2M, DOSPX, DOSWAVE.

Three important assumptions help to simplify the problem:

- the materials comply with the laws on linear behaviour and so allow the use of sub-structuring methods;

- taking the stationary state as read, we can work in the frequency domain by applying the Fourier transform.

- the piles are sufficiently slender to be able to use beam kinematics in calculating stresses and displacements.

The originality of the CLAPIFOU code lies in the joint use of the finite element method and integral equations.

At the present time, the code is limited to the case of a rigid foundation, above the ground, lying on verticle piles of the same length, with either moving or fixed heads, in a horizontally stratified medium. It was ratified during its creation by comparing it to solutions of an analytical type or to solutions obtained using provisional finite element calculations (KAUSEL). Nevertheless, experimental proof always being necessary, it was decided, having attempted the experiment in the laboratory on a small scale model in a hydraulic gradient tank, to test the code at full scale.

III. DESCRIPTION OF TESTS CARRIED OUT ON THE PLANCOET SITE

To validate the code, a series of dynamic tests were carried out on the PLANCOET site in August 1987, on a group of two piles and a group of six piles in collaboration with the regional laboratory of the Highways department (Ponts et chaussées) in St Brieuc (cf figure 1). Metallic profile piles HEA280, 6.5metres long were used, joined rigidly at the top. They had been hammered into place in soft silt formations.

Taking into account the low mechanical characteristics of these formations, increased amplitude tests were carried out so as to establish the linear field of the response of each group of piles. Moreover, the frequency field explored was limited to between 1 and 60 Hz, which made it possible, in addition to covering the habitual range of seismic frequencies, to show the radiative damping.

Accelerometers were placed along the entire length of the piles to be measured. Each accelerometer was attached to the pile's core by means of a magnetic plate.

The tests were conducted in the following way:

A dynamic excitation was applied using a CMB hydraulic jack, developping a stress factor of ± 20,000 N for a length of ±15mm. Several generators and conditioners were used to control this stimulation.

After setting to the stimulation frequency, the force amplitude was increased to the required displacement value and then measurements were taken; two other tests with increasing amplitude were then carried out. Thus the whole field of frequencies was scanned beginning with the highest frequency (60Hz). All the measurements were then processed using the Fourier transform in such a way as to determine the stimulation band relative to the stimulation frequency on each spectrum. The amplitudes were obtained by double integration in the frequency domain Phase measurement, which is useful not only to evaluate the damping but also to trace the immediate distortion of the piles, is done using a FFT analyser, which gives the complex transfer function (amplitude and phase) between the two concerned variables(force and displacement at level 0.00 of the pile).

IV. TEST RESULTS

So as to limit the number of curves, only the results relative to the highest displacement amplitude are given, taking into account the ratified linearisation of the pile groups. From the different curves obtained (temporal signals, Fourier spectra, transfer functions), it was possible to establish the maximum deformation for each frequency, the phase distribution and the immediate distortion (the pole's fixed position at any given time) and the impedance matrix coefficients.

IV.1 Behaviour of the two-pile group

The examination of the piles' deformations in figure 2 firstly shows that displacement occurs at a depth of between 0 m and 1.5m. and that the part above the ground remains rigid and the piles distort in the same way It can be seen from the evolution of the phase, and on the immediate deformation drawings, that the group of piles behave in a quasi static way up to 10 Hz. At this frequency , the head becomes out of phase with the rest of the pile. Examination of the impedance curves (figure 3) shows that the translational or rotational impedances are practically constant in the 0 to 40 frequency band .

IV.2 Behaviour of the six-pile group

From measurements taken from several piles in the group, it can be seen from the deformations (figure 4) that most of the displacement occurs above a depth of 1.5m, as in the previous case. The six piles move in synchronisation with the same amplitude,. the part above the ground behaving like a rigid block.

The group's behaviour is quasi static up to about 10 Hz. It is at this frequency that the first alteration appears, then a second from 25 Hz and a third at 60 Hz. The phase increase at ground level is shown by a radiative damping. Unlike the two-pile group, the translational impedance after a minimum of 10 Hz greatly increases, up to 30 Hz (figure 5), whereas the rotational impedance stays relatively constant in the 0 to 40 Hz frequency range

The comparison between the six-pile and two-pile groups' impedances shows that the group effect is very important. For example at 3 Hz the ratio between the impedance of the six-pile group and the two-pile group is only 1.4.

V. TEST SIMULATIONS USING CLAPIFOU

The mechanical characteristics of the ground were determined from laboratory tests carried out on samples taken from near the two pile groups. These tests on resonant column allowed us to determine Young's dynamic modulus and the internal damping of the material. The characteristics obtained for the 5 levels in question, are given in the following table.

depth	ρ (kg/m^3)	E (N/m^2)	ν	η
0 to 1 m	1,840	3.57E7	0.49	0.15
1 to 1.5	1,850	4.50E7	0.49	0.02
1.5 /3.5	1,830	5.40E7	0.49	0.08
3.5 /5.5	1,740	6.20E7	0.49	0.06
5.5 /6.5	1,770	9.20E7	0.49	0.05

V. 1 How the calculations were obtained

The CLAPIFOU code is made up of several modules DOS2M, DOSPX and DOSWAVE. Only the first two modules were used.

- The DOSWAVE module calculates the incident wave field (P, SH, SV) compatible to the stratified medium constituting the ground foundation, when an earthquake spreads in a half space from infinity.

- The DOS2M module calculates the necessary GREEN functions to construct the soil flexibility matrix at the level of the piles. The GREEN functions show the ground's displacements ,following the 5 degrees of freedom, caused by force or moment units created by a given source of excitation

The ground is modeled by viscoelastic layers with the mechanical properties (ρ,E,ν,β=2η). The piles are divided into regular units corresponding to a fraction of the thickness of the layers. The sources are of the cylindrical surface type.

Using a FOURIER transform, the GREEN functions are calculated in the frequency domain, and then we return to the cartesian domain using a HANKEL transformation.

The method developped in DOS2M is a method of integral equations as this does not necessitate a complete meshing of the ground field and the field of displacement is made clear in the form of an integral.

- Using the results obtained, the DOSPX module determines the complex displacement of the foundation and of the piles from the resolution of the linear system. It contains a code of finite beam elements for the piles, and a code to solve problems of the GAUSS-SEIDEL type in blocks.The representative blocks used, for the soil-pile-foundation interaction, are the results of DOS2M.

In the calculations, the piles are split into elements of 0.50m.The part above ground is modeled as a rigid foundation, which simultaneously undergoes a horizontal force and an overturning moment due to the leverage existing between the point of application of the force and the surface of the ground.

V.2 Examination of the results

The maximum immediate distortion curves and the evolution of phase with depth, compared to the results of the tests, are shown on figure 6. For the two-pile group, there was a good correlation between the maximum deformation calculated and the measured results. There was almost a perfect correlation at 20 Hz, below this frequency, the simulated amplitudes are lower than those measured. The calculated phase is very low for low frequencies (3 and 5 Hz) and the deviation becomes greater with depth in relation to the measured phases.

The quasi static domain spreads to about 20 Hz, the amplitude of the bulge of the immediate deformation being clearly lower than that which was measured. The examination of the impedances shows a large difference between the simulated values and the measured values particularly for the real parts. The experimental system seems more flexible. This deviation can be explained by not taking into account the crossed terms in the evaluation of the experimental impedances, because if we look at the error made by not regarding these terms in the calculation, we find about the same error of deviation.

The group effect is particularly apparent in rotation, because if the impedance of the group is compared to twice the single pile impedance, we find 1 in horizontal translation and about 1.3 in rotation.

The comparison of impedances (cf figure 7) shows a good correlation between the real and imaginary parts of the measured and calculated impedances.

VI CONCLUSION

In the case of the two-pile group,the comparison between the results of computation and those of experimentation at Plancoët is globally satisfying;the only restriction concerns the simulation of the phase for which we have no explanation.
In the case of the six-pile group,the comparison is not yet terminated;as a matter of fact,the first results obtained whith the knewn characteristics of the soil are not conclusive,so a little sensibility study has been realized to appreciate the influence of the Young's shear moduli of the different soil layers.Thus,it has been shown that a difference of 20% concerning the first soil's layer could generate an increase or a decrease of the displacements of about 30%(the variation of the phase being opposite).But it is well known how difficult it is to determine the value of the shear modulus of the first layers(by in situ or laboratory tests);so,a complementary in situ tests campaign (cross-hole and vibrating plate) has been engaged in order to determine precisely the dynamic characteristics of the ground.
Computer codes ,as CLAPIFOU ,now reach high degree of sophistication and it becomes necessary to develop new techniques of in situ or laboratory measurements of the mechanical characteristics of soils.

REFERENCES

/1/ AUBRY D. et al - DOS2M/DOSPX - Diffraction d'ondes sismiques en milieu multicouche- Diffraction d'ondes sur les pieux.
Chatenay-Malabry,Laboratoire de Mécanique des Sols - Structures de l'Ecole Centrale des Arts et Manufactures - Novembre 1985.

/2/ BONAZ R. et PECKER A - Essais dynamiques sur groupes de pieux.
Plancoët - Août 1987 - Note n°1 - Décembre 1987

/3/ RALIJAONA M. - Etude des fondations sur pieux soumises à des actions dynamiques à l'aide du logiciel CLAPIFOU.
T.F.E. de l'ENTPE - Juin 1988..

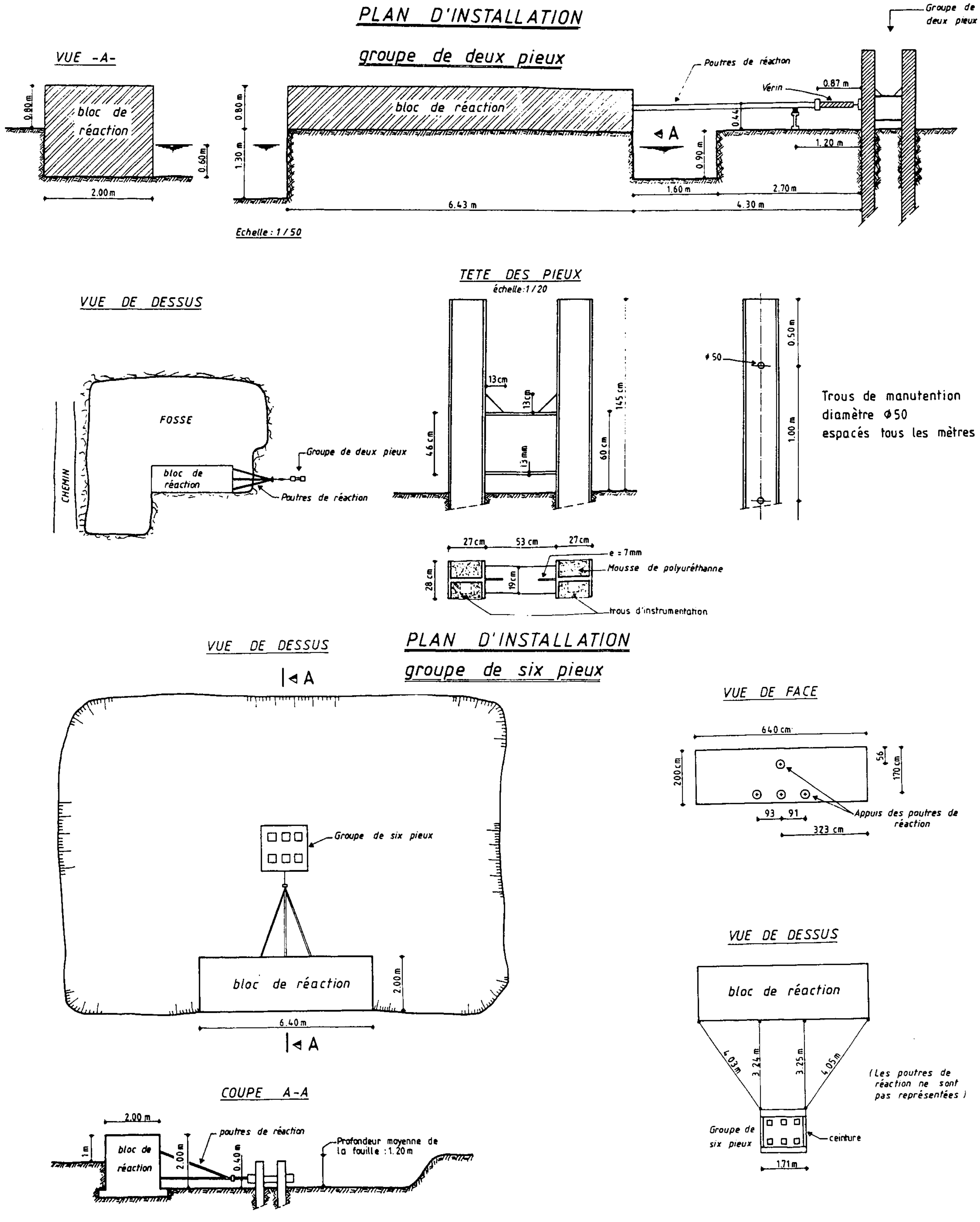
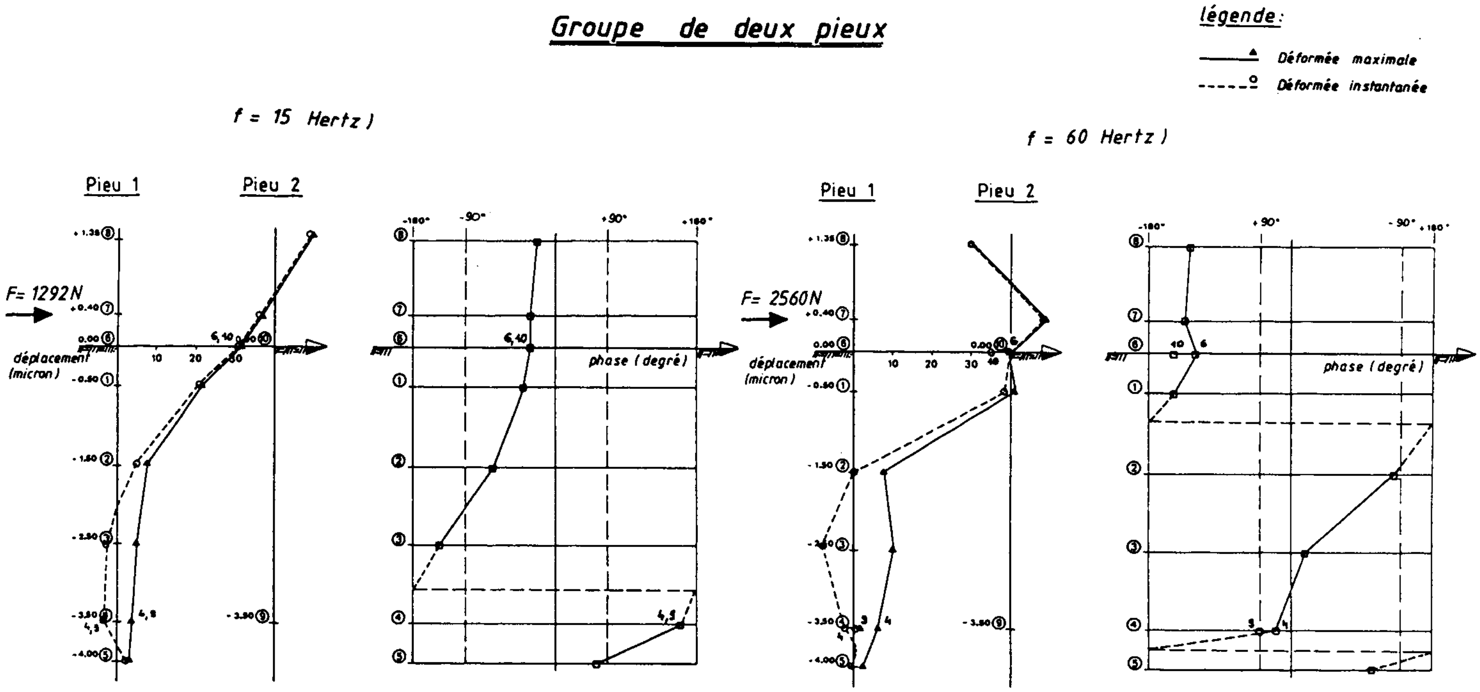


fig 1 : implantation plan



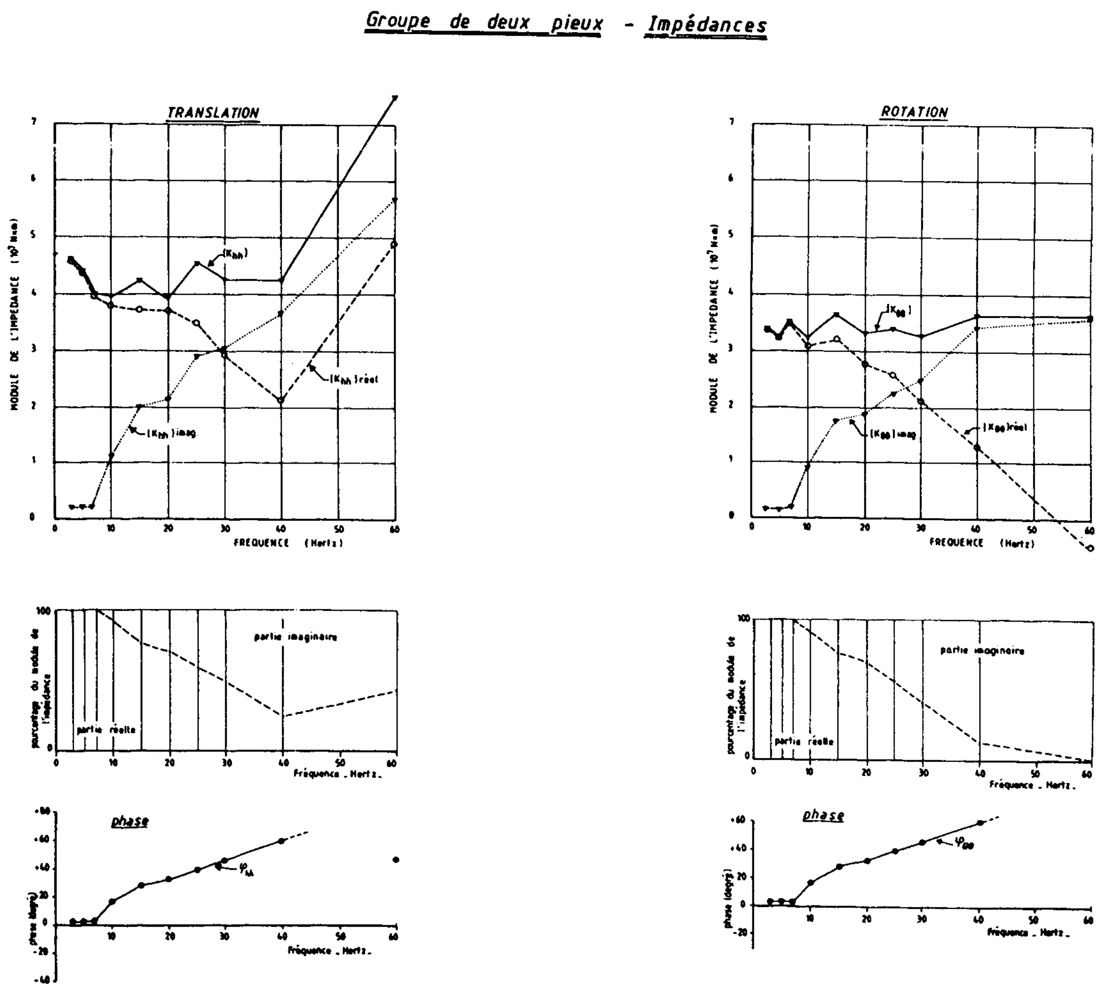
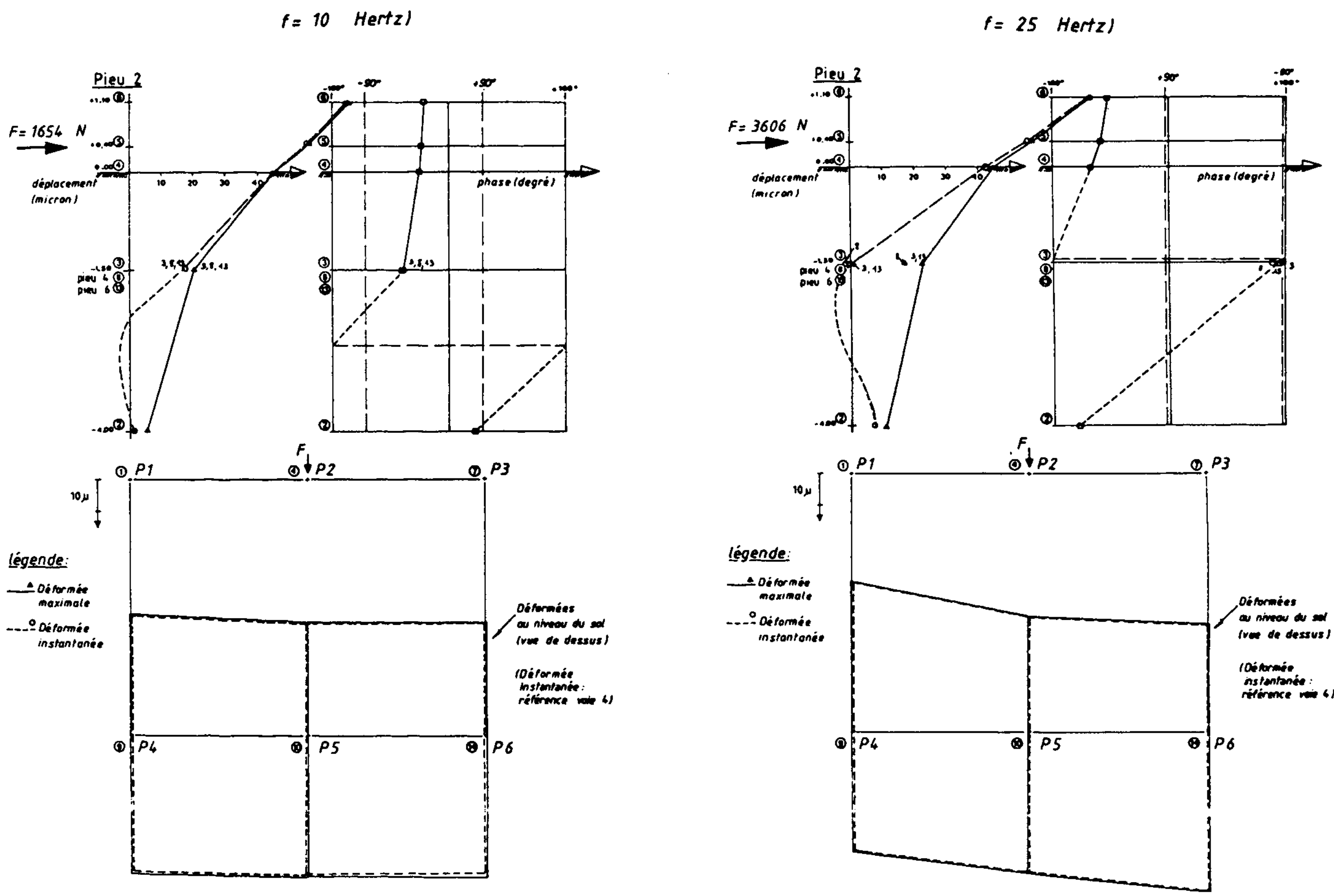


fig 2 and fig 3 : test results of the two-pile group

Groupe de six pieux



Groupe de six pieux - Impédances

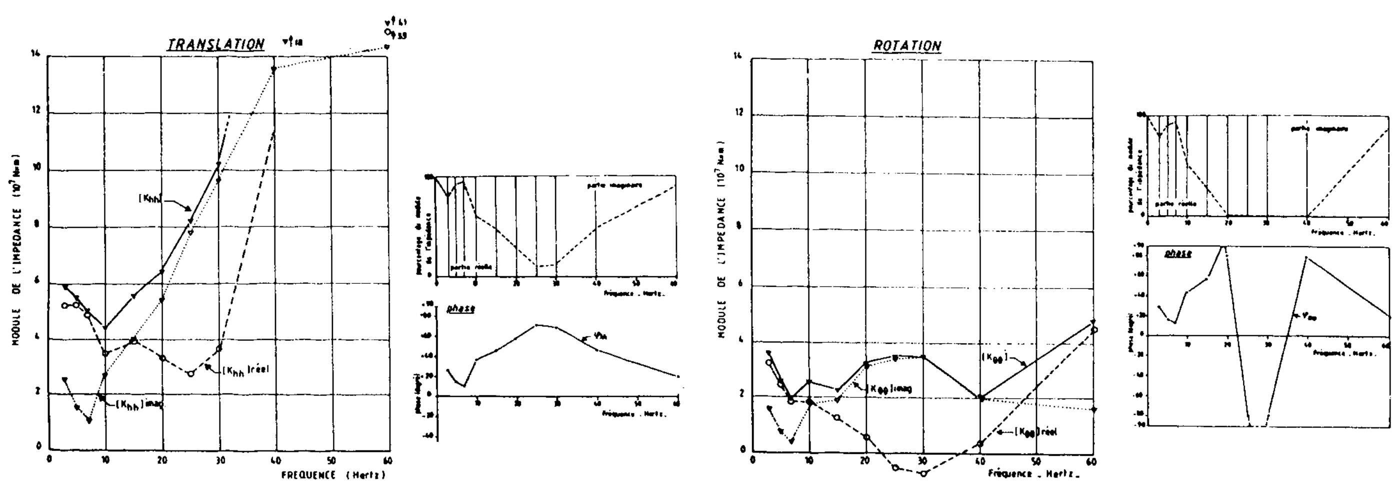


fig 4 and fig 5 : test results of the six-pile group

Groupe de deux pieux

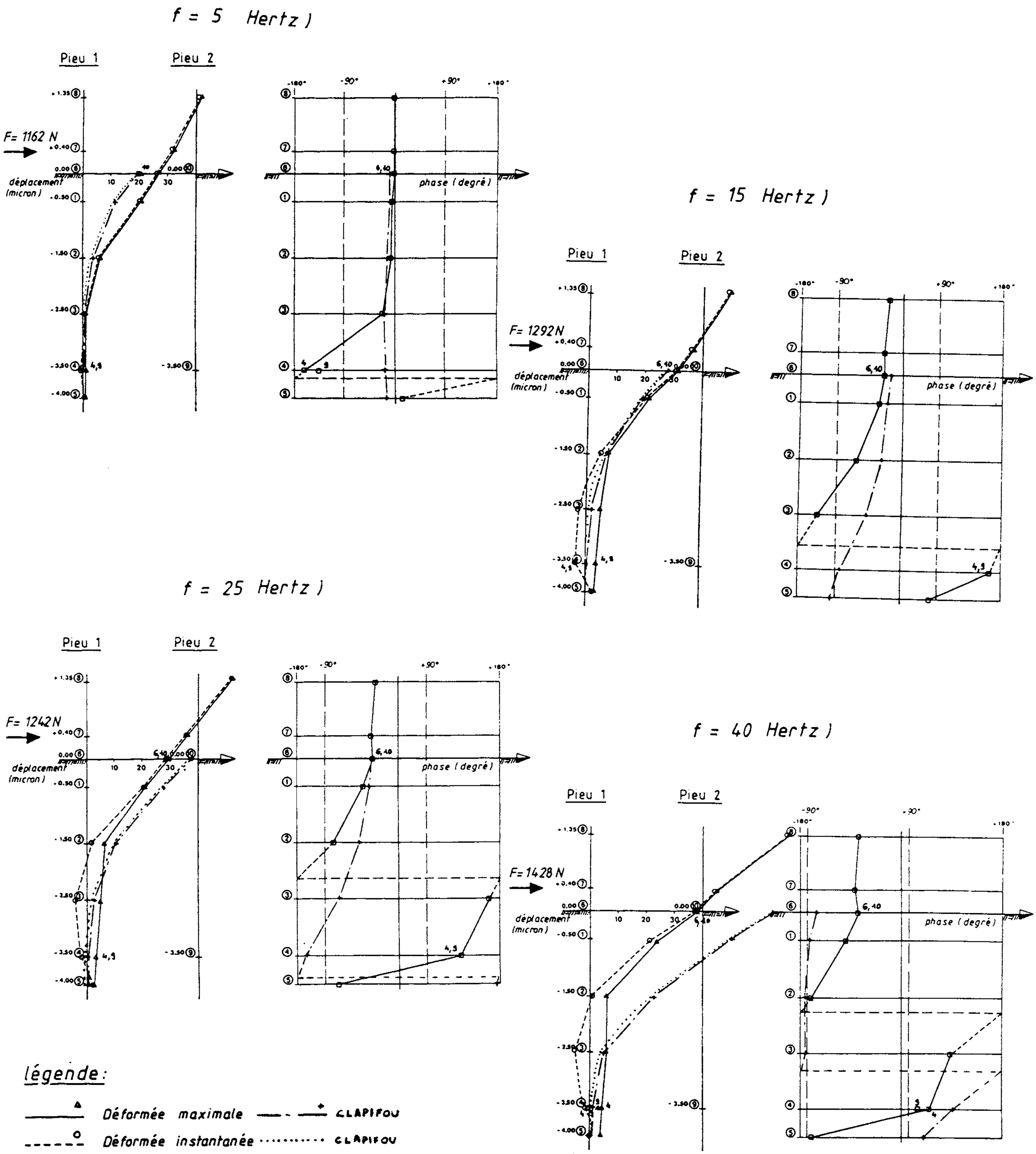


fig 6 : comparison with CLAPIFOU

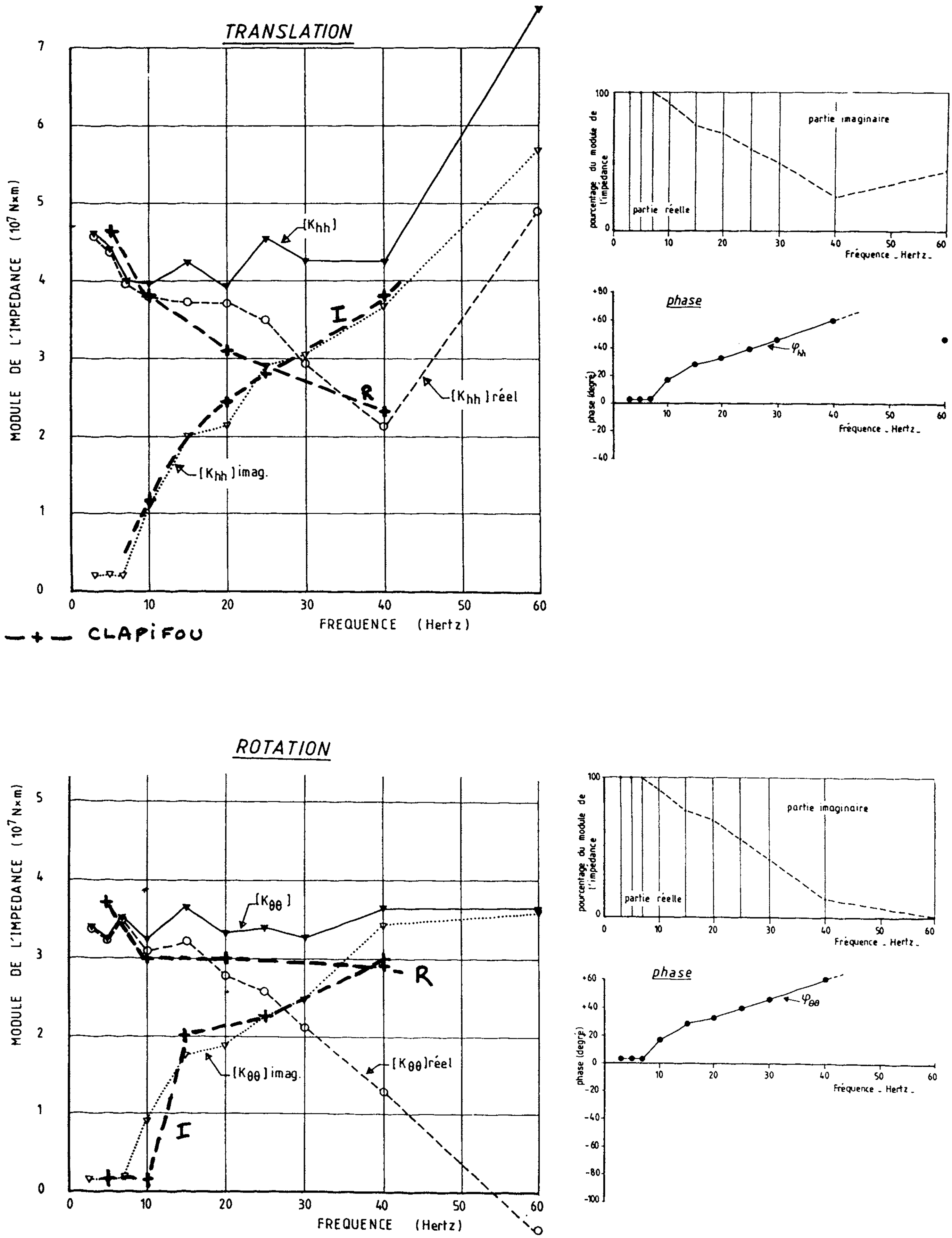


fig 7 : comparison with CLAPIFOU