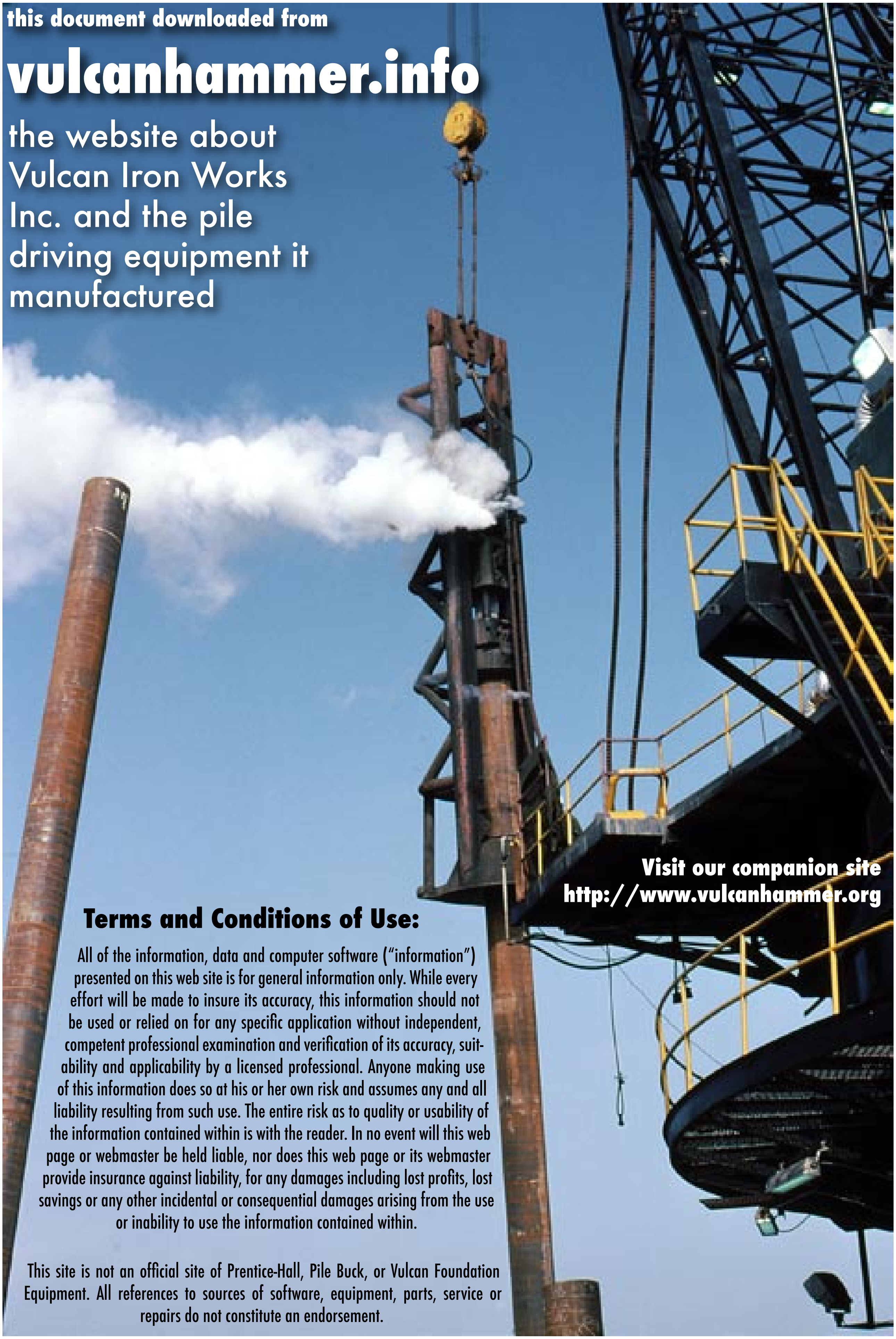

PARAMETERS FOR FRICTION PILES IN MARINE SOILS

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INTRODUCTION

The aim of this paper is to show how self-boring pressuremeter parameters can be used to predict the load-displacement curves of friction piles, by means of simple numerical analyses : either by load-transfer functions analysis (section I) or by finite element analysis assuming a linear elastic behaviour for the soil mass (section II).

In section III, the results of such theoretical analyses are compared with the experimental results of full-scale pulling out tests performed on two tubular piles driven in marine soils.

I. Bases of load-transfer function analyses

The basic principle of this approach is to consider that the mobilization of shaft friction on an axially loaded pile is a local phenomenon, i.e. the unit friction, f, at a given level, is function *only* of the vertical displacement, v, of the pile at this level. This assumption, initially proposed by CAMBEFORT (1964), was shown to be a good approximation by finite element analyses (FRANK, 1974). Subsequent work (see references in BAGUELIN, FRANK, 1980) allowed to determine the shaft friction curve as follows (Fig. 1) :

- if G_o is the initial tangent modulus of the shear curve (τ, γ) of a soil element, then the initial slope of the shaft friction curve (f, $\frac{v}{r_o}$) is G_o/k. The coefficient k depends mainly on the length/diameter ratio ($l/2\ r_o$) of the pile, and is given by charts (ORSI, 1978) or by the approxi-

Such a determination requires to know the shear curve (τ, γ) at various levels. The self-boring pressuremeter, called PAF (an acronym for Pressiomètre Autoforeur), can provide routinely such curves, which are derived from the expansion curves (see BAGUELIN, JEZEQUEL, SHIELDS, 1978). However, these curves correspond to an horizontal loading, while the shaft friction involves a vertical shearing. The approximation, which will be made using the shear curve (τ, γ) as obtained from PAF-tests, is expected to be a good one as long as the soil is not too much anisotropic.

The shaft friction curves having been determined at every level in this way, the overall response of the pile in a tension loading can be derived ; it can also be done for a compression loading if the tip response can be determined, or, in certain cases, neglected. The derivation is obtained by considering the equilibrium of a shaft element, and its axial deformation (Fig. 2), which yields two equations :

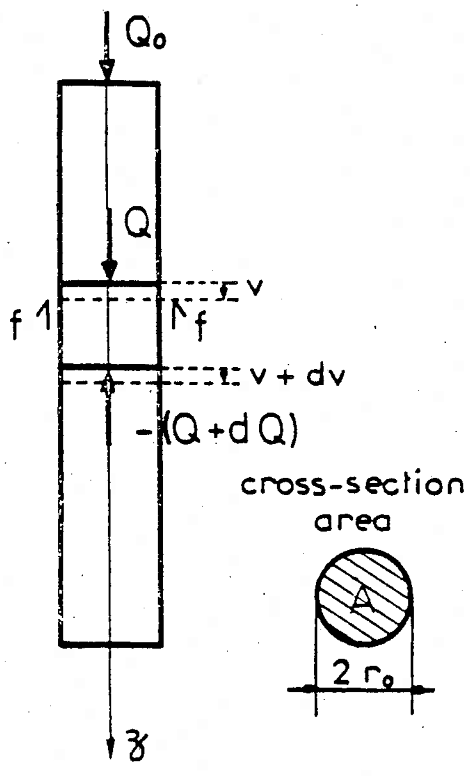

Figure 2 - Equilibrium and deformation of a shaft element of pile under axial load.

$$dQ = -2\pi r_o \, f.dz \qquad (1)$$

$$\frac{dv}{dz} = -\frac{Q}{EA} \qquad (2)$$

Combining these equations, a second order differential is obtained :

$$EA \frac{d^2v}{dz^2} - 2\pi r_o \, f(v) = 0 \qquad (3)$$

Each contact element includes one node of the soil and one node of the pile and is given an area of influence. Initially, the two nodes are linked together by two very stiff springs, one acting normally to the contact surface, the second one acting tangentially to this surface.

When the normal force at the nodes is a tension whose value exceeds the tensile strength multiplied by the influence area, the stiffness of the two springs are set to zero, and the two nodes move away independently.

If this is not the case, the tangential force is then checked against the shear strength multiplied by the influence area. If this strength is exceeded, the tangentially acting spring is removed and the two nodes can slide along the contact surface, with total forces set to the maximum value (sliding with friction).

It can be noticed that the plasticity criteria at the contact are used in terms of forces, and not in terms of stresses. Since our finite element model : ROSALIE (GUELLEC, HUMBERT, RICARD, 1976) is of displacement type, this approach is expected to give a better accuracy.

The use of a simple elastic behaviour in the soil mass for practical applications has been justified by comparative analyses in elastic and elasto-plastic soils, both including contact elements (BARBAS, FRANK, 1981).

An example is given in Fig. 3 for a pile 6 m long, $r_o = 0.30$ m, loaded incrementally in compression until full mobilization of the shaft friction and beginning of the punching at the tip. Fig. 4 shows the load-settlement curves at the pile head (total load, Q_t, and shaft friction, Q_s) for 2 cases of soil behaviour : purely elastic and elasto-plastic. In both cases, the shear strength at pile-soil contact corresponds to $\phi_c = 25°$, $c_c = 0$. It can be seen that the two sets of curves are practically identical. These analyses were not intended to take into account the full punching at the pile tip, a phenomenon which requires clearly an elasto-plastic behaviour of the soil near the tip, but also a large displacement modelization.

Such theoretical examples have clearly shown that it was far more important to modelize correctly the soil-pile contact than to in-

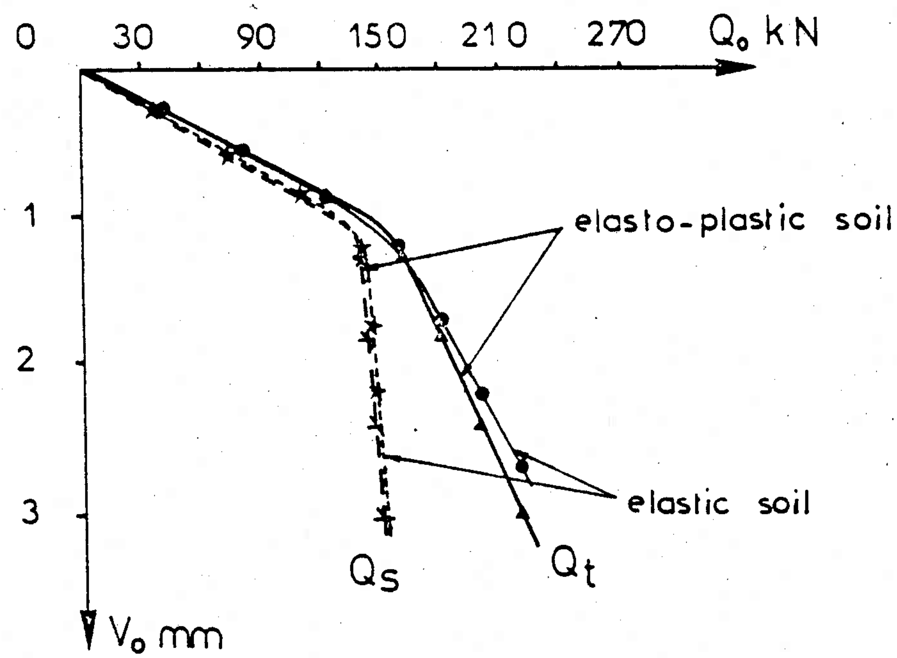

Figure 4 – Total load Q_t and shaft friction load Q_s settlement curves for an elastic soil and an elasto-plastic soil (BARBAS, FRANK, 1981).

clude plasticity in the soil mass, with regard to the shaft friction mobilization.

III. Application to full-scale loading tests

Two full-scale static pulling out tests were carried out at two sites : CRAN and PLANCOET. They were part of a more comprehensive program run by the Saint-Brieuc LPC for the Institut Français du Pétrole (IFP) and including cyclic tests (see PUECH, JEZEQUEL, 1980 and a separate paper by PUECH, BOULON and MEIMON at this conference). The test data are first described, then the application of the two types of analysis (load-transfer function and finite element), and finally the experimental and theoretical results are compared and discussed.

3.1. Test data

The CRAN site consists of about 18 m of alluvial fine deposits of marine origin with the following layers and average geotechnical pa-

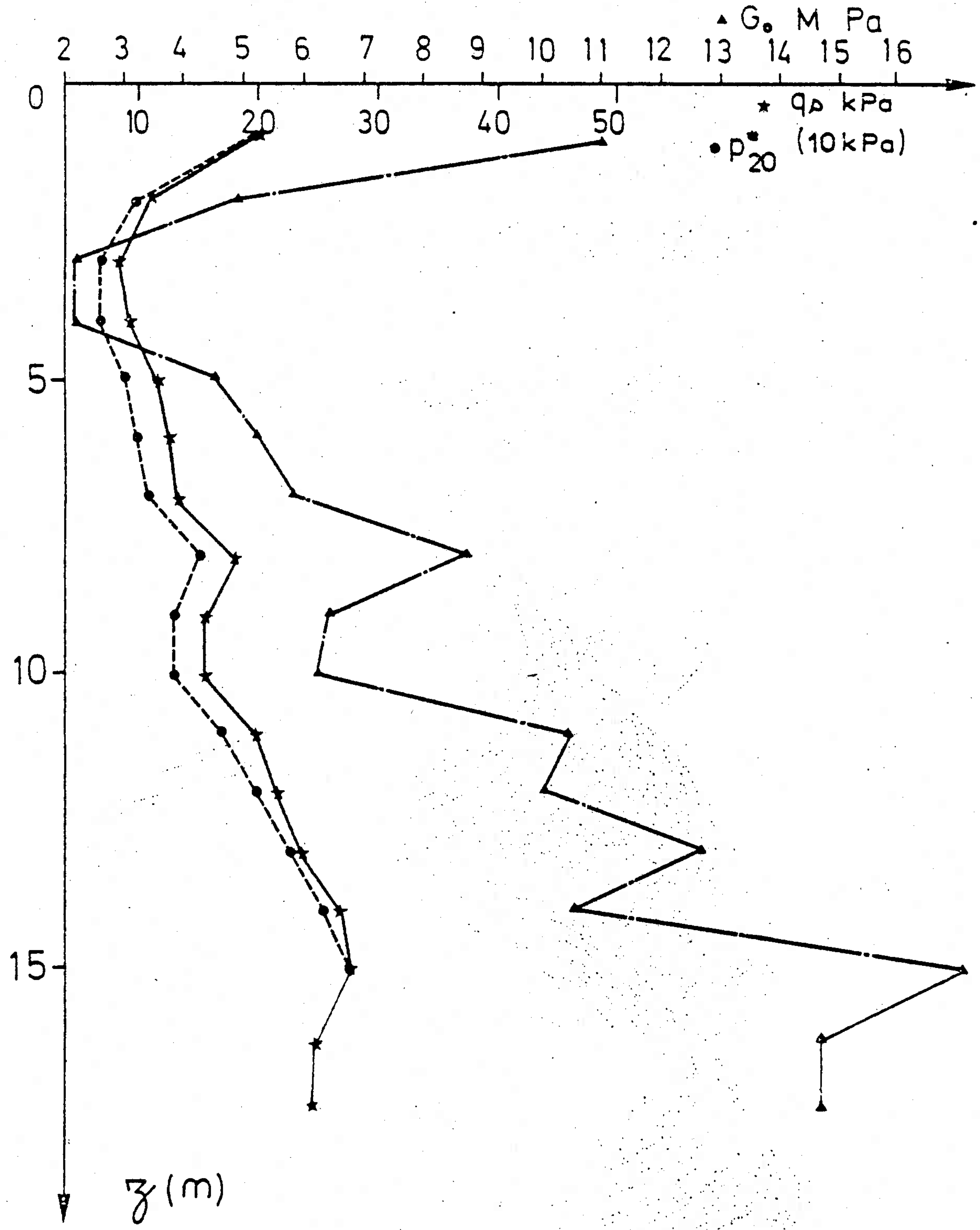

Figure 5 - Self-boring parameters p^*_{20} and G_o and maximum unit friction q_s for CRAN site.

3.2. Application of the two types of analyses

For both types of analyses (load-transfer function and finite element), the values of the maximum unit shaft friction, q_s, must be determined at each level. Standard pressuremeter rules (BAGUELIN, JEZEQUEL, SHIELDS, 1978) were used as illustrated in Fig. 7, with p_1^* equal to p_{20}^*, a correlation which is valid for these types of soils. The q_s profiles thus obtained are given in Fig. 5 and 6.

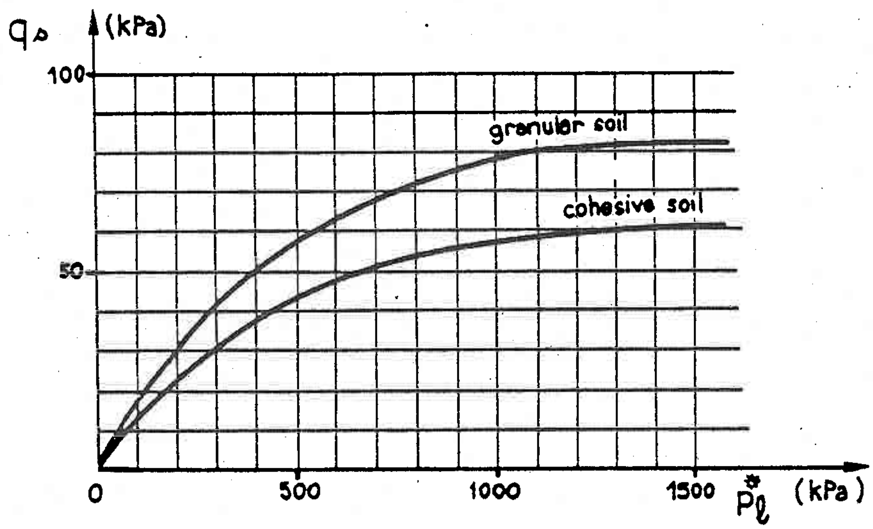

Figure 7 - Maximum unit friction q_s as a function of the net limit pressure p_1 for displacement steel piles (BAGUELIN, JEZEQUEL, SHIELDS, 1978).

For the load-transfer function analysis, the value of k for each pile is determined with $\nu = 0.5$ with ORSI's chart :

CRAN	$1/2\ r_o = 62$	$k = 4.9$
PLANCOET	$1/2\ r_o = 48$	$k = 4.6$

The influence of the non linear part of the shear curves on the shaft friction curves was found to be negligible for the 2 sites, as illustrated in Fig. 8 at 3.0 m depth on the PLANCOET site.

For the finite element analyses, horizontal soil layers, generally 2 m thick along the piles, were considered with elastic parameters : $\nu = 0.48$ and $E = 2(1+\nu)G_o \simeq 3\ G_o$, with G_o from Fig. 5 and 6.

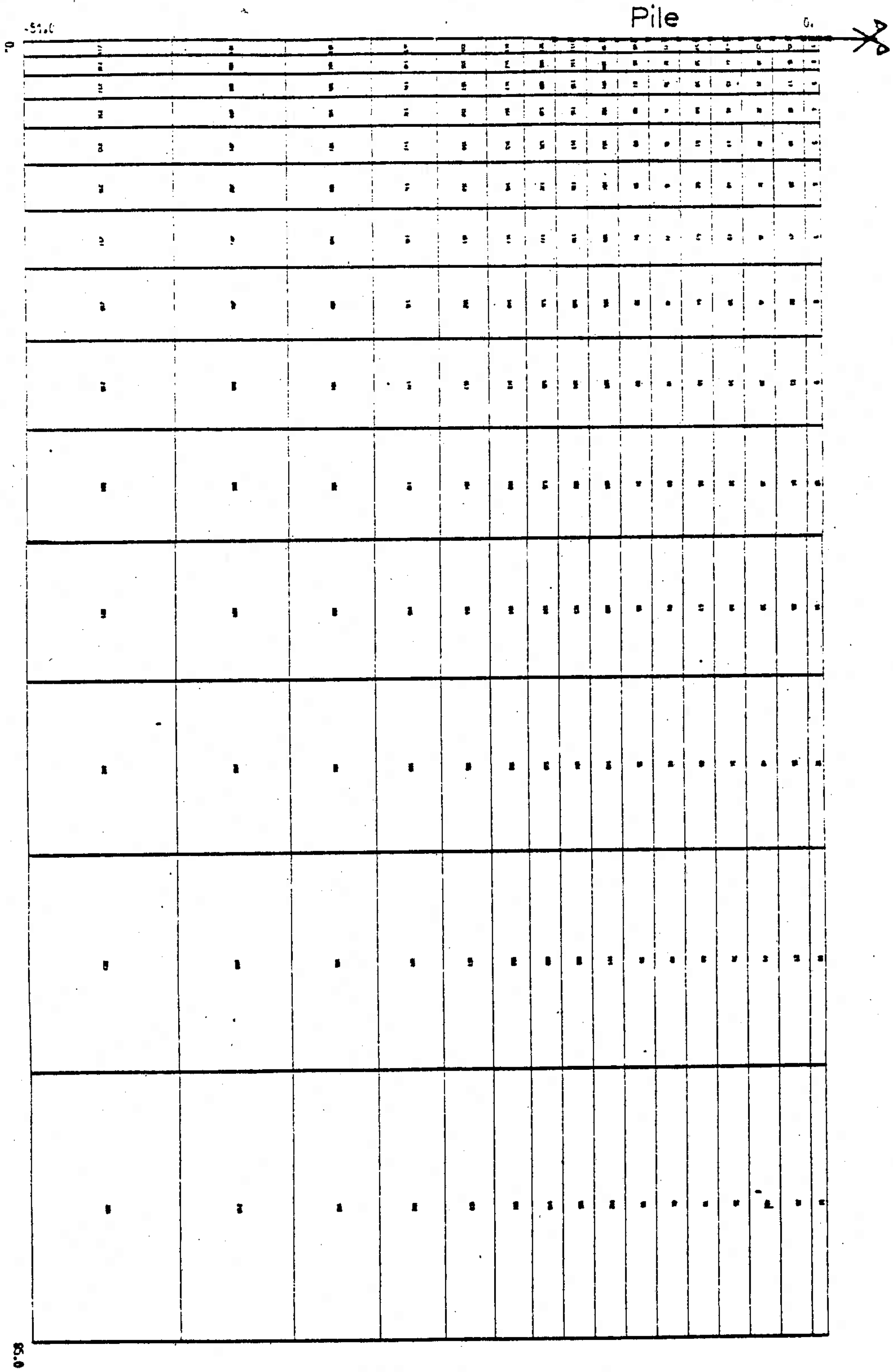

Figure 9 - Finite element mesh used in the case of the analysis of CRAN pile.

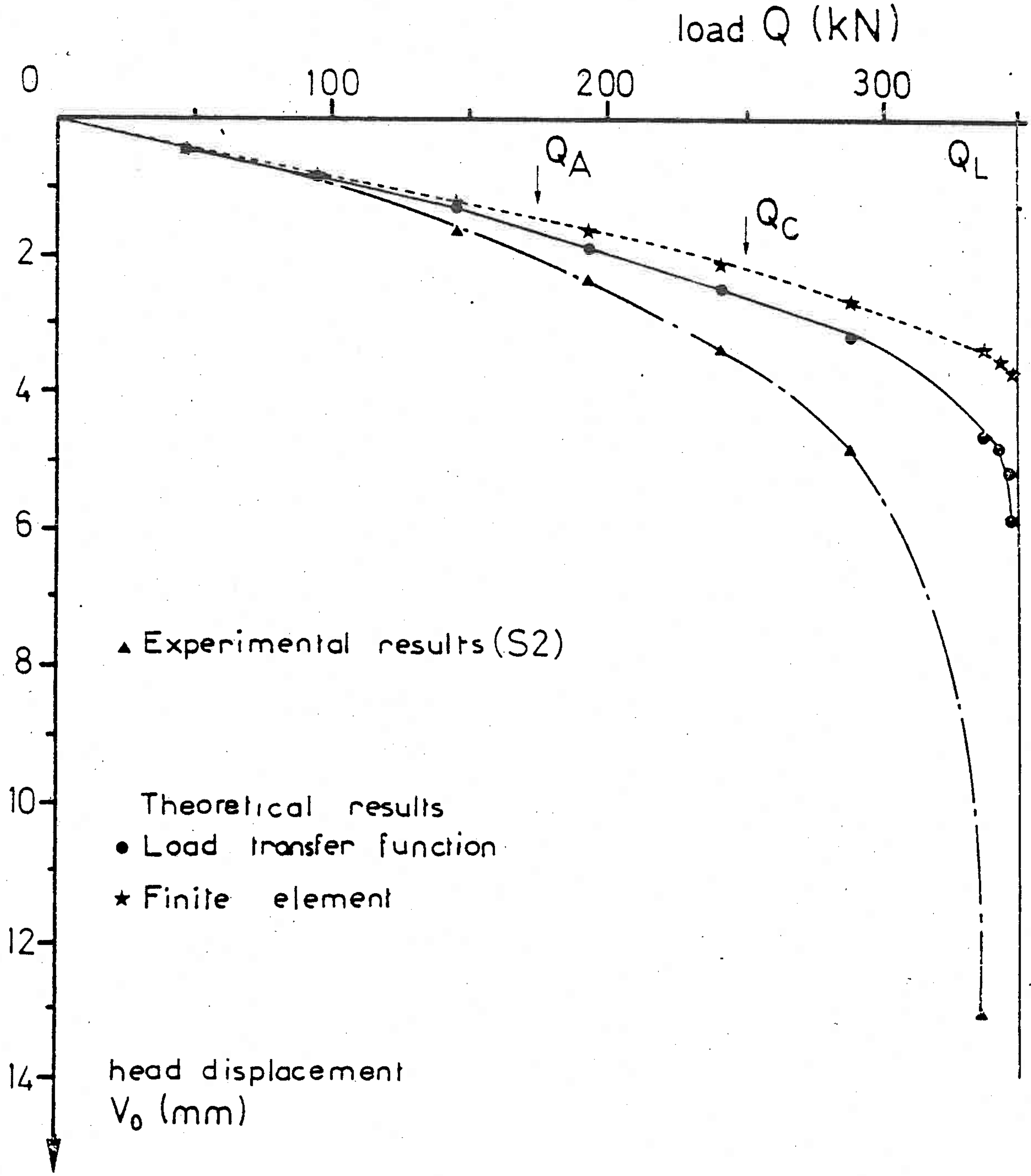

Figure 11 - Comparison of the experimental and theoretical load-displacement curves for the pulling-out test at PLANCOET.

use directly the laws of distribution of the vertical shear and of the vertical displacement in the soil mass around the piles, laws which are already known (see BAGUELIN and FRANK, 1980).

Aknowledgements

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