

A program for analysing a pile under lateral loading

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ABSTRACT: The paper presents a program for analysing a pile with circular or rectangular section under lateral loading, which will be referred to below as *Matei's Program* (or *M.P.*).

The program computes deflection, shear, bending moment and soil response, allowing for the non-linear behaviour of both the soil and the pile. Soil behaviour is modelled by p-y curves generated automatically, following recommendations published by N. Rădulescu (1998), for homogeneous sands. The modulus of subgrade reaction (K_s) can be calculated by the program. Several types of pile-head boundary conditions may be selected.

With the help of this program, the effects of several parameters and especially the effects of the shape of the pile section on the behaviour of the pile were studied.

Also, a comparative study was made between *M.P.* and *LPILE Plus 4.0* (*Ensoft, inc.*), both programs following a similar algorithm for computing displacements and forces.

1. INTRODUCTION

The computational program presented here uses the model illustrated in Figure 1.

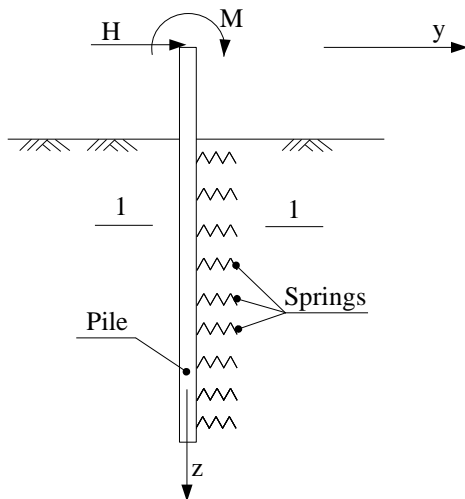


Figure 1. Model for analysis.

The pile is modelled by the finite element method as a series of bar elements and the soil is modelled as a series of independent, non-linear springs, whose behaviour is described by p-y curves, such as the one in Figure 2.

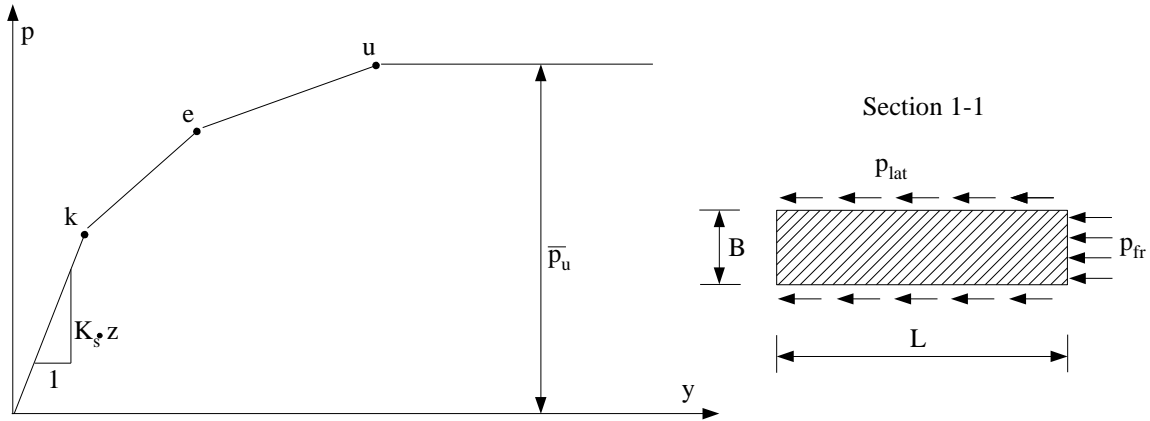


Figure 2. Example p-y curve.

$$\bar{p}_u = \bar{p}_{fr} + \bar{p}_{lat} = p_{fr} \cdot B + p_{lat} \cdot L \quad (1)$$

2. COMPARISON BETWEEN ANALYSES PERFORMED WITH *M.P.* AND WITH *LPILE PLUS 4.0* (ENSOFT, INC.)

In the analysis examples presented, the pressure p_{fr} mentioned in figure 2 and equation (1) was calculated for $z > z_{cr}$ with the equations (2) and (3) (for $z \leq z_{cr}$, other equations were used)

$$p_{fr} = A_s \cdot \gamma \cdot z \cdot (K_0 \cdot K_p \cdot e^{(\pi \cdot tg \phi)} - K_a + K_0 \cdot tg \delta) \quad (2)$$

$$p_{fr} = A_s \cdot \gamma \cdot z \cdot F_\phi \cdot K_p \quad (3)$$

where A_s is a coefficient depending on z , $\delta = \phi/2$ and $F_\phi = 3$ for $\phi = 30^\circ \dots 40^\circ$.

M.P. normally uses equation (2). There is no interface for selecting between equations (2) and (3), therefore, in order to use equation (3), it is necessary to modify and recompile the program.

Analyses were performed with *M.P.* and *LPILE Plus 4.0* (*Ensoft, inc.*) for the pile shown in Figure 3, for three values of the internal friction angle of the soil (ϕ): 30° , 35° and 40° . The maximum displacement is represented in Figure 3 as a function of the horizontal force applied (H). The displacement calculated with *LPILE Plus 4.0* (*Ensoft, inc.*) was up to 23.6% higher than that calculated with *M.P.* (for $\phi = 35^\circ$ and $H = 500$ KN), but, as can be observed in Figure 3, the results are generally comparable.

Also, the maximum bending moment obtained with *LPILE Plus 4.0* (*Ensoft, inc.*), was up to 8% higher (for $\phi = 35^\circ$ and $H=350$ KN).

3. ANALYSES FOR PILES WITH DIFFERENT SHAPES OF THE SECTION

Other analyses were performed with *M.P.* for the pile shown in Figure 4. Four types of section were considered (a, b, c and d); for each of them, the maximum displacement of the pile is represented in Figure 4 as a function of the horizontal force applied (H).

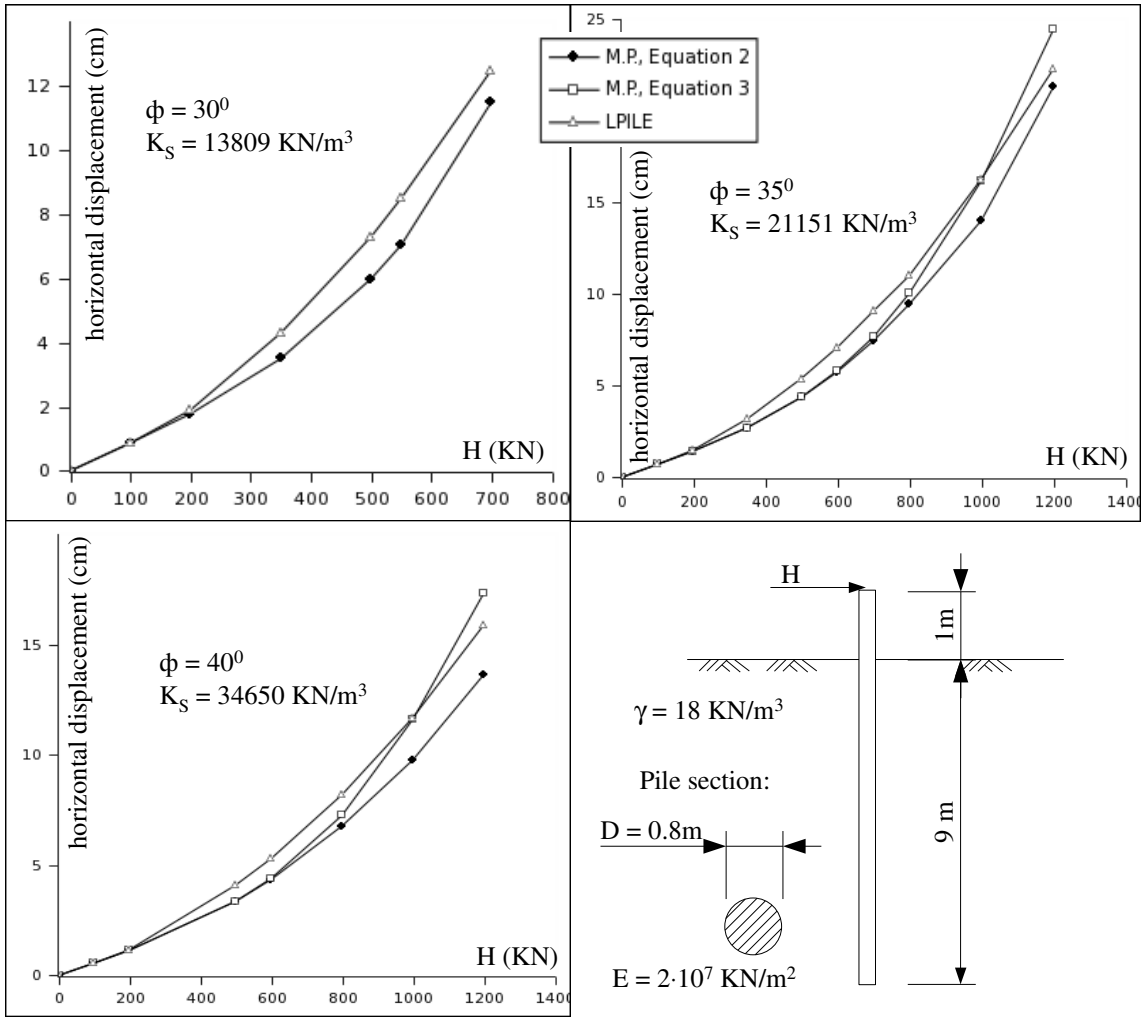


Figure 3. Results of analyses performed with *LPILE Plus 4.0* (Ensoft, inc.) and *M.P.*

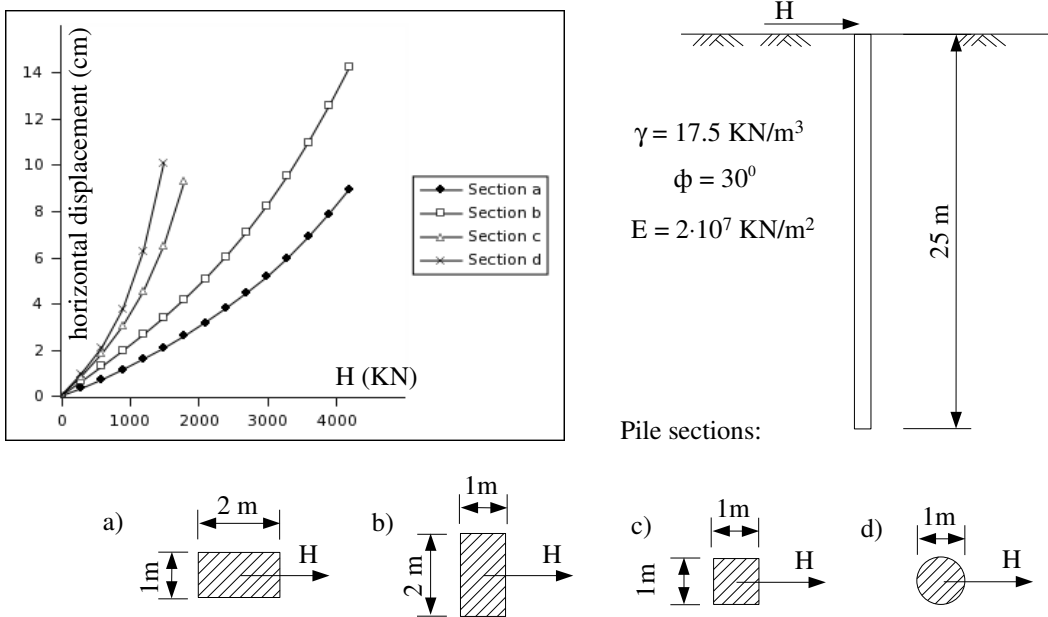


Figure 4. Results of analyses performed with *M.P.*

4. CONCLUSIONS

Only a few analysis examples are presented in this paper and it is therefore difficult for any significant conclusions to be drawn from them. The Program (*M.P.*) and its documentation are available at www.ppm.ro, under the terms of the GNU General Public License, Version 2 (www.gnu.org).

REFERENCES

Rădulescu, N. 1998. *Fundații de adâncime. Parametri caracteristici de interacțiune*. București : Conspress