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Journal of Scientific Research

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Numerical simulation of the pressuremeter test

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Published on 20 July 2014

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Numerical simulation of the pressuremeter test

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Abstract – The pressuremeter is an in-situ test, based on the application of static loading by introducing a cylindrical probe into a borehole, this test having essential objective to determine the relation-ship between the pressure applied to the ground and the displacement of the borehole wall. In our study, we present a literature search on this test and the essential detail of the theoretical and analytical study of the expansion of a cylindrical cavity. A numerical modeling of the pressuremeter test is possible and can procure the information sought.

Keywords: pressuremeter test, finite element, cylindrical cavity, displacement, deformation,

I. Introduction

In most of the problems encountered by geotechnical engineers the precise evaluation of parameters of soil behavior is required for analysis of deformation and strength of these soils and induced shifts in the structures, many methods to estimate the properties of soils are currently used in situ or in the laboratory.

Pressuremeter, invented by Louis Menard (1955 and 1959), which falls into the category of tests in-situ became a fixture massively used today in foundation projects [2], [3]. The construction and operation of the test are coded by a standard specific to each country that provides the state of the practice. Due to its simplicity of execution and speed of measures, the pressuremeter test has several advantages that are extremely interesting to determine such parameters that are used to the foundation design and calculation of settlements. In many situations, it happens that the test is not practicable because of the terrain characteristics. Modeling digital test is possible and can provide the information sought [1]. Our study concerns the finite element modeling of the pressuremeter test. It presents a numerical simulation results using the code Plaxis in 2D and local computation (Symef) in 1D.

II. The pressuremeter test

II.1. Pressuremeter theory

The in situ tests include, among others, penetration tests, shearing, expansion and seismic testing [4], [5]. expansion and seismic testing [4], [5]. Their use is almost systematically for any work major in civil engineering. But their speed advantage adds the variable

quality of these tests with the analysis mainly based on empirical considerations lacking theoretical foundations [4] - [6].

Due to its simplicity and speed enforcement measures pressuremeter test has several advantages that do extremely interesting to determine and deduct some soil parameters [5], [7], [8]

The standard pairs of pressuremeter test consists of three components, Tri-cellular probe, the pressure controller - volume (CPV) and tubes connection. (Figure1)



Figure 1. Pressuremeter test devices.

The pressuremeter test is to achieve horizontal expansion of a cylindrical probe in a borehole at a given depth until the rupture test uses the mechanisms of resistance of the soil presence of horizontal stress resulting. Usually the application of a load vertical [5], [7].

II.2. Theoretical study of the expansion of a cavity

The deformation of a ground under the expansion of membrane is represented as a pressuremeter expanding a cylindrical cavity [1], [5], [8] - [10].

- ✓ Consisting of a perfect elastic-plastic material monophasic
- ✓ Plastic behavior is assumed to obey Mohr - Coulomb.
- ✓ Characterized by a modulus of elasticity E, Poisson ν , cohesion C and friction angle ϕ

II.3. Numerical simulation by finite element of The pressuremeter test

The successful numerical model extended horizontal 6 m and a height of 0.2 m corresponding to the length of the central cell h . It has added a layer of 0.2 m above the first model, to study and interpret the kinematics of the expansion of a cylindrical cavity.

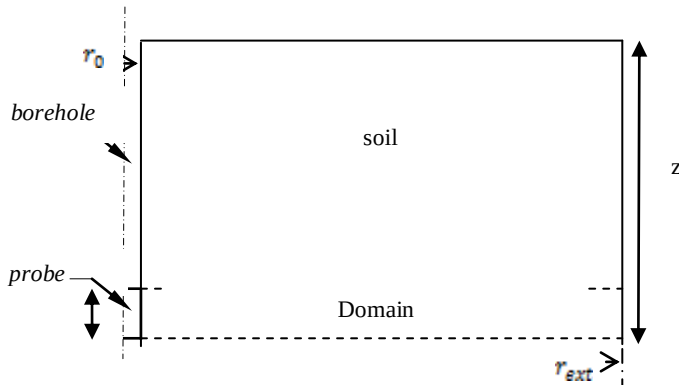


Figure 2: Schematic of the physical domain. [1]

III. Modeling of pressuremeter test

III.1. Problem

The pressuremeter test requests a domain cylindrical interior bounded by the circumference of the probe or the pressure P is applied to the outside and by a circumference of radius r_{ext} . The conditions limits of this problem can be established displacement or stress [11].

- ✓ At the edge of the probe: ($r=r_0$)
- ✓ At the end of the domain ($r=r_{ext}$): $U=0$
- ✓ $\frac{\sigma_r - \sigma_\theta}{r} = \frac{d\sigma_r}{dr}$

The stress tensor must check the equilibrium equation Figure 3 shows the conditions of the expansion pressiometric probe into the ground.



Figure 3: Conditions of the expansion probe pressiometric in soil [1,11].

The stresses in the soil are assumed are:

$$\begin{cases} \sigma_z = \sum \gamma_i h_i \\ \sigma_r = P_0 = K_0 \sigma_z \\ \sigma_\theta = \sigma_r \end{cases} \quad (2)$$

With

γ_i, h_i : The unit weights and thicknesses of layers above the level of the test.

K_0 : Coefficient of land at rest.

III.2. Discretization

The soil mass is represented by a segment line AB (model one-dimensional), discretized element dimensional base. Displacement in a base member is given as a function of displacements to the nodes ;

$$U = N \cdot U^e \quad (3)$$

U^e : displacement vector of the nodes.

N : matrix of interpolation functions.

IV. Simulation of the pressuremeter test with Plaxis

The main steps of an analysis in Plaxis are; definition of the geometry, boundary conditions, definitions of material parameters, Mesh, initial conditions, Phases calculation and visualization results, The calculation model is set in two phases (the most initial phase) as follows:

Phase 0: initiation of geostatic stresses; The initial stresses are determined; Stress vertical and horizontal due to own weight

Phase 1: Application of the vertical load due to upper layers of the massif

The application of a vertical load: The soil is studied a depth of $z=24.4m$ and vertical load due the weight of earth layer above is:

$$\text{Model 1: } \sigma_v = \gamma \cdot Z = 440 KPa.$$

$$\text{Model 2: } \sigma_v = \gamma \cdot (Z - 0.2) = 435.6 KPa.$$

Phase 2: Application of horizontal loading due to incremental pressuremeter;

In this phase, we applied a horizontal load, which corresponds to the progressive charge pressuremeter.

V. Results

The PLAXIS code offers the possibility of a detailed operating calculations tabulated and curves.

V.1. Stress

The figure 4 (a) and (b) show the horizontal stresses after loading test pressuremeter, (a): model 1, (b): model 2

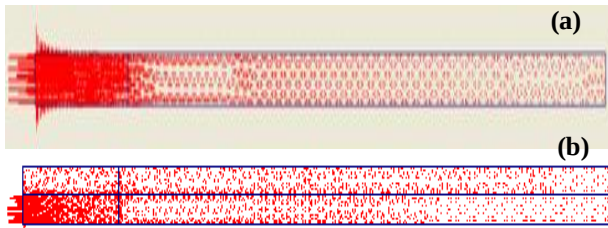


Figure 4 : Stress ; (a) : model 1, (b) : model 2.

The two figures show a concentration of stresses in the vicinity of the borehole

The figures 5 (a) and (b) respectively represent the stress distributions of the two models studied.

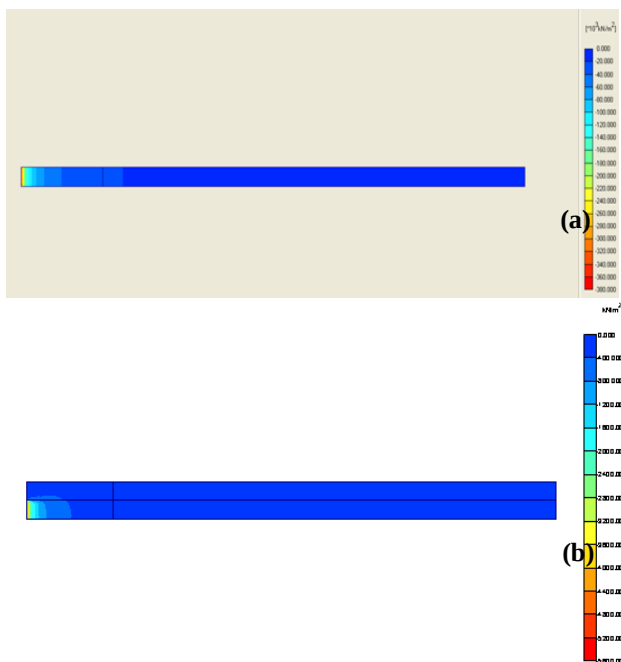


Figure 5 : Distribution of constraints ; (a) : model 1, (b) : model 2.

From the two figures above, be noted that the distribution is very clear for Model 1 (Fig. (a)).

V.2. Displacement et deformation

a). Displacement

The pressuremeter test changes the state of initial stresses in the soil, which leads to more or less important in the ground ambient.

The figures 6 (a) and (b) respectively represent the displacements of the two models studied.

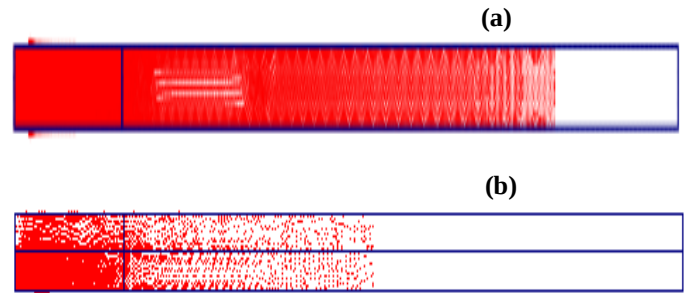


Figure 6 :Horizontal displacement ; (a) : model , (b) : model 2.

The analysis of Figures 6 (a) and (b) shows that the expansion is small in the model 2. figure7.

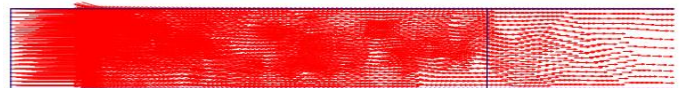


Figure 7 : Expansion due to horizontal displacements for model 1

It is noted that the model 1 is the most adopted as the expansion of the cylindrical cavity is most remarkable that the model 2.

b) Deformation

From displacement, you can also determine the deformed configuration.

Figures 8 (a) and (b) respectively show the deformations of the two models studied

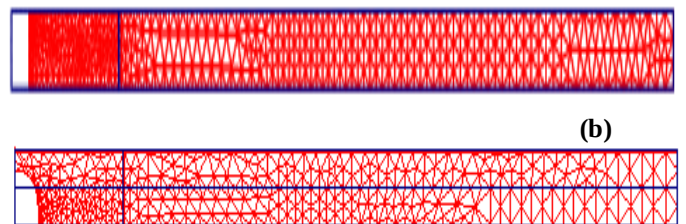


Figure 8 : Deformation, (a) : model 1, (b) : model 2.

From Figures 8 (a) and (b), we also note that the expansion of the cylindrical cavity is most remarkable that the model 1, In the model 2 we note that it is rather the expansion of a spherical cavity.

V.3. Comparaison of results between Plaxis and Symef

After presenting and characterized the first results of modeling the pressuremeter test in Plaxis (displacement, stress, strain, ...), we will now try to simulate our model calculation with code Symef calculation to show validity of the results obtained by Plaxis, by adjusting the parameters of the model of Plaxis 2D to Symef 1D.

a). Structure Symef code [1]

This is a code of finite element developed locally at the University of bechar. It communicates with the use of interactive commands or batch files.

Using batch file is desirable because it allows you to check the data and commands and schedule a parametric study. This code has been used in several studies.

Symef is composed of several independent executable modules but using the same database. Each module is designed for a specific type of calculation: linear static, geometric nonlinearity, material non-linearity, the contact friction adhesion dynamics.

b). Comparison

Before presented the results obtained with Plaxis and Symef, we note that the soil is assumed pulverulent and elastoplastic behavior, whose characteristics are the following:

$E=95\text{MPa}$, $\nu=0.33$, $C=5\text{ KPa}$, $\varphi=40^\circ$, $\psi=18^\circ$, $\gamma=18\text{ KN/m}^3$, $Z=24.4\text{m}$

Figures 9, 10 and 11 respectively represent the variation of the load (pressure) as a function of the relative change in volume ($\Delta V / V$) or in function of the displacement of the soil ; the relative variation of volume as a function displacement. These results are obtained by Symef and Plaxis code.

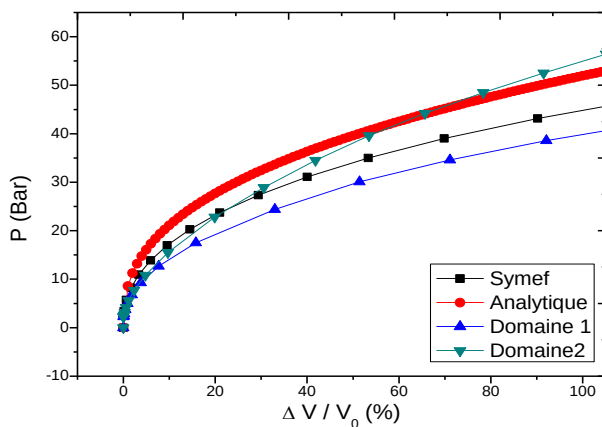


Figure 9: Variation of load as a function of the relative change in volume

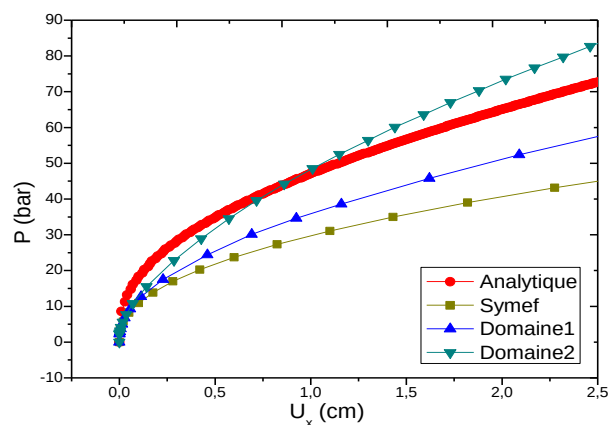


Figure 10: Variation of the load as a function of displacement.

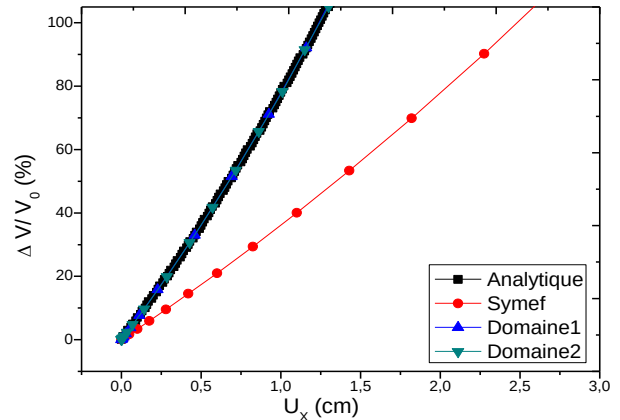


Figure 11: Variation of the volume as a function of displacement.

Figures 9, 10 and 11 illustrate the relationship between the effective load applied by the pressuremeter and soil characteristics, comparing the results of the two models studied by the Plaxis software with that of Symef.

The information contained in the curves of figures above), allow us to interpret the effect of the pressure on the ground.

It may be noted that there is a gap between the curves of the same figure is mainly due to a hand calculation hypothesis. Indeed Symef 1D assumes a cinematic plane strain (the expansion is done only in the horizontal plane while Plaxis 2D allows vertical deformation (plan r, z et θ, z) of the additional layer in the model 1).

We also observe that for small displacements (low relative changes in the volume), the distance between the curve corresponds to that of the model with Symef (model 2) is low, this difference decreases with increasing of the load applied until the point of intersection between the two curves corresponding to varying the volume of the order of 65% (displacement of about 1.2 cm) and 37 bar pressure for varying the volume (48 bar and travel variation). After this point of intersection, the gap increases with increase of the load applied.

Corresponding curves for Model 1 (domain1), we note that otherwise in the case of model2, we observe that the gap the deformed between model 2 and Symef decreases with increasing load applied, which results in convergence between the two curves.

We conclude this section by saying that despite some minor inconveniences are mainly due to the two-dimensionality, the Plaxis model 1 gives a good agreement with the local code Symef,

Table 1: contains the values of the corresponding pressure levels for different models.

model	Limit pressure (Bar)	displacement (cm)
analytical	51,93 [12,13]	1,35 [12,13]
Symef	44 [1]	2,35 [1]
Model1	32	1,3
Model 2	51,5	1,45

Table 1: Limit Values and equivalent displacement pressure for different models.

For conventional pressure is defined by doubling the volume $\Delta V/V = 100\%$ we note that the model gives a good agreement with the theoretical model (range 0.8%) and the result of Symef (14%)

VI. Conclusion

The pressuremeter test is an in situ static loading test ground up, made with a inserted into a borehole and the radially expandable cylindrical probe. Having essential objective to determine the relationship between the pressures applied on the soil and moving the borehole wall for He is particularly well suited to the study of shallow foundations and deep foundations.

In this paper, the numerical simulation was performed by finite element purpose is to study the kinematics of the pressuremeter test. This simulation was performed using the code with a Symef 1D model using the criterion of Drucker Prager and PLAXIS using the 2D analysis software for loading and deformation by an elastoplastic calculation with a criterion Mohr-Coulomb

We conclude that, despite some minor inconveniences mainly due to the two-dimensionality, modeling Plaxis gives us a good agreement with the local code Symef.

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