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Numerical Modeling of the Test on Slope Pressuremeter

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Abstract— **In this paper we presents the results of numerical simulation of the pressuremeter test performed in a massive with a slope. The objective is the determination of pressuremeter characteristics, the module and the limit pressure. The results are compared with previous works (Bornnal, 1999) and the analytical results, simulations are made using a computer code based on the finite element method (Plaxis) with two laws elastoplastic behavior, Mohr-Coulomb and Cam Clay. The existence of a slope therefore requires the determination of the initial stress state of the massive that is to be performed numerically.**

Keywords — **Cam-clay, Mohr- Coulomb, Initial stress, Plaxis2d, Pressuremeter test, Pression limit, Slope**

I. INTRODUCTION

Building work based foundation near a slope has become increasingly common, hence the need for reliable methods for the design and calculation of these foundations.

Beyond the problem of choosing a law of behavior appropriate to the problem at hand, determining the parameters of the law of value remains a critical step for geotechnical modeling. These parameters can be identified from laboratory tests and / or testing in place, or with both types of tests.

In this paper there is great interest on the Ménard pressuremeter tests; which is a massively used nowadays in the latter unit foundation projects was invented by Louis Menard (1955 and 1959). The approach is usually to take the test on one hand the pressuremeter modulus, and secondly the limit pressure.

The purpose of this paper is to make a numerical interpretation of the results of pressuremeter test at a loading floor to meet a certain number of questions about the possible development of the limit pressure and the stress field around the probe.

II. HISTORY AND DEVELOPMENT OF PRESSUREMETER

The pressuremeter test was invented by German Kögler the 1930, in order to measure a soil deformation modulus. Due to the technology of the time, the unit was not operational. Furthermore, the inventor has failed to correctly interpret the results and the unit was immediately abandoned.

In 1954 a young French engineer, Louis Ménard, took up the idea in the refining: the inflatable cylinder Kögler, he added two guard cells to the central measuring cell, avoiding the expansion of the to drilling and thus making interpretable test. The unit became operational quickly because of advances in technology: Rubber cells consist admitting large deformations and especially invention of semi-rigid plastic tubing making possible the realization of in-depth testing. But the contribution of Louis Ménard has focused on defining Pressuremeter soil characteristics and developing rules of interpretation for the design of foundations using these parameters (Amar and Jézéquel 1998).

III. MODELING OF THE GENESIS OF THE SLOPE

From a geotechnical perspective, the genesis of a slope involves different mechanisms that can either be of geological origin or anthropogenic. Table 1 summarizes the most common cases encountered in practice. To simulate a simplified way these three types of real mechanisms, three slope Genesis procedures are considered, called settlement procedures respectively, excavation and over-consolidation.

From the analysis of mechanisms that can be reasonable estimate of the history of creation of a slope, simplified Procedures for various simulations of this story are set. For a given elastoplastic constitutive law, the application of these procedures to mass with a slope, through numerical simulations, will study the influence of the genesis of the slope on the stress state and hardening obtained within the massif.

IV. INITIAL STRESS STATE IN A SLOPE

The stress state in an up soil mass is highly dependent on the history of the stresses suffered by the massive over time. Modeling by finite elements of a geotechnical problem within a soil mass thus poses the problem of initializing the stress field:

- In the case of a massive horizontal surface, the stress state is known; it is determined by estimating the pressure coefficient K0 land to rest.

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- In the case of a massive complex geometry, the stress state is difficult to estimate its initialization can be done by numerical simulation of the supposed historic.

IV. 1. Geometric and geotechnical characteristics of the model

The problem is treated in plane strain in the plane (O, X, Y), with the conditions to travel in limits: horizontal displacements are zero on the vertical limits of the range, the vertical displacements are zero based. The geometry and dimensions of the model under consideration are defined in figure 1. The mass is subjected to its own weight and only includes an embankment height (H = 10m), whose surface is inclined at an angle (β = 26.5 °) relative to the horizontal. The characteristic size (d = 20m) of the model defines the distance to which are applied the boundary conditions.

For this study we used the laws of elastoplastic behavior, these models are completely defined by parameters for the Mohr-Coloumb model defined by (E, ν , c, φ, ψ) and the Cam-Clay model defined by (E, ν , λ , k , M , e_0, p_{co}) (Magnan and Mestat,1997 ; Mestat ,1993 and Khemissa and al., 1993).

The calculation parameters are shown in Table II, they are derived from parameters found in the literature and correspond to a clay (Bornarel, 1999)

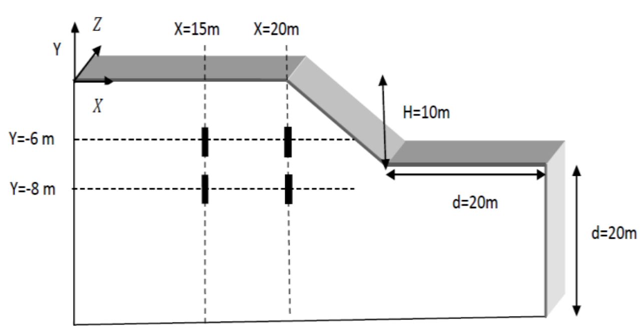

Figure 1: Geometry of the problem and positions pressuremeter tests (Bornarel, 1999)..

TABLE I
Different mechanisms of the genesis of the slope (Bornarel, 1999).

Mechanism	Geological origin	Anthropogenic origin
Deposit	Natural deposit (talus, alluvium	bank
Excavation	natural erosion	Excavation
Overload and excavation	historic missing overload (glacier erosion)	Excavation mass

TABLE II:
Parameter set (Bornarel, 1999).

Parameter	Cam-Clay Modifié	Mohr-Coulomb
Unit weight γ(kN/m^3)	15	15
Young's modulus E(MPa)	15	15
Poisson ratio (ν)	0,3	0,3
Plasticity	λ=0,1 ; k =0,08 ; M=1,3 ; e_0=2 ; p_{co}=0	c=0 kN/m^2; φ=32,3° ; ψ= 0^0

From simplified numerical procedures reproducing different historical creation of a slope in a soil mass, the states of stress and strain hardening obtained are analyzed. The ISO values are shown in Figure 2: in the case of (a) settlement procedure, and also in the case of (b) excavation procedure and finally in case (c) Procedure over consolidation.

V. SIMULATING THE PRESSUREMETER TEST

V.1. Basic assumptions

The general assumptions taken into account are:

1) The simulations are performed in small deformations,
2) The test is analyzed in drained conditions (effective stress)
3) The mode of deformation of the pressuremeter probe is the plane strain.

V.2. Pressuremeter probe Dimensions

A total height of sensor H = 70 cm, and diameter D = 62 mm, with a height of the measuring cell of 40 cm, 15 cm and two guard cells.

V.3. Soil mass cases of sloping

The pressuremeter tests are simulated at different points of the slope whose positions are defined on the (Figure 1). The initial states correspond to the three slope creating simulation procedures are used compaction procedure, excavation and over-consolidation (Figure 2). The type of pressuremeter is used with the prior drilling.

We model a soil volume by taking 15-node elements considering the axisymmetric case with respect to the vertical axis. Mesh dimensions are in the following figure (Figure 3).

V.4. Boundary conditions and loadings

The soil is free on the vertical walls of drilling and vertical movement is possible on the two vertical borders.

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With regard to loading, two loads are involved in this problem:

1) A load "type A" due to the weight of the land prior to drilling for which there are two different loads: a) a uniform vertical load applying down-hole drilling and equal to γ.z with γ being the specific weight of the land and z being the depth of drilling. b) a horizontal load varies linearly with depth, and applying on the vertical wall of the drill hole, $K_0.\gamma.Z, K_0$ the coefficient value being ground at rest (Figure 4). This loading will then obtain uniform initial stress state throughout the soil mass. (Al Husein 2001).
2) A "Type B" loading that simulates the loading applied by the probe on the ground (Figure 4). This loading is applied radially on a length equal to the length of the probe, in downhole. (Al Husein 2001).

VI. Results And Discussions

Figure 4 shows for two models Mohr Coulomb and Cam-Clay the results of radial displacements in the depth Y = 6 m and Y = 8 m. This case is important because it will serve as a reference relative to simulations in the case of presence of the slope.

The initial state is obtained by geostatistical simulation of the settlement of a horizontal solid subjected to gravity. Figure 6 shows the same against a scheme for the case of a steep mountain. Pressiometric the expansion curves for various depths are shown in

Figure 4 (solid horizontal) and Figure 5 (slope solid) for both models (Mohr-Coulomb model and modified Cam-Clay). These different tests are used to draw the two laws of behavior, and for selected parameters, the profile of the conventional limit pressure depending on the depth Y of the test. The test results depend only on the Y towards which it is made.

These results are consistent with the classic curves of the pressuremeter test (Figure 6) for both models; the curves exhibit a marked curvature. For greater depths, they become almost linear.

Pressuremeter curves will be given in the form ΔV / V0 = f (p-p0), where V0 is the initial volume of the probe, its current volume V, p0 initial horizontal radial stress at the probe, and (p p0) is the pressure applied to the probe to the considered load increment. The current volume V of the probe is obtained directly in the case of massive horizontal (axisymmetric model).

For comparison with the analytical or empirical functions several authors have proposed approximations based on the work of Hughes et al., 1977. The study was performed in small elastic deformations and large plastic deformations. The volume variations are modeled by the classical relationship where ψ is the dilatancy angle, the limitation of this approach is that it does not estimate the limit pressure to infinity. Under these conditions the expansion curve is written in Bornarel, 1999:

$$\frac{p + c\cot g\varphi}{p_0 + c\cot g\varphi} = (1+\sin\varphi)\left[\frac{E}{2(1+\nu)(p_0 + c\cot g\varphi)\sin\varphi(1+\sin\psi)} 2\left(\frac{r_s - R_s}{R_s}\right)\right]^{\left(\frac{\sin\varphi}{1+\sin\varphi}\right)(1+\sin\psi)}$$

(1)

Fawaz 1993 indicates that the conventional limit pressure is the applied pressure corresponds to the doubling of the volume of the sensor or a relative change in volume equal to 42%.

$$\frac{p + c\cot g\varphi}{p_0 + c\cot g\varphi} = (1+\sin\varphi)\left[\frac{E}{2(1+\nu)(p_0 + c\cot g\varphi)\sin\varphi} 2\left(\sqrt{2}-1\right)\right]^{\left(\frac{\sin\varphi}{1+\sin\varphi}\right)(1+\sin\psi)} \quad (2)$$

To the settling procedure, the limit pressures decrease as the test position approaches the slope, reflecting the influence thereof on the test results.

Note that in Fascicle 62 the calculation of the equivalent pressure limit is based on a linear approximation of the pressure limit as a function of depth. The results are summarized in Table III.

Table III
Comparison Of Results

Cam-Clay	analytical (Equation 1)	Analytical (Equation 2)	Plaxis		(Bornarel ,1999)	
			Y=6m	Y=8m	Y=6m	Y=8m
limit pressure	410,94 kN/m²	465,58 kN/m²	314 kN/m²	408,20 kN/m²	350 kN/m²	400 kN/m²

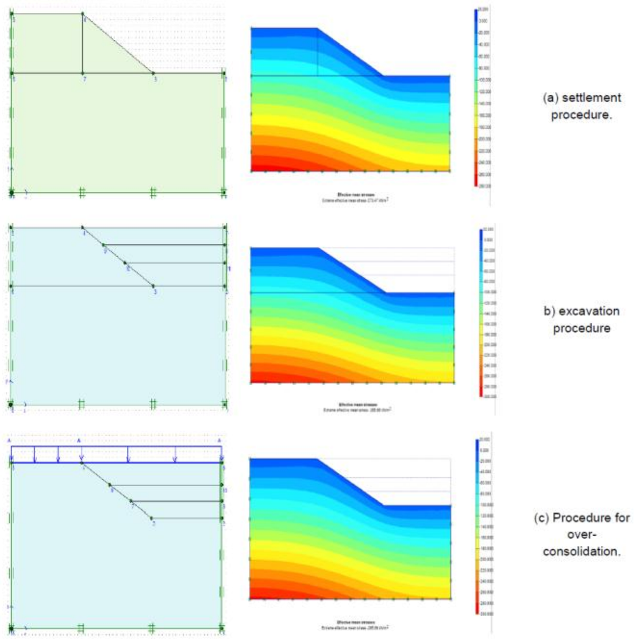


Figure 2: Procedure for the genesis of a slope. Initial state (Ouabel, 2015)

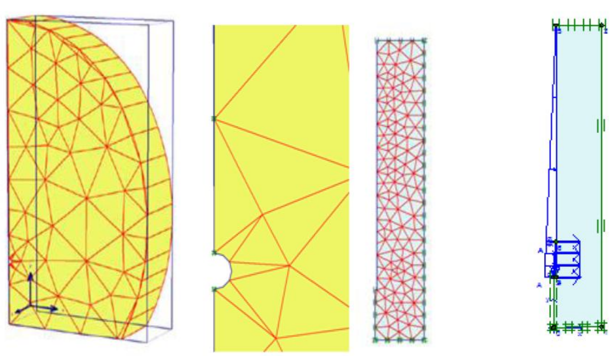


Figure 3: Detail of mesh in 3D, and plane around pressuremeter., And the two types of loading (Ouabel, 2015)

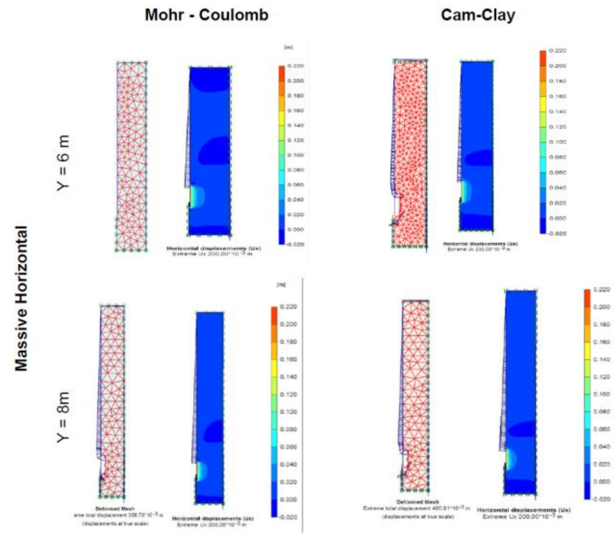
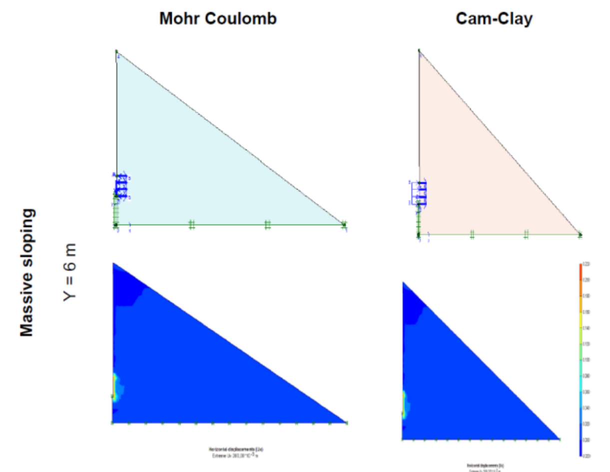


Figure 4: Case of a horizontal solid for two depths and two models. (Ouabel, 2015)



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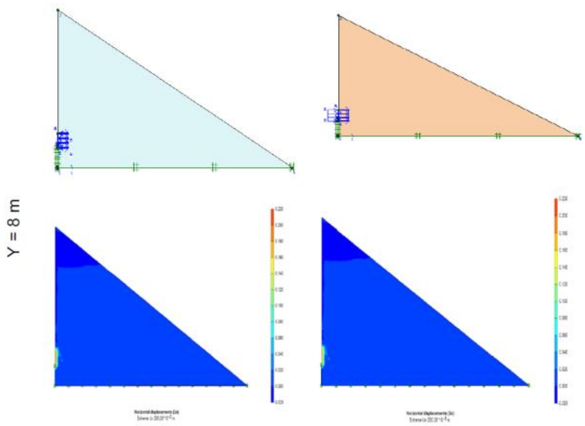

Figure 5: Case of a solid slope for two depths and two models. (Ouabel, 2015)

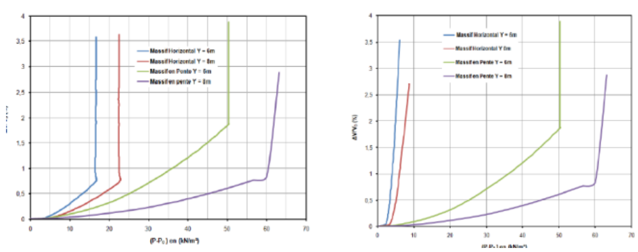

Figure 6: Curves pressuremeter expansion: Mohr-Coulomb model. & Cam-Clay Model (Ouabel, 2015)

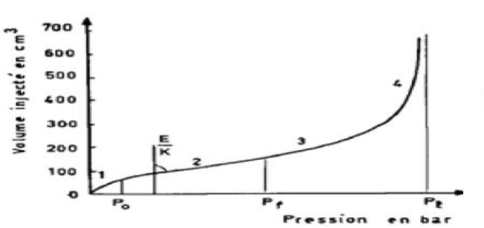

Figure 7: pressuremeter curve (Amar Jezequel, 1985.1972, 1973)

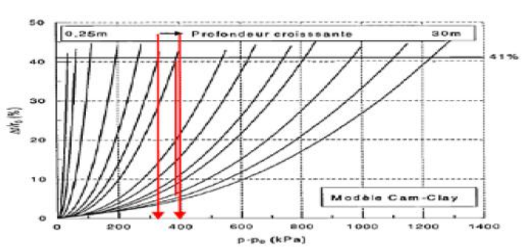

Figure 8: Horizontal Massif. Expansion curves (Bornarel, 1999).

VII. CONCLUSION

The modeling of the pressuremeter test (determination of pressuremeter characteristics) digitally is much more delicate and it seems prima facie the difficulty is great when we present a slope for both behavioral pattern related to the difficulties defining the initial state of the soil.

These different states of stress and strain hardening obtained can be used as initial state in the modeling of a subsequent solicitation massif (pressuremeter test) the possible influence of the history of the massif through modeling these initial states.

From these results, we see that numerical simulation with Plaxis, which we did, gave results comparable to conventional pressuremeter curves qualitatively (shape of the curve).

Regarding the analytical and numerical comparison of the limit , numerical simulations we made with the modified Cam-Clay model and Mohr Coulomb, data have comparable results to the analytical values quantitatively (slope the curve).

It is clear that this result still requires improvement in order to make practical conclusions in relation to the practice of engineering: experimental aspects and calculation of shallow foundations on a slope according to standards and regulations.

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