SSNV202 – Test œdometric drained with the law of Camclay

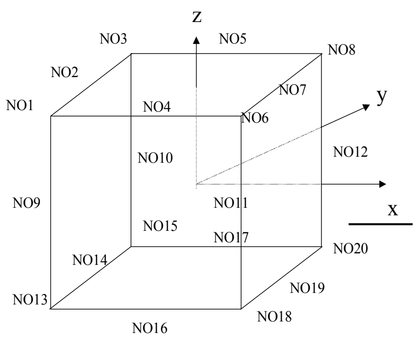
Summary

This test makes it possible to validate the elastoplastic mechanical law of Camclay specific to the normally consolidated grounds. This law integrates an elastoplastic hydrostatic mechanism (of which the elastic part is not - linear and the threshold of flow corresponds to the pressure of consolidation) coupled to an elastoplastic mechanism deviatoric (of which the elastic part is linear). The behavior is *hardening* or *polishing substance* according to the combination of the two mechanisms.

One is carried out *œdometer in pure mechanics* (equivalent under drained hydraulic conditions). The calculated solutions are compared with results resulting from software FLAQ of calculation of soil mechanics. This test comprises only one modeling: one starts from a state of the normally consolidated ground to $p_{co}=10^{+4}\,Pa$

1 Problem of reference

1.1 Geometry



The triaxial compression test is carried out on only one isoparametric finite element of cubic form `HEXA20`. The length of each edge is worth 1. The following meshs are defined :

DROITE :	*NO3 NO5 NO8 NO10 NO12 NO15 NO17 NO20*
GAUCHE :	*NO1 NO4 NO6 NO9 NO11 NO13 NO16 NO18*
DEVANT :	*NO6 NO7 NO8 NO11 NO12 NO18 NO19 NO20*
DERRIERE :	*NO1 NO2 NO3 NO9 NO10 NO13 NO14 NO15*
BAS :	*NO13 NO14 NO15 NO16 NO17 NO18 NO19 NO20*
HAUT :	*NO1 NO2 NO3 NO4 NO5 NO6 NO7 NO8*

1.2 Material properties

The elastic properties are :

- Poisson's ratio: $\nu=0.3$
- The Young modulus: $E=7.2.10^{+5}\,Pa$

The unelastic properties (Camclay) are:

- initial porosity: $\varphi_0=0.667$ (correspondent with an index of the vacuums $e_0=\frac{\varphi_0}{1-\varphi_0}=2$)
- slope of the right-hand side of critical condition: $M=1.02$
- critical pressure: $p_{cr}=p_{co}/2=5.10^{+3}\,Pa$ (state of the normally consolidated ground)
- pressure of reference: $pref=100\,Pa$ [1]
- angle of friction: $\varphi=21\,°$
- angle of dilatancy: $\psi=21\,°$
- coefficient of compressibility: $\lambda=0.2$
- coefficient of swelling: $\kappa=0.05$

1 This pressure does not have any particular physical meaning, and is used only with ends as digital standardisation.

Because of elastic law non-linear reserve, it is necessary to check the coherence of the initial mechanical data with the initial state of stresses: indeed, the non-linear elastic law is written as follows:

$$\dot{P}'=K\,\dot{\varepsilon}_v^e=\frac{P'(1+e_0)}{\kappa}\dot{\varepsilon}_v^e \quad [1]$$

$$\dot{s}=2G\,\dot{\tilde{\varepsilon}} \quad [2]$$

where P' represent the voluminal effective constraint, K^t the tangent module of compressibility, G the modulus of rigidity, ε_v^e voluminal elastic strain, s the tensor of the diverter of the constraints and $\tilde{\varepsilon}$ that of the deformations. The symbol * indicate the derivative compared to the time of the quantities considered.

One sees that the non-linear aspect of the law is carried by the voluminal part, with a module of compressibility K depending on the state of effective stress voluminal P'. The deviatoric part remains linear, with a modulus of rigidity $G=\frac{E}{2(1+\nu)}$ determined starting from the mechanical data.

It proves thus necessary to initially check coherence between the values of G and of K, and more exactly, to check that one has well at the beginning $0<\nu<0.5$. One arrives thus at the following conditions:

$$P'\geq 0 \text{ and } E<\frac{3P'(1+e_0)}{\kappa} \quad [3]$$

The first condition indicates that one does not tolerate a state of voluminal stress negative (poroelastic stability condition of material), while the second come down to raise the value of E according to the state of voluminal stress current. Thus, on the basis of a normally consolidated state, that is to say $P'_0=p_{co}$, the second inequality shows that a quite selected module must observe the condition:

$$E<1.8 10^6 Pa \quad [4]$$

1.3 Boundary conditions and loadings

A test oedometric consists in imposing on the test-tube one *vertical radial force* all in *maintaining the distortions lateral constant* . It perhaps drained (the pore water pressure of fluid does not vary during the test) or not-drained (one turns off the tap: the pore water pressure of fluid evolves in the sample). One is interested here in the case drained, simpler, because not utilizing the influence of the pore water pressure of the fluid and *modélisable of this fact by a pure mechanical calculation* .

In the model considered, the cubic element represents a eighth of the sample. The limiting conditions are thus the following ones:

- Conditions of symmetry:
  - $u_z=0.$ on the group of mesh BAS
  - $u_x=0.$ on the group of mesh $DERRIERE$
  - $u_y=0.$ on the group of mesh $GAUCHE$
- Conditions of side pressure:
  - $u_x=0.$ on the group of mesh $DEVANT$
  - $u_y=0.$ on the group of mesh $DROITE$
- Conditions of isostatic constraint:
  - $P'=p_{co}=10^{+4} Pa$ on all the element (operator CREA_CHAMP)
- Conditions of loading:
  - The loading is carried out in only one phase:
  - displacement imposed on the group of meshs $HAUT$ enter $t=0.$ and $t=10.$ varying $u_z=0$ with $u_z=-0.1$ (axial deformation of 10%).

1.4 Results

The solutions post-are treated with the point $NO8$, in terms of voluminal effective constraint P' , of equivalent constraint Q and of index of the vacuums e .

The validation is carried out by comparison with solutions FLAQ provided by the CIH.

2 Modeling A

2.1 Characteristics of modeling

Modeling A is *three-dimensional* and *non-linear statics* .
The initial preconsolidation of the sample is equal to $p_{co}=10^{+4}\,Pa$. It is checked that the Young modulus respects the inequality [4]: $E<1.8\times10^{+6}\,Pa$.

The vertical displacement imposed on the higher facet varies between 0. and – 0.1 in 70 pas de time enter $t=0.$ and $t=10$. During calculation, one activates the automatic subdivision of the step of time to manage the situations of nonconvergence of local integration.

In the integration of the equilibrium equations, one asks for a reactualization of the tangent matrix, which is provided by the routines of the law of Camclay and accelerates convergence appreciably. One also asks for the subdivision of the step of time (order `DEFI_LIST_INST`) to treat the situations of failure of local integration due to too large increments of loading.

2.2 Sizes tested and results

2.2.1 Values tested

The solutions are calculated at the point $NO8$ and compared with references FLAQ. They are given in terms of voluminal effective constraint P', of equivalent constraint Q and of index of the vacuums e , and recapitulated in the following tables:

$P'=\frac{1}{3}trace(\sigma')$ (variable interns V3)

ε_{zz}	Code_Aster	GEFDYN	relative error
-0.1%	10132.3	10070.0	0.6%
-0.5%	10505.9	10500.0	0.1%
-1%	11014.5	11010.0	0.1%
-2%	12499.3	12480.0	0.2%
-10%	41989.0	41840.0	0.4%

$Q=\sqrt{\frac{3}{2}s:s}$ (internal variable $V4$)

ε_{zz}	Code_Aster	GEFDYN	relative error
-0.1%	514.6	521.0	-1.2%
-0.5%	1998.8	2016.0	-0.9%
-1%	3051.1	3068.0	-0.5%
-2%	4189.7	4219.0	-0.7%
-10%	12904.9	13020.0	-0.9%

e (internal variable $V7$)

ε_{zz}	Code_Aster	GEFDYN	relative error
-0.1%	1,998	1,997	0.03%
-0.5%	1,986	1,985	0.03%
-1%	1,971	1,970	0.03%
-2%	1,941	1,940	0.03%
-10%	1,701	1,700	0.03%

As an indication, the time CPU spent on the BULL machine with the version *Code_Aster* 9.0.15 is of $9.13\,s$.

2.2.2 Comments

The relative error remains lower than 1%, which is satisfactory.

3 Summary of the results

ON represent in the following curves the various comparisons enters *Code_Aster* and GEFDYN, in terms of way of loading in the plan (P', Q) (Figure **1**), and of evolution of the index of the vacuums (Figure **2**).

In this last figure, one reveals two solutions *Code-aster* :

- The solution in 1 phase, which corresponds to modeling A;
- The solution in 2 phases, where one replaced the pure and simple assignment initial stress field p_{co} (CREA_CHAM) by an unelastic calculation (Camclay) of isotropic consolidation until the pressure p_{co} .

Procedure adopted in modeling A being that used for calculation FLAQ.
In terms of way of loading in the plan (P', Q) (Fig. **1**), one finds an excellent convergence of the solutions between FLAQ and ASTER, as well into 1 phase as into 2.
With regard to, on the other hand, the index of the vacuums (fig. **2**), if the solution *Code_Aster* in 1 phase coincides well with solution FLAQ, it is all differently for the solution *Code_Aster* in 2 phases. This is explained easily: during the isotropic unelastic loading (Camclay), the index of the vacuums evolved, and passed from $e_0 = 2.$ with $e \approx 1.82$.

This result thus shows in what the two approaches (in 1 or 2 phases) are not completely equivalent, and which it is advisable to have conscience.

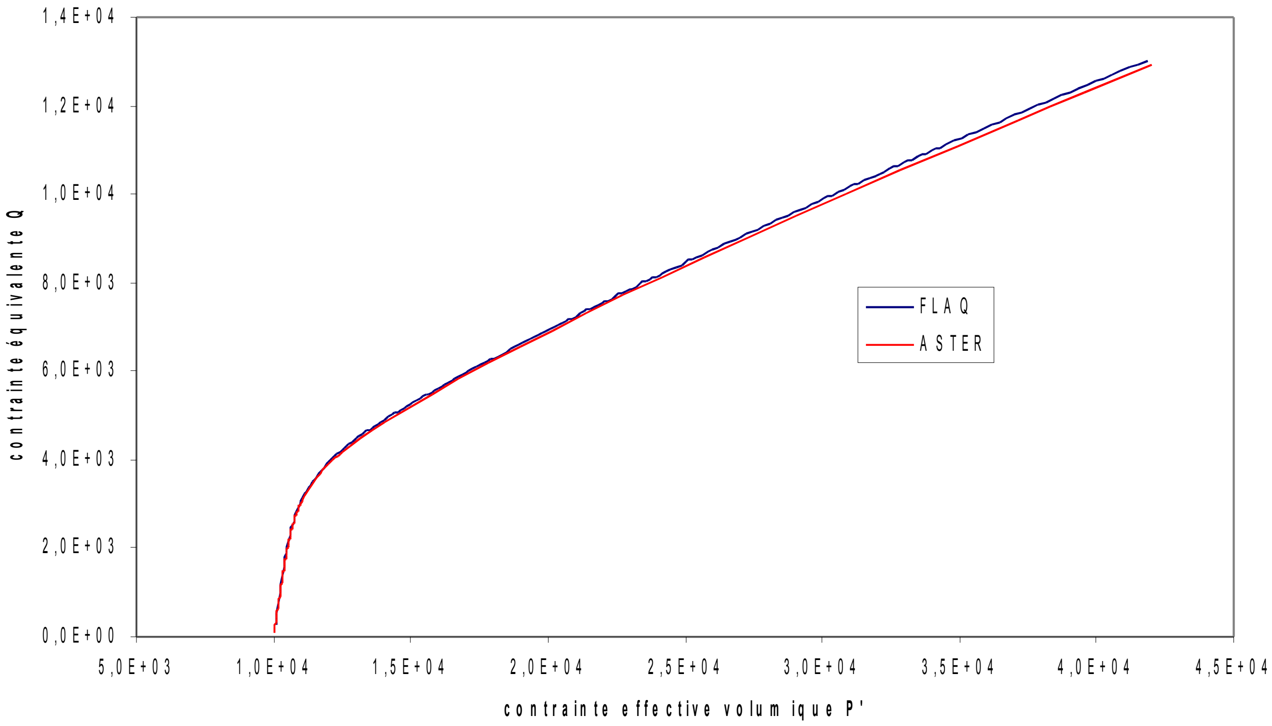


Figure **1** : *Way of loading of the plan* (P', Q) *: comparison enters the Code_Aster solutions and FLAQ .*

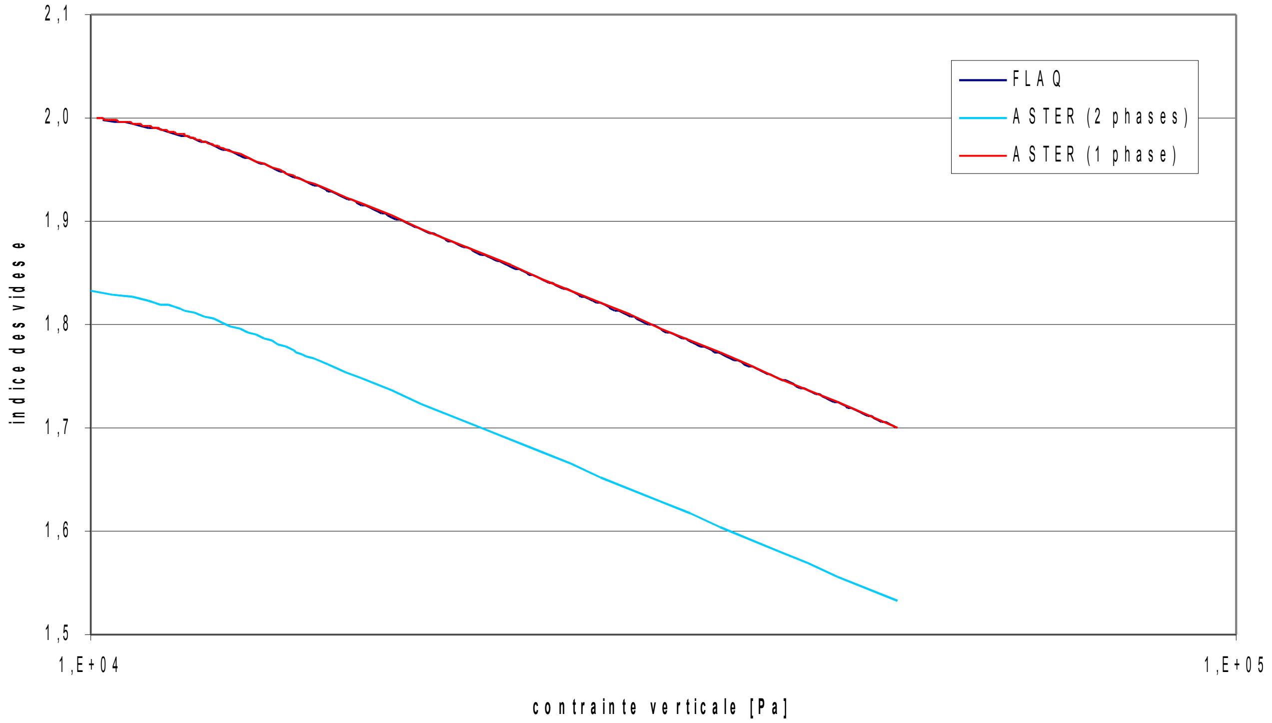


Figure **2** : *Index of the vacuums according to the vertical constraint: comparison enters the solutions FLAQ and Code_Aster for two calculations: in a phase and two phases .*