SSNV202 – Test œdometric drained with the model of Camclay

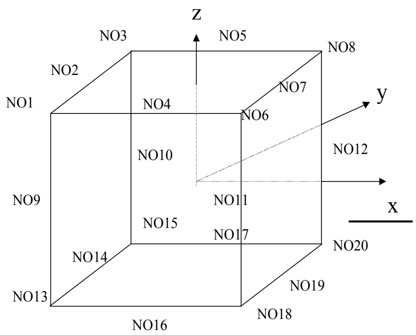
Summarized

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

A œdometer *in pure mechanics is produced* (equivalent under drained hydraulic conditions). The calculated solutions are compared with results resulting from software FLAQ of computation of soil mechanics. This test comprises only one modelization: one starts from a state of the normally consolidated soil 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. One defines the meshes following ones :

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: $\varphi_0=0.667$ (corresponding with an index of the vacuums $e_0=\frac{\varphi_0}{1-\varphi_0}=2$)
- slope of the right of critical condition: $M=1.02$
- critical pressure: $p_{cr}=p_{co}/2=5.10^{+3}\,Pa$ (state of the normally consolidated soil)
- pressure of reference: $pref=100\,Pa$ [1]
- friction angle: $\varphi=21$ °
- 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 numerical standardization.

Because of elastic model nonlinear reserve, it is necessary to check the coherence of the initial mechanical data with the initial stress state: indeed, the nonlinear elastic model is written as follows:

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

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

where P' the voluminal effective stress, K^t the tangent modulus of compressibility represents, G the shear modulus, ε_v^e the voluminal elastic strain, s the tensor of the deviator of the stresses and $\tilde{\varepsilon}$ that of the strains. The symbol * indicates derivative compared to the time of the quantities considered.

One sees that the nonlinear aspect of the model is carried by the voluminal part, with a modulus of compressibility K depending on the voluminal stress state effective P'. The deviatoric part remains linear, with a shear modulus $\mathrm{G}=\frac{\mathrm{E}}{2(1+\nu)}$ 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:

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

the first condition indicates that one does not tolerate a negative voluminal stress state (poroelastic stability condition of the material), while the second come down to raise the value of E according to the current voluminal stress state. 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 modulus must observe the condition:

$$E<1.810^6\,Pa \quad [4]$$

1.3 Boundary conditions and loadings

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

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 $DROITE$
- constraints statically determinate:
  - $P' = p_{co} = 10^{+4} Pa$ on all the element (operator `CREA_CHAMP`)
- conditions of loading:
  - The loading is carried out in only one phase:
  - displacement imposed on the mesh group $HAUT$ enters $t=0.$ and $t=10.$ varying from $u_z = 0$ to $u_z = -0.1$ (axial strain of 10%).

1.4 Results

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

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

2 Modelization A

2.1 Characteristic of the modelization

The modelization A is *three-dimensional* and *static nonlinear* .
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 time step enter $t=0.$ and $t=10$. During computation, one activates the automatic subdivision of the time step to manage the situations of nonconvergence of local integration.

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

2.2 Quantities tested and Values

2.2.1 results tested

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

$P'=\frac{1}{3}trace(\sigma')$ (local variable 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%

$Q=\sqrt{\frac{3}{2}s:s}$ (local 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 (local 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 TEMPS 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

One represents in the following curves the various comparisons between *Code_Aster* and GEFDYN, in terms of way of loading in the plane (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 the modelization A;
- The solution in 2 phases, where one replaced the pure and simple assignment stress field initial p_{co} (CREA_CHAM) by an unelastic computation (Camclay) of isotropic consolidation until the pressure p_{co} .

Procedure adopted in the modelization A being that used for computation FLAQ.
In terms of way of loading in the plane (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 $e_0=2.$ to $e\approx 1.82$.

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

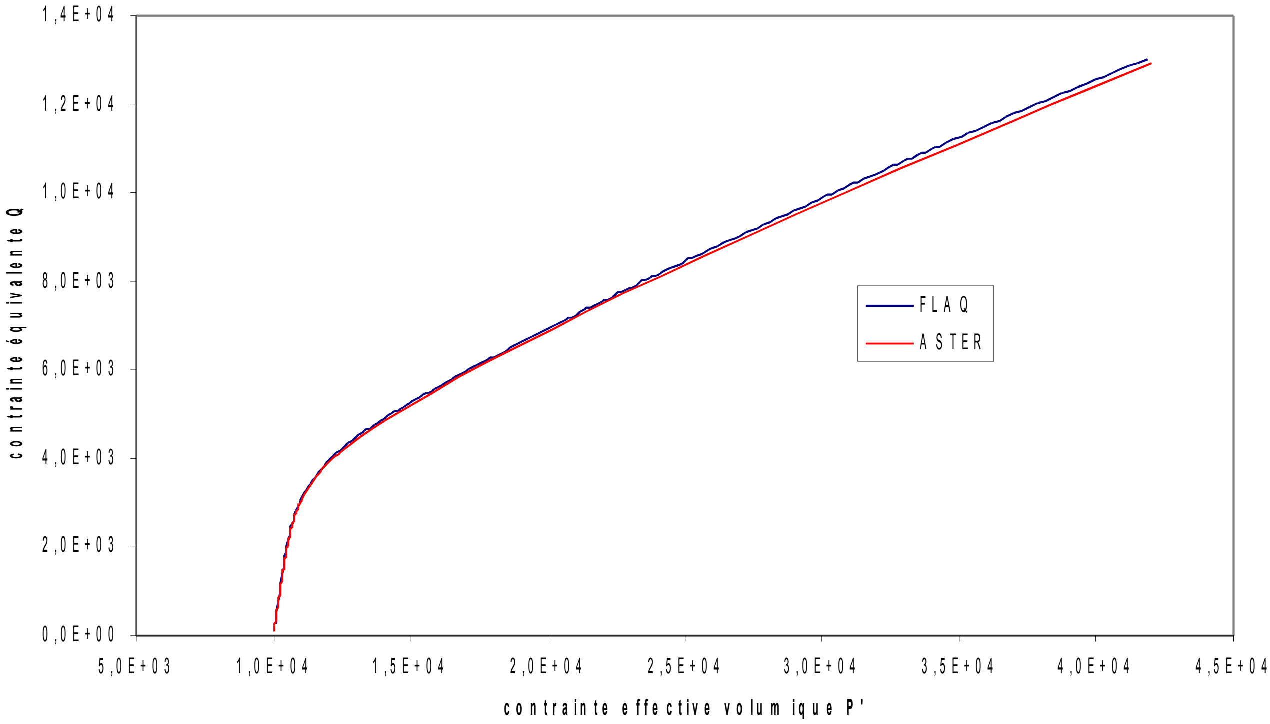


Figure **1** : *Way of loading of the plane* (P',Q) *: comparison enters solutions Code_Aster and FLAQ .*

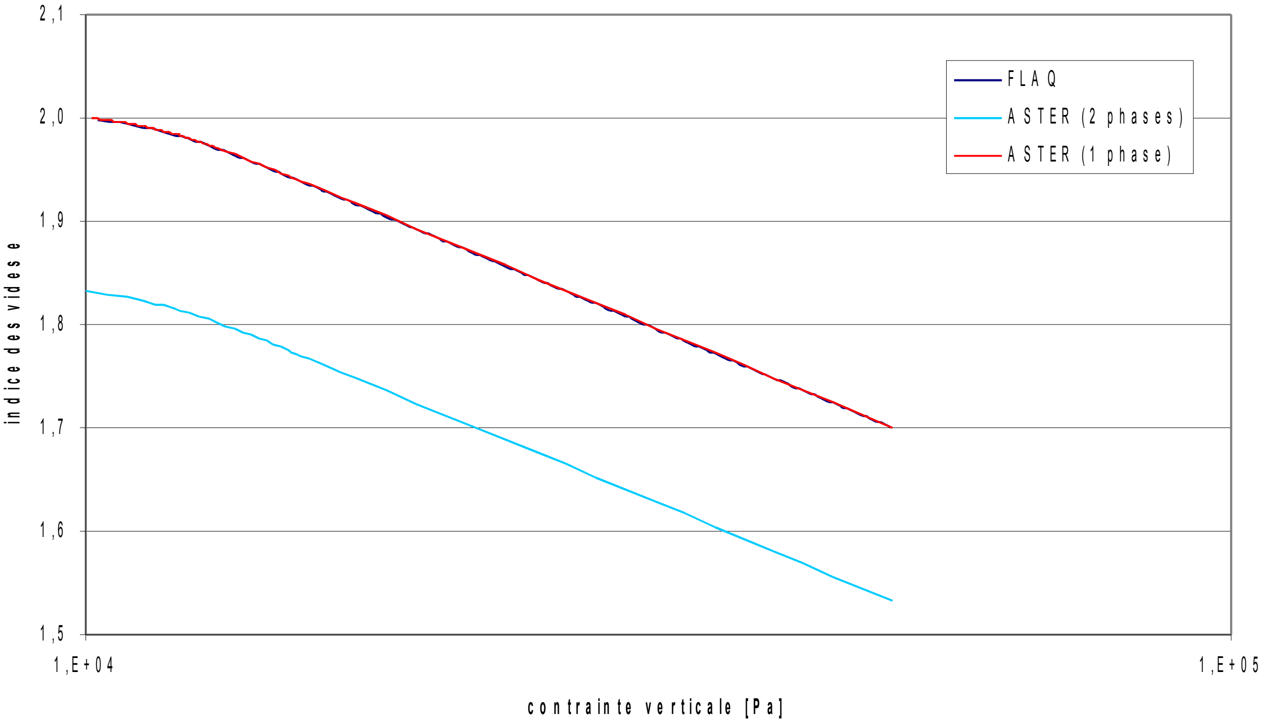


Figure **2** : *Index of the vacuums according to the vertical stress: comparison enters the solutions FLAQ and Code_Aster for two computations: in a phase and two phases .*