WTNV124 - Test of desaturation-consolidation with the model of Barcelona

Summarized:

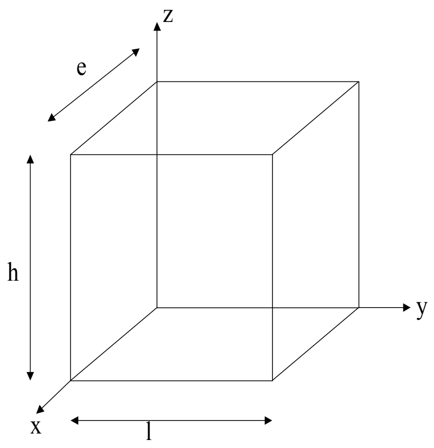
This test makes it possible to validate the model of Barcelona, which integrates an elastoplastic mechanical model coupled with the hydraulics (and possibly with the thermal) in condition of nonsaturation of the liquid phase. This model integrates an elastoplastic hydrostatic mechanism (of which the elastic part is not - linear and the flow threshold corresponds to a pressure of variable consolidation with suction) coupled to an elastoplastic mechanism deviatoric. The characteristics of these mechanisms depend on suction (i.e. of the difference between gas pressure and fluid pressure). There exist in particular two mechanisms of hardening in completely coupled pressure and suction. The surface of load of the model of Barcelona is appeared (in the diagram pressure hydrostatics-deviator and for a given suction) as an ellipse cutting the hydrostatic axis in two points: the value of the pressure of consolidation and the cohesion of the material proportional to suction. In condition of complete saturation, this criterion is reduced to that of the model Camwood-Clay specific to the saturated normally consolidated soils.
This test carried out in hydro-mechanical coupling (modelization HHM) understands two ways of loading:

1) a way of desaturation while making increase the capillary pressure beyond the hydrous threshold of plasticity,
2) a hydrostatic way of compression on the désaturé sample.

The modelization is realized in 3D.

1 Problem of reference

1.1 Geometry



height: $h = 1\text{m}$
width: $l = 1\,m$
thickness: $e = 1\,m$

1.2 Properties of the material

thermoelastic Properties:

$E = 22.4\,E7\,Pa$
$\nu = 0.3$
$\rho = 2500\;kg/m^3$

Shear modulus $\mu = 7.76\,10^6\,Pa$
initial Porosity $PORO = 0.14$
Modulates plastic compressibility with of saturated $\lambda = 0.25$,
elastic Modulus of compressibility $\kappa = 0.05$,
critical line Slope $M = 0.9$,
critical Pressure equal to half of the pressure of consolidation to saturation $PRES\_CRIT = 3.E7Pa$,
Pressure of reference $PA = 1.E5$ Pa

Parameters making it possible to calculate the modulus of compressibility according to suction $\lambda(p_c) = \lambda(0)[(1-r)\exp(-\beta p_c) + r,]$
$r = 0.75, \beta = 12.5\;E-6$

Slope of cohesion $k_c = 0.6$

initial Threshold of suction `PC0_INIT` $p_{c0}(0) = 6E7$

Modulates elastic compressibility of suction $\kappa_s = 0.01$

Modulates plastic compressibility of suction $\lambda_s = 0.05$

hydraulic Properties : the hydraulic properties of the material which are independent of the model of Barcelona but nevertheless necessary to carry out coupled computation are presented in the table below:

Liquid water	Density ($kg.m^{-3}$) Heat with constant pressure ($J.K^{-1}$) Opposite of the coefficient of compressibility (Pa^{-1}) intrinsic Permeability (m^2) viscosity	1.103 4180 0.510-9 1.10-18 1.10-3
initial State	Porosity Temperature (K) capillary Pressure (Pa) Pressure of gas (Pa) initial Saturation out of Constant	fluids 0,14 293 1.51 107 1.51 105
0,99	Constant of perfect gases	8,315
homogenized Coefficients	homogenized Density ($kg.m^{-3}$) capillary Curve Coefficient of Biot	2400 $S(P_c)=0.99(1-6\ 10^{-9}\ p_c)$ 1

1.3 Boundary conditions and loadings

the first way of loading consists in carrying out a desaturation, with a constant hydrostatic pressure $P=1.E7\,Pa$ (the gas pressure is kept constant with $PRE2=1.E5\,Pa$ during all the test). The capillary pressure varies from zero until $PRE1=7.E7\,Pa$, beyond the threshold of plasticization equal initially to $PRE1=6.E7\,Pa$. Hardening due to the increase in suction causes an increase in the threshold of consolidation, since two hardenings hydrous and mechanical are coupled in the model of Barcelona. One checks it while following the second way consisting in putting a hydrostatic pressure exceeding the initial threshold ($P_{con}=6.E7Pa$) without causing plasticization.

1.4 Initial conditions

the initial stress (effective stress of Bishop) is selected in such way that the stress used in the behavior ($\sigma=\sigma_T+p_{gz}1^d$) is inside the surface of load.

2 Deviatoric reference solution

In the absence of loading, an exact solution is available for the strains and the thresholds of hardening at all the stages of the loading:

Reversible voluminal strain in mechanical loading $\varepsilon_v = \frac{\kappa}{1+e_0} Ln \frac{P}{P_0}$

reversible voluminal Strain in hydrous loading $\varepsilon_v = \frac{\kappa_s}{1+e_0} Ln \frac{p_c + p_{atm}}{p_{atm}}$

total voluminal Strain in hydrous loading, after crossing of the threshold: $\Delta\varepsilon_v = \frac{\lambda_s}{(1+e_0)} Ln \frac{p^+{}_c + p_{atm}}{p^-{}_c + p_{atm}}$ si $p_c > p_{c0}$

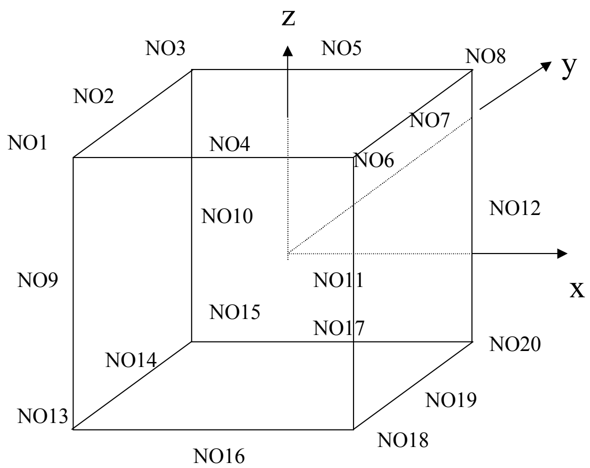
Total voluminal strain in mechanical loading, after crossing of the threshold of consolidation: $d\varepsilon_v = \frac{\lambda(p_c)}{1+e_0} \frac{dP}{P}$

Coupling of the thresholds: $\frac{dp_{c0}}{p_{c0} + p_{atm}} = \frac{\lambda - \kappa}{\lambda_s - \kappa_s} \frac{dP_{cr}}{P_{cr}}$

3 Modelization A

3.1 Characteristic of the modelization

Modelization 3D



3.2 Characteristic of the mesh

Many nodes:	20
Number of meshes:	1 of type HEXA20
	6 of type QUAD 8

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*

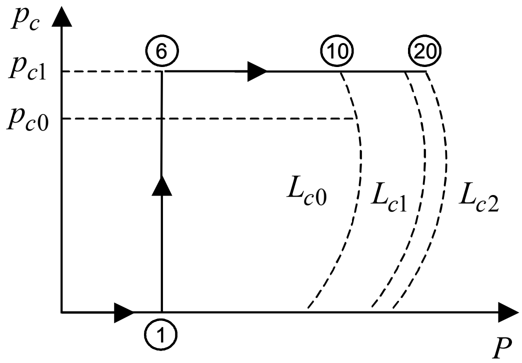
To represent the 1/8ème of structure, the boundary conditions in displacement imposed are:

On the face BAS : $DZ=0$
On the face $GAUCHE$: $DY=0$
On the face $DERRIERE$: $DX=0$

The loading is made up by the same distributed pressure in compression on the 3 meshes: *'HAUT'*, *'DROITE'* and *'DEVANT'* to simulate a hydrostatic test. All the nodes are compelled with a constant gas pressure and with a suction varying of 0 with 7.10^{7Pa}

3.3 Quantities tested and results

It is about a homogeneous test, the place of observation of the fields is indifferent. One will test displacement u_z with node 8 at time 1 (end of the hydrostatic way), at time 6.0 (crossing of the hydrous threshold) as well as the local variables of indicator of plasticity and critical pressure to the same node. One tests then the same fields at time 10 (loading purely hydrostatic by crossing the old threshold thus without plasticization) and finally at the time 20 when the new mechanical threshold is crossed (plasticization).



Values of u_z :

	Time	Reference
1st loading	1.	-2.324-03
2nd loading	6.0	-1.0621-02
3rd loading	10.0	-1.3549-02
4th loading	20.	-1.779-02

plastic Indicator (mechanical threshold):

	Time	Reference
1st loading	1.	0
2nd loading	6.0	0
3rd loading	10.0	0
4th loading	20.	1

Indicator of hydrous irreversibility:

	Time	Reference
1st loading	1.	0
2nd loading	6.0	1
3rd loading	10.0	0
4th loading	20.	0

Value of the hydrous threshold:

	Time	Reference
1st loading	1.	3E+05
2nd loading	6.0	4E+05
3rd loading	10.0	4E+05
4th loading	20.	4.3913E+5

Value of the mechanical threshold:

	Time	Reference
1st loading	1.	2E+05
2nd loading	6.0	3.8368E+05
3rd loading	10.0	3.8368E +05
4th loading	20.	4E+05

4 Summary of the results

One gets results on displacements or the values of the thresholds of consolidation very close to the analytical solution and, this, whether one is in the plastic range or reversible.