WTNV126 – Answer to mixed ways of saturation-consolidation with the model of Barcelona

Summary:

The goal of this test is to show the capacity of the model of Barcelona to describe the answer to complex ways of loading. In particular, the experiment highlights the unicity of the response in volumetric term of deformation to mixed requests (mechanical pressure and capillary pressure) taking ways different but to degree from saturation growing and bordering with the same state of stress (existence of a surface of state in the absence of requests désaturantes). On the other hand, it is known that the phases of desaturation destroy the unicity of the answer in deformation.
One thus subjects a sample of ground initially partially désaturé to a succession of homogeneous requests in hydrostatic pressure and capillary pressure:

I. a mixed request without desaturation, with two ways leading to the same state in clear constraint and capillary pressure:

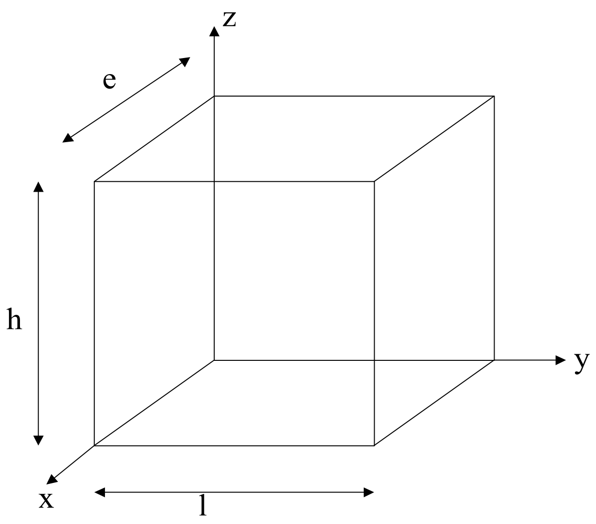
1) a way in hydrostatic pressure until a pressure $P1$ higher than the threshold of consolidation then a complete resaturation of material.
2) a way of damping (capillary pressure decrease) until resaturation supplements then consolidation until the pressure $P1$. One then observes the unicity of displacement resulting from the two ways of constraint.

II. One continues the request starting from the preceding point of load, with always two ways leading to the same state of mechanical stress and capillary pressure:

1) a way in hydrostatic pressure until a pressure $P2 > P1$ then a desaturation of material.
2) a way of drying (desaturation) then consolidation until the pressure $P2$. One then observes a significant difference between displacements resulting from the two ways.

1 Problem of reference

1.1 Geometry



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

1.2 Properties of material

- Modulus of rigidity $\mu=2.76\,10^{6}\,Pa$
- Initial porosity $PORO=0.14$
- Plastic module of compressibility with of saturated $\lambda=0.2$,
- Elastic module of compressibility $\kappa=0.02$,
- Critical line slope $M=1.$,
- Critical pressure equalizes with half of the pressure of consolidation to saturation $PRES\_CRIT=2.\,10^{5}\,Pa$,
- Pressure of reference $PA=10^{5}\,Pa$
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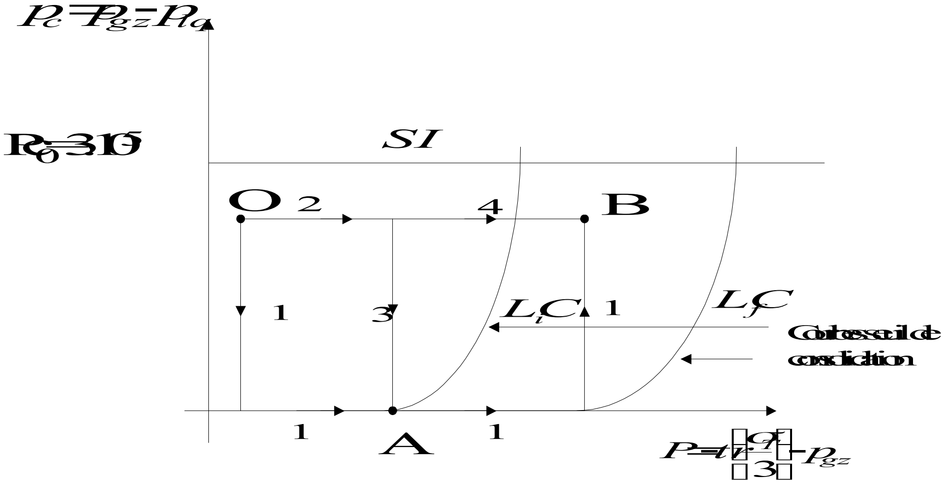
- Parameters allowing to calculate the module of compressibility according to the capillary pressure $\lambda(p_c)=\lambda(0)\left|(1-r)\exp(-\beta\,p_c)+r,\right|$
- $r=0.75,\beta=12.5\;10^{-6}$
- Slope of cohesion $k_c=0.6$
- Initial plastic threshold of the capillary pressure `PC0_INIT` $P_{c0}(0)=3\,10^{5}\,Pa$

- Elastic module of compressibility of suction $\kappa_s = 0.008$
- Plastic module of compressibility of suction $\lambda_s = 0.08$

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

Liquid water	Density ($kg.m^{-3}$)	1.10^3
	Heat with constant pressure ($J.K^{-1}$)	4180
	thermal dilation coefficient of the liquid (K^{-1})	10^{-4}
Skeleton	Heat-storage capacity with constant constraint	800
Initial state	Porosity	0.14
	Temperature (K)	293
	Capillary pressure (Pa)	$2\ 10^5$
	Gas pressure (Pa)	10^5
	Initial saturation in liquid	0.1
Constants	Constant of perfect gases	8.315
Homogenized coefficients	Homogenized density ($kg.m^{-3}$)	2400
	Capillary curve	$S(P_c) = 0.99(1 - 4.49.10^{-6} p_c)$
	Coefficient of Biot	1

1.3 Boundary conditions and loadings



<u>Way 1 up to the point A (hydrostatic damping then compression)</u>

Starting from a state unsaturated and with a state of initial stresses selected in such way that the clear constraint ($\sigma = \sigma_T + p_{gz} 1^d$) is inside the criterion, the sample is wet until complete saturation. Then, it is subjected to a hydrostatic compression with plasticization.

<u>Way 2 and 3 up to the point A (hydrostatic compression then damping)</u>

From the same initial state, one compresses the sample before wetting it completely.

Thus one compares the answer in displacement of the sample with the point A .

<u>Way 4</u>

One continues the hydrostatic loading in a state unsaturated, initiated by way 2, up to the point B .

<u>Way 1 of the point A at the point B</u>

The hydrostatic loading is continued from A up to a certain level of hydrostatic compression, then the sample is subjected to a drying up to the point B .

Thus one compares the answer in displacement of the sample with the point B , resulting from the way 1 and that resulting from way 2 and 4.

1.4 Initial conditions

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

2 Reference solution

An exact solution is available for the deformations and the thresholds of work hardening at all the stages of the loading:

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

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

Total voluminal deformation 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 $p_c > p_{c0}$

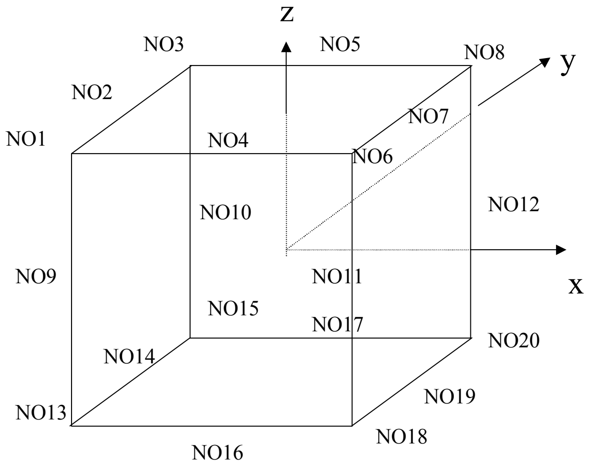
Total voluminal deformation in mechanical loading, after crossing of the threshold of consolidation: $d\varepsilon_v = \frac{\lambda(p_c)}{1+e_0} \frac{dP}{P}$

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

3 Modeling A

3.1 Characteristics of modeling

Modeling `3D`



3.2 Characteristics of the grid

Many nodes:	20
Many meshs:	1 of type `HEXA 20` 6 of type `QUAD 8`

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*

To account for the $1/8^{ème}$ 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 same pressure divided into compression on the 3 meshs: $'HAUT'$, $'DROITE'$ and $'DEVANT'$ to simulate a hydrostatic test. All the nodes are compelled with a constant gas pressure.

3.3 Sizes tested and results

It is about a homogeneous test, the place of observation of the fields is indifferent. Displacement will be tested u_z with the node $NO8$ as well as the internal variables $v1$ (the pressure criticizes), $v2$ (the indicator of plasticity), $v4$ (hydrous indicator of irreversibility) with the same node.

At the point A :

Values of u_z :

	Moment	**Reference**	***Aster***	**% difference**
Chemin 1	12.	-3.2671-02	-3.264935-02	-0,066
Ways 2 and 3	12.	-3.2660-02	-3.264929-02	-0,033

Values of $v1$ (Critical Pressure):

	Moment	**Reference**	***Aster***	**% difference**
Chemin 1	12.	3.+05	3.0000024+05	1.48E-06
Ways 2 and 3	12.	3.+05	3.0000000+05	6.92E-09

Values of $v2$ (mechanical indicator of plasticity):

	Moment	**Reference**	***Aster***	**% difference**
Way 1	12.	1.	1.	-
Ways 2 and 3	12.	1.	1.	-

Values of $v4$ (hydrous indicator of irreversibility):

	Moment	**Reference**	***Aster***	**% difference**
Way 1	12.	0	0	-
Ways 2 and 3	12.	0	0	-

At the point B :

Values of u_z :

	Moment	**Reference**	***Aster***	**% difference**
Way 1	24.	-1.8415-02	-1.84048-02	-0,055
Way 4	12.	-4.4036-02	-4.40067-02	-0,066

Values of $v1$ (Critical Pressure):

	Moment	**Reference**	***Aster***	**% difference**
Way 1	24.	3.5+05	3.50000047+05	-1.55E-05
Way 4	12.	6.81280+05	6.81230+05	-0,007

Values of $v2$ (mechanical indicator of plasticity):

	Moment	**Reference**	***Aster***	**% difference**
Way 1	24.	1.	1.	-
Way 4	12.	0.	0.	-

Values of $v4$ (hydrous indicator of irreversibility):

	Moment	**Reference**	***Aster***	$\%$ **difference**
Way 1	24.	0	0	-
Way 4	12.	0	0	-

4 Summary of the results

It is noticed that the results got at the point A following damping and hydrostatic compression (chemin1) or following hydrostatic compression and with damping (ways 2 and 3) are almost identical whereas those obtained to the point B following a hydrostatic compression of a ground unsaturated (way 4) or following hydrostatic compression with a water-logged soil and of its drying (way 1) are not identical.

These observations are well reproduced by Code_Aster and are consolidated in experiments according to the or not monotonous monotonous growth of saturation.