WTNV126 – Response at mixed paths of saturation-consolidation with the model of Barcelona

Summarized:

The goal of this test is to show the capacity of the model of Barcelona to describe the response at complex paths of loading. In particular, the experiment highlights the unicity of the response in volumetric term of strain with mixed requests (mechanical pressure and capillary pressure) taking paths different but with degree from saturation growing and bordering with the same stress state (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 response in strain.
One thus subjects a sample of soil 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 stress and capillary pressure:

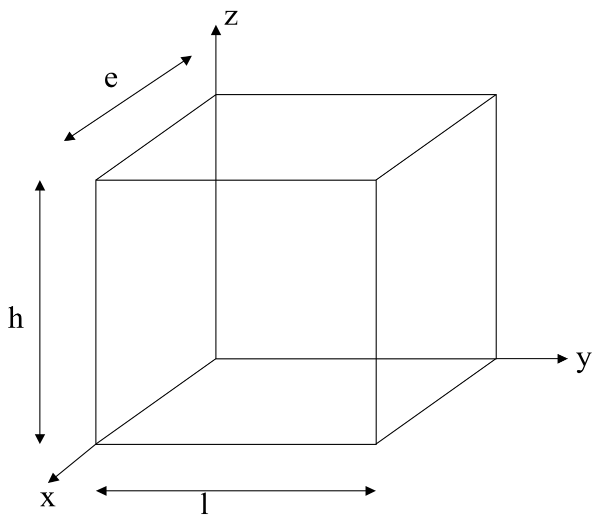
1) a way in hydrostatic pressure until a pressure $P1$ higher than the threshold of consolidation then a complete resaturation of the material.
2) a way of damping (capillary pressure decrease) until resaturation supplements then consolidation until the pressure $P1$. One then observes the unicity of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

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

1) a way in hydrostatic pressure until a pressure $P2>P1$ then a desaturation of the 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 paths.

1 Problem of reference

1.1 Geometry



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

1.2 Properties of the material

- Shear modulus $\mu=2.76\,10^{6}\,Pa$
- initial Porosity $PORO=0.14$
- Modulates plastic compressibility with of saturated $\lambda=0.2$,
- elastic Modulus of compressibility $\kappa=0.02$,
- critical line Slope $M=1.$,
- critical Pressure equal to 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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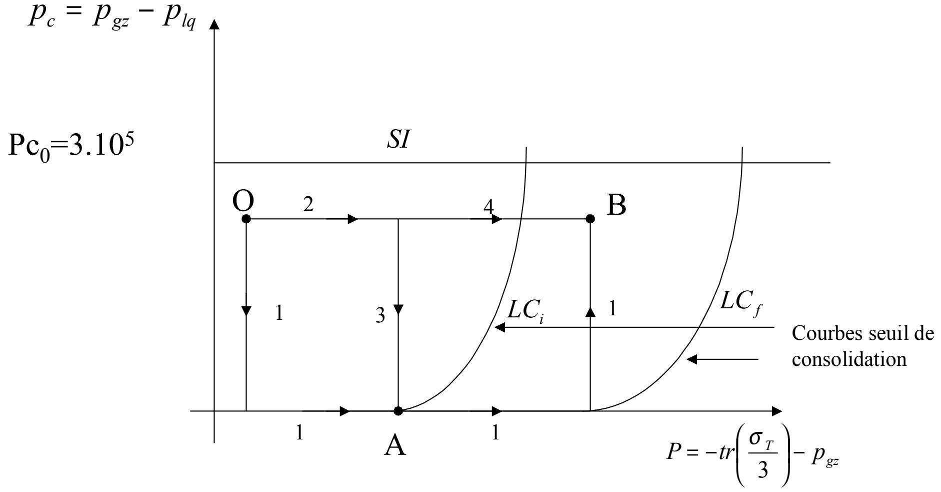
- Parameters making it possible to calculate the modulus of compressibility according to the capillary pressure $\lambda(p_c)=\lambda(0)\left[(1-r)\exp(-\beta\,p_c)+r,\,\right]$
- $r=0.75,\beta=12.5\;10^{-6}$
- Slope of cohesion $k_c=0.6$
- initial plastic Threshold of capillary pressure `PC0_INIT` $P_{c0}(0)=3\,10^{5}\,Pa$

- Modulates elastic compressibility of suction $\kappa_s = 0.008$
- Modulates plastic compressibility of suction $\lambda_s = 0.08$

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 ($kg.m^{-3}$)	1.103
	Heat with constant pressure ($J.K^{-1}$)	4180
	thermal coefficient of thermal expansion of the fluid (K^{-1})	10-4
Squelette	Heat capacity with constant stress	800
initial State	Porosity	fluids
	Temperature (K)	0,14
	capillary Pressure (Pa)	293
	Pressure of gas (Pa)	2.105.105
	initial Saturation out of Constant	
0,1	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>Path 1 up to the point A (damping then hydrostatic compression)</u>

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

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

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

Thus one compares the response in displacement of L "sample with the point A .

<u>Path 4</u>

One continues the hydrostatic loading with L" state unsaturated, initiated by path 2, up to the point B .

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

the hydrostatic loading is carried on from A jusqu" on a certain level of hydrostatic compression, then the sample is subjected to a drying up to the point B .

Thus one compares the response in displacement of L "sample with the point B , resulting from the path 1 and that resulting from path 2 and 4.

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 criterion.

2 Reference solution

an exact solution is available for the strains and the thresholds D" 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 $p_c > p_{c0}$

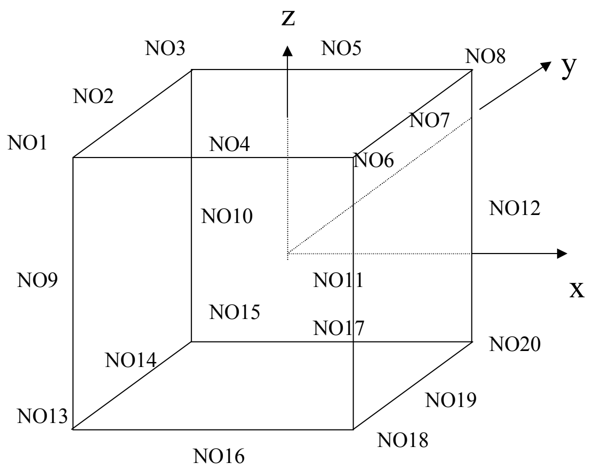
Total voluminal strain in mechanical loading, after crossing of the threshold of consolidation:
$d\varepsilon_v = \frac{\lambda(p_c)}{1+e_0} \frac{dP}{P}$

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.

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 the node $NO8$ as well as the local variables $v1$ (the pressure criticizes), $v2$ (the indicator of plasticity), $v4$ (hydrous indicator of irreversibility) with the same node.

With point: A

Values of u_z :

	Time	Reference	Aster	% difference
Path 1	12.	-3.2671-02	-3.264935-02	-0.066
Paths 2 and 3	12.	-3.2660-02	-3.264929-02	-0.033

Values of $v1$ (critical Pressure):

	Time	Reference	Aster	% difference
Path 1	12.	3.+05	3.0000024+05	1.48E-06
Paths 2 and 3	12.	3.+05	3.0000000+05	6.92E-09

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

	Time	Reference	Aster	% difference
Path 1	12.	1.	1.	-
Paths 2 and 3	12.	1.	1.	-

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

	Time	Reference	Aster	% difference
Path 1	12.	0	0	-
Paths 2 and 3	12.	0	0	-

To point: B

Values of u_z :

	Time	Reference	Aster	% difference
Path 1	24.	-1.8415-02	-1.84048-02	-0.055
Path 4	12.	-4.4036-02	-4.40067-02	-0.066

Values of $v1$ (critical Pressure):

	Time	Reference	Aster	% difference
Path 1	24.	3.5+05	3.50000047+05	-1.55E-05
Path 4	12.	6.81280+05	6.81230+05	-0.007

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

	Time	Reference	Aster	% difference
Path 1	24.	1.	1.	-
Path 4	12.	0.	0.	-

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

	Time	**Reference**	***Aster***	$\%$ **difference**
Path 1	24.	0	0	-
Path 4	12.	0	0	-

4 Summary of the results

One notices that the results got at the point A following damping and hydrostatic compression (chemin1) or following hydrostatic compression and with damping (paths 2 and 3) are almost identical whereas those obtained at the point B following a hydrostatic compression of a soil unsaturated (path 4) or following the hydrostatic compression of a water-logged soil and of its drying (path 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.