WTNV123 - Triaxial compression test with suction fixed with the model of Barcelona

Summary:

This test makes it possible to validate the model of Barcelona, which integrates an elastoplastic mechanical law coupled with hydraulics (and possibly with thermics) in condition of nonsaturation of the liquid phase. This law integrates an elastoplastic hydrostatic mechanism (of which the elastic part is not - linear and the threshold of flow 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 pressure of liquid still called capillary pressure). There exist in particular two mechanisms of work hardening in pressure and capillary pressure completion coupled. The surface of load of the model of Barcelona is appeared (in the diagram pressure hydrostatic-diverter and for a given capillary pressure) as an ellipse cutting the hydrostatic axis in two points: the value of the pressure of consolidation and the cohesion of material proportional to the capillary pressure. In condition of complete saturation, this criterion is reduced to that of the model CAM_CLAY specific on the saturated normally consolidated ground.

This test carried out in hydro-mechanical coupling (modeling HHM) declines itself in three modelings:

Modeling A understands two ways of mechanical loading, the capillary pressure being fixed at a value corresponding to a degree of saturation of 10%:

- a hydrostatic way of compression
- a way obtained by maintaining the pressures lateral confining on the sample and by imposing an additional vertical pressure, which induces a triaxial state of stresses, until reaching the surface of load and generating plastic deformations in the contracting field.

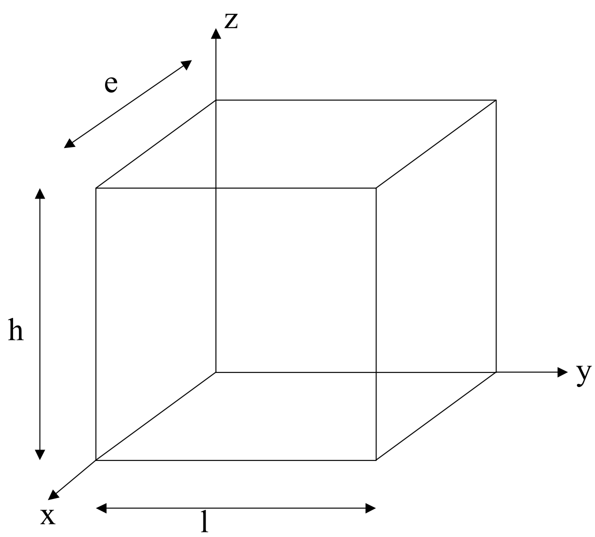
Modeling B takes again modeling A but with convergence criteria of balance on each generalized constraint.

Modeling C continues modeling B by a deviatoric discharge then hydrostatic conclusive by a deviatoric refill plasticizing in the dilating field.

All these modelings are carried out in 3D on a hexahedral element.

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 $\lambda=0.2$
Elastic module of compressibility KAPA $\kappa=0.02$
Critical line slope $M=1.$
Critical pressure equalizes with half of the pressure of consolidation to saturation $\text{PRES\_CRIT}=2.10^5\,Pa$,
Pressure of reference $PA=10^5\,Pa$
Parameters allowing to calculate the module of compressibility according to the capillary pressure $\lambda(p_c)=\lambda(0)(1-r)\exp(-\beta\,p_c)+r$, $r=0.75$, $\beta=12{,}5.10^6$
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 KAPAS $\kappa_S=0.008$
Plastic module of compressibility of suction LAMBDAS $\lambda_S=0.08$

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
		4180

	Heat with constant pressure ($J.K^{-1}$)	10^{-4}
	thermal dilation coefficient of the liquid (K^{-1})	
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

(*) this data transmitted in THM_INIT by the keyword DEGR_SATU only one indicative value has, only the initial capillary pressure and the capillary curve determine initial saturation.

1.3 Boundary conditions and loadings

For all modelings, one starts with a hydrostatic way of loading, with a constant capillary pressure $PRE1=2.10^5\ Pa$ starting from a hydrostatic initial state until a total hydrostatic pressure of $\sigma_T=8.10^5\ Pa$. The gas pressure is kept constant $PRE2=10^5\ Pa$. Then, the pressure is kept P on the side faces and one increases the vertical pressure until $\sigma_{T_{11}}=11.10^5\ Pa$ in compression in order to obtain a state of stress biaxial of revolution. The capillary pressure and the gas pressure are kept constant. One then crosses the plastic threshold in the contracting field.
For modeling C , one continues the loading by carrying out a discharge of the deviatoric constraint (of $11.10^5\ Pa$ with $6.10^5\ Pa$), then a hydrostatic discharge (of $6.10^5\ Pa$ with $1{,}5.10^5\ Pa$) and finally a deviatoric refill in order to plasticize in the dilating field.

1.4 Initial conditions

The initial constraint (forced effective of Bishop) is selected in such way that the constraint used in the behavior ($\sigma=\sigma_T+p_{gz}1^d$) do not violate the criterion. The initial capillary pressure, is equal to $2.10^5\ Pa$.

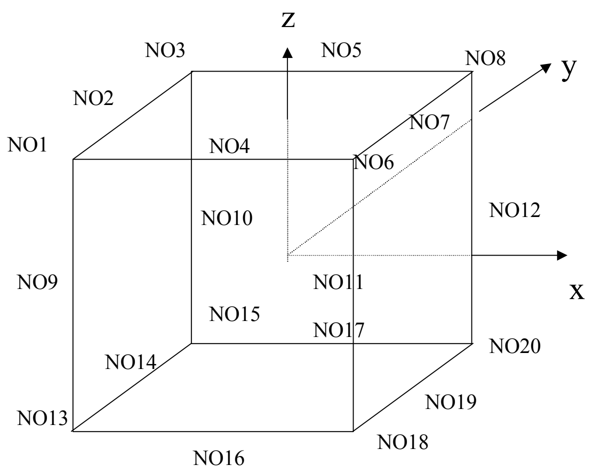
2 Reference solution

An exact solution for displacement exists as much as the loading is hydrostatic. For the second way the analytical solution is not available, one carries out a test of nonregression.

3 Modeling A

3.1 Characteristics of modeling

Modeling 3D



3.2 Characteristics of the grid

Many nodes:	20
Many meshs:	1 of type HEXA20
	6 of type QUAD8

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 represent it $1/8^{ème}$ structure, the boundary conditions imposed in displacement 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. Then, the pressure distributed is kept constant on the side faces $DROITE$ and $DEVANT$, the vertical pressure increases on the face $HAUT$.

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 $NO8$ at moment 6 (end of the hydrostatic way) like at moment 20 (end of the test) as well as the internal variables of indicator of plasticity and pressure criticizes with the same node.

Identification	Type of reference	Value
u_z at moment 6. (1 er loading)	'NON_REGRESSION'	-1.84046E-2
u_z at moment 20. (2 eme loading)	'NON_REGRESSION'	-6.9675E-2
Plastic indicator at moment 6.	'NON_REGRESSION'	1.0
Plastic indicator at moment 20.	'NON_REGRESSION'	1.0
Pressure criticizes in condition of saturation at moment 6. (1 er loading)	'NON_REGRESSION'	3.5E+5
Pressure criticizes in condition of saturation at moment 20. (2 eme loading)	'NON_REGRESSION'	4.48913E+5
Value of the hydrous threshold at moment 6. (1 er loading)	'NON_REGRESSION'	3.6876E+5
Value of the hydrous threshold at moment 20. (2 eme loading)	'NON_REGRESSION'	6.4522E+5

One tests the extraction of an internal variable to the node N_1 mesh M_1 (field 'VAEX_ELNO') :

Identification	Type of reference	Value
X_1 With the sequence number 1 of the result PCR .	'NON_REGRESSION'	3.21424E+5
X_1 With the sequence number 1 of the result $SEUIL$.	'NON_REGRESSION'	3.0E+5
X_1 With the sequence number 24 of the result $INDETA$.	'NON_REGRESSION'	1.0
X_1 With the sequence number 24 of the result	'NON_REGRESSION'	0.0

SEUIL .		

4 Modeling B

It acts exactly of the same modeling as previously but with a test of convergence on each generalized constraint. The results are appreciably the same ones.

5 Modeling C

5.1 Characteristics of modeling

It is always the same modeling but with a prolongation the loading until plasticization in the dilating field.

5.2 Sizes tested and results

Displacement is tested u_z with the node $NO8$ at moment 34 (deviatoric discharge), at moment 46 (hydrostatic discharge) and finally at moment 60 as well as the internal variables of indicator of plasticity and critical pressure and hydrous threshold with the same node and the same moments.

Values of u_z :

	Moment	***Type of reference***	**Reference**
1 er loading	6.	NON_REGRESSION	-1.84049-02
2nd loading	20.	NON_REGRESSION	-6.95388-02
3rd loading	34.	NON_REGRESSION	-7.812751-03
4th loading	46	NON_REGRESSION	-1.74106-02
5th loading	60	NON_REGRESSION	-6.75288-02

Plastic indicator (mechanical threshold):

	Moment	***Type of reference***	**Reference**
1 er loading	6.	NON_REGRESSION	1
2nd loading	20.	NON_REGRESSION	1
3rd loading	34.	NON_REGRESSION	0
4th loading	46	NON_REGRESSION	0
5th loading	60	NON_REGRESSION	0

Pressure criticizes in condition of saturation:

	Moment	***Type of reference***	**Reference**
1 er loading	6.	NON_REGRESSION	3.5+05
2nd loading	20.	NON_REGRESSION	4.48913+05
3rd loading	34.	NON_REGRESSION	4.48913+05
4th loading	46	NON_REGRESSION	4.48913+05
5th loading	60	NON_REGRESSION	4.48913+05

Value of the hydrous threshold:

	Moment	***Type of reference***	**Reference**
1 er loading	6.	NON_REGRESSION	3.68765+05
2nd loading	20.	NON_REGRESSION	6.45223+05
3rd loading	34.	NON_REGRESSION	6.45223+05
4th loading	46	NON_REGRESSION	6.45223+05
5th loading	60	NON_REGRESSION	6.45223+05

6 Modeling D

6.1 Characteristics of modeling

It acts same modeling as A but with taking into account of thermics (modeling 3D_THHM), the temperature being blocked. The purpose of this modeling is just to check well the good passage in the routines of thermics.

6.2 Sizes tested and results

The sizes tested and results are of course the same ones as for modeling A.

7 Modeling E

7.1 Characteristics of modeling

It acts same modeling as A but with taking into account of thermics, the temperature being blocked. One is here in selective modeling (modeling `3D_THHMS`). The purpose of this modeilsation is just to check well the good passage in the routines of thermics at the time of selective modeling.

7.2 Sizes tested and results

The sizes tested and results are of course the same ones as for modeling A.

8 Modeling F

8.1 Characteristics of modeling

It acts same modeling as A but with taking into account of thermics, the temperature being blocked. One is here in lumpée modeling (modeling 3D_THHMD). The purpose of this modeilsation is just to check well the good passage in the routines of thermics at the time of lumpée modeling. Only the first ways of mechanical loading is tested here.

8.2 Sizes tested and results

One tests the extraction of an internal variable to the node N_1 mesh M_1 (field 'VAEX_ELNO') :

Identification	Type of reference	Value
X_1 With the sequence number 1 of the result PCR .	'NON_REGRESSION'	3.21424E+5
X_1 With the sequence number 1 of the result $SEUIL$.	'NON_REGRESSION'	3.0E+5

9 Summary of the results

The only results of reference relate to the first hydrostatic loading. In this case displacements and the thresholds in pressure and capillary pressure are calculated with a precision higher than 1%.