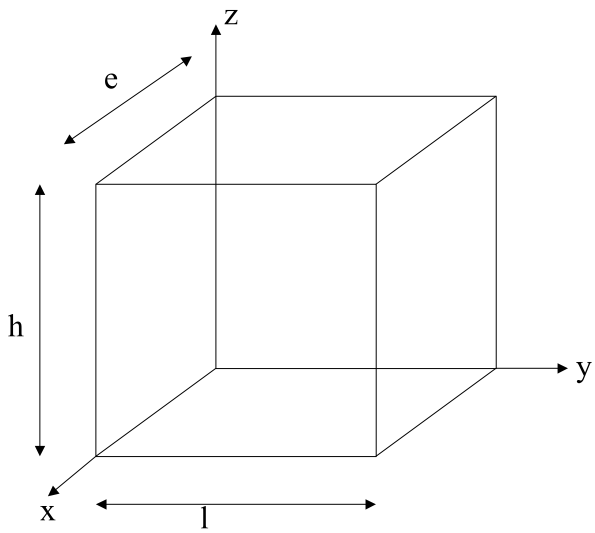
SSNV160 - Hydrostatic test with the law CAM_CLAY

Summary:

This test makes it possible to validate the mechanical law elastoplastic Cam_Clay specific to the normally consolidated grounds of which the elastic part is non-linear and the plastic part is hardening or lenitive. This test is a hydrostatic test of compression. A reference solution is given. Modelings has and B which called on linear research are reabsorbed, this is why only modelings C and D are written. Modeling E is added to test the operator SIMU_POINT_MAT, for same simulation on a material point.

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

Parameters specific to CAM_CLAY :

in modeling C:
$\mu=3.846154\,10^6\,Pa$, $PORO=0.5$, $\lambda=0.2$, $\kappa=0.05$, $M=1.02$, $\text{PRES\_CRIT}=10^7\,Pa$, $K_{cam}=6.5\,10^6\,Pa$; $P_{trac}=-10^5\,Pa$

in modeling D : $\mu=6\,10^6\,Pa$, $PORO=0.66$, $\lambda=0.25$, $\kappa=0.05$, $M=0.9$, $\text{PRES\_CRIT}=3.\,10^5\,Pa$, $K_{cam}=0.$; $P_{trac}=0$; in this case the constraints are initialized.

1.3 Boundary conditions and loadings

In modeling C:

The hydrostatic test is carried out with a state of homogeneous stresses which starts with $\sigma_{xx}=\sigma_{yy}=\sigma_{zz}=P_{trac}$. One increases then P until $P_{\sup}$ by carrying out a loading with Cam_Clay followed by a discharge until P_{trac} .

In modeling D:

The hydrostatic test is carried out with a state of homogeneous stresses: $\sigma_{xx}=\sigma_{yy}=\sigma_{zz}=P$. One does a first elastic design until $P=PA$. One increases then P until $P_{\sup}$ by carrying out a loading with Cam_Clay followed by a discharge until PA.

1.4 Initial conditions

In modeling C:

In this modeling, an initial compressibility is given like a parameter material, $K_{cam}=6{,}5 10^6 \quad Pa$, it is thus not necessary to initialize the fields of the constraints.

In modeling D:

The value of initial compressibility is worthless $K_{cam}=0$. It is thus necessary to initialize the state of stresses, because in the expression of the hydrostatic constraint of the law CAM_CLAY, for a worthless voluminal deformation, the constraint is nonworthless.

To initialize this constraint, one chose to carry out at the beginning a purely elastic calculation while making evolve the pressure of $0.$ with $1.E5\,Pa$. One extracts from this calculation only the stress field at the points of gauss. This stress field resulting from the elastic design is regarded as the initial state of the hydrostatic constraint necessary to the law CAM_CLAY following calculation.

2 Reference solution

2.1 Method of calculating

In a hydrostatic test: $\sigma_{xx} = \sigma_{yy} = \sigma_{zz}$ and the hydrostatic constraint is $P = -\frac{tr(\sigma)}{3}$ (convention of the soil mechanics).

For the calculation of the total voluminal deformation, one distinguishes the two cases:

1^er^ case : Case of non-linear elasticity, the hydrostatic pressure is lower than the pressure of consolidation; $P < P_{consolidation} = 2P_{cr} - P_{trac}$

$$P = P_0 \exp(k_0 \varepsilon_v^e) + \frac{K_{cam}}{k_0}\left(\exp(k_0 \varepsilon_v^e) - 1\right) \text{ or } \varepsilon_v^e = \frac{1}{k_0} Ln\left[\frac{k_0 P + K_{cam}}{k_0 P_0 + K_{cam}}\right]$$

In this case, the total deflection is equal to the elastic strain: $\varepsilon_v = \varepsilon_v^e$

2^ème^ case : Case of plasticity, the hydrostatic pressure exceeded the pressure of consolidation, there is thus hardening:

$P > 2P_{cr} = P_{consolidation}$, $P = 2P_{cr}$ after plasticization.

and the critical pressure evolves as follows

$P_{cr} = P_{cr0} \exp(k \varepsilon_v^p)$

and voluminal deformation: $\varepsilon_v^p = \frac{1}{k} Ln\left[\frac{P + P_{trac}}{2P_{cr0}}\right]$

In this case, it is necessary to take into account the plastic deformation in the calculation of the total deflection $\varepsilon_v = \varepsilon_v^e + \varepsilon_v^p = \frac{1}{k_0} Ln\left[\frac{k_0 P + K_{cam}}{k_0 P_0 + K_{cam}}\right] + \frac{1}{k} Ln\left[\frac{P + P_{trac}}{2P_{cr0}}\right]$

2.2 Sizes and results of reference

The test is homogeneous. One tests the voluminal deformation in an unspecified node where components are equal: $\varepsilon_{xx} = \varepsilon_{yy} = \varepsilon_{zz} = -\frac{\varepsilon_v}{3}$

2.3 Uncertainties on the solution

None. Exact analytical result.

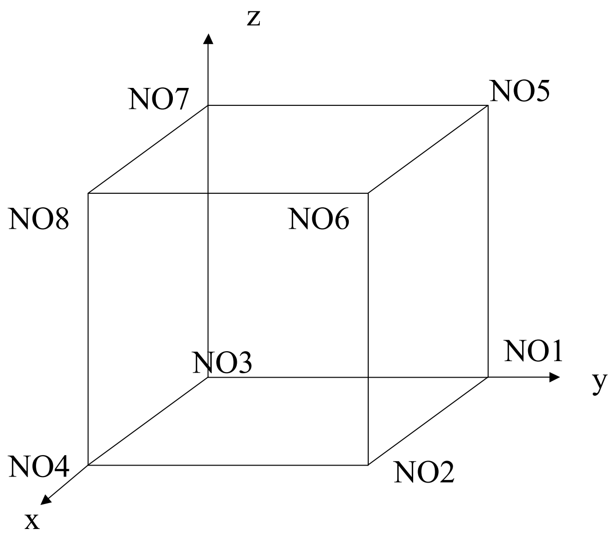
2.4 Bibliographical reference

- Charlez Ph. A. (Total Report): example of model poroplastic: the model of Cam_Clay

3 Modeling C

3.1 Characteristics of modeling

Modeling 3D



3.2 Characteristics of the grid

Many nodes:	8
Many meshs:	1 of type HEXA 8
	6 of type QUAD 4

The following meshs are defined:

ARRIERE	*NO1 NO3 NO7 NO5*
AVANT	*NO2 NO6 NO8 NO4*
DROITE	*NO1 NO5 NO6 NO2*
GAUCHE	*NO3 NO4 NO8 NO7*
BAS	NO1 NO2 NO4 NO3
HAUT	*NO5 NO7 NO8 NO6*

To account for the 1/8ème structure, the boundary conditions in displacement imposed are:

On the nodes $NO1$, $NO2$, $NO4$ and $NO3$: $DZ=0$
On the nodes $NO3$, $NO4$, $NO8$ and $NO7$: $DY=0$
On the nodes $NO2$, $NO6$, $NO8$ and $NO4$: $DX=0$

The loading is made up by same pressure divided into compression on the 3 meshs: $HAUT$, $DROITE$ and $ARRIERE$ to simulate a hydrostatic test.

3.3 Sizes tested and results

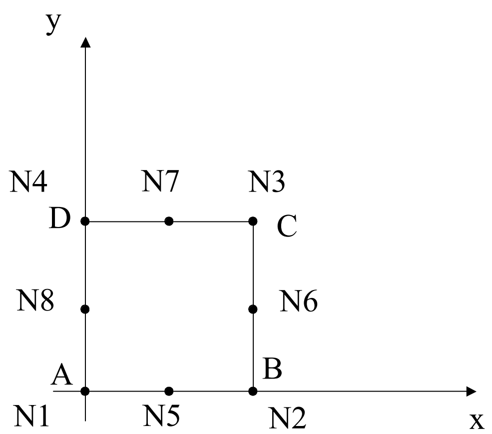
The component ε_{xx} with the node $NO6$ was tested, in this case $\varepsilon_{xx} = \varepsilon_{yy} = \varepsilon_{zz}$

Moment	Reference	Aster	% difference
5000.	-4.7698-02	-4.7698-02	1.19E- 04%
6000.	-4.9840-02	-4.9840-02	9.63E- 07%
6500.	-5.0861-02	-5.0861-02	6.57E- 07%
7000.	-5.1852-02	-5.1852-02	1.34E- 05%
7500.	-5.2815-02	-5.2815-02	3.74E- 06%
8000.	-5.3750-02	-5.3750-02	1.17E- 05%
9000.	-4.0516-02	-4.0516-02	-2.67E- 06%
10000.	-2.2572-03	-2.2572-03	1.53E- 04%

4 Modeling D

4.1 Characteristics of modeling

Axisymmetric modeling



4.2 Characteristics of the grid

Many nodes: 8
Many meshs: 1 of type QUAD 8
4 of type SEG3

The following meshs are defined: AB , BC , CD and DA
To represent a quarter of the structure, one puts the boundary conditions following:
On AB : $DY=0$
On AD : $DX=0$
One imposes an equal pressure on the meshs BC and CD to simulate a hydrostatic test.

4.3 Sizes tested and results

The component ε_{xx} with the node C was tested, in this case $\varepsilon_{xx}=\varepsilon_{yy}=\varepsilon_{zz}$

Moment	Reference	Aster	% difference
5000.	-9.12015-03	-9.12015-03	1.88E- 06%
6000.	-1.01533-02	-1.01533 – 02	9.18E- 06%
6500.	-1.24211-02	-1.24211-02	3.04E- 06%
7000.	-1.45209-02	-1.45209-02	4.31E- 05%
7500.	-1.64757-02	-1.64757-02	2.60E- 05%
8000.	-1.83042-02	-1.83042-02	3.12E- 05%
9000.	-1.66740-02	-1.66740-02	4.38E- 05%
10000.	-6.52079-03	-6.52079 – 03	1.24E- 05%

5 Summary of the results

Values obtained with *Code_Aster* are in agreement with the values of the analytical solution of reference.