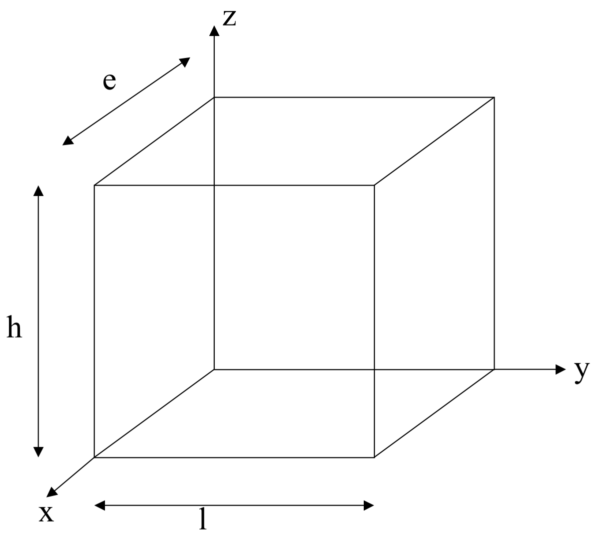
SSNV160 - Hydrostatic test with model `CAM_CLAY`

Summarized:

This test makes it possible to validate the mechanical model elastoplastic Cam_Clay specific to the normally consolidated soils of which the elastic part is nonlinear and the plastic part is hardening or lenitive. This test is a hydrostatic compression test. A reference solution is given. The modelizations has and B which called on the linear search are reabsorbed, this is why only the modelizations C and D are written. The modelization E is added to test operator `SIMU_POINT_MAT`, for same simulation on a material point.

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

Parameters specific to `CAM_CLAY` :

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

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

1.3 Boundary conditions and loadings

In the modelization C:

The hydrostatic test is carried out with a stress state homogeneous 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 the modelization D:

The hydrostatic test is carried out with a stress state homogeneous: $\sigma_{xx} = \sigma_{yy} = \sigma_{zz} = P$. 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 the modelization C:

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

In the modelization D:

The value of initial compressibility is null $K_{cam} = 0$. It is thus necessary to initialize the stress state, because in the statement of the hydrostatic stress of model `CAM_CLAY`, for a voluminal strain null, the stress is non-zero.

To initialize this stress, one chose to carry out at the beginning a purely elastic computation while making evolve the pressure of $0.$ with $1.\mathrm{E}5\,Pa$. One extracts from this computation 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 stress necessary to model `CAM_CLAY` of following computation.

2 Reference solution

2.1 Method of calculating

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

For the computation of the total voluminal strain, one distinguishes the two cases:

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

$$P=P_0\exp(k_0\varepsilon_v^e)+\frac{K_{cam}}{k_0}\left(\exp(k_0\varepsilon_v^e)-1\right) \text{ or } \varepsilon_v^e=\frac{1}{k_0}Ln\left(\frac{k_0P+K_{cam}}{k_0P_0+K_{cam}}\right)$$

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

2nd 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 the voluminal strain: $\varepsilon_v^p=\frac{1}{k}Ln\left(\frac{P+P_{trac}}{2P_{cr0}}\right)$

In this case, it is necessary to take into account the plastic strain in the computation of the total deflection $\varepsilon_v=\varepsilon_v^e+\varepsilon_v^p=\frac{1}{k_0}Ln\left(\frac{k_0P+K_{cam}}{k_0P_0+K_{cam}}\right)+\frac{1}{k}Ln\left(\frac{P+P_{trac}}{2P_{cr0}}\right)$

2.2 Quantities and results of reference

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

2.3 Uncertainties on the solution

None. Result analytical exact.

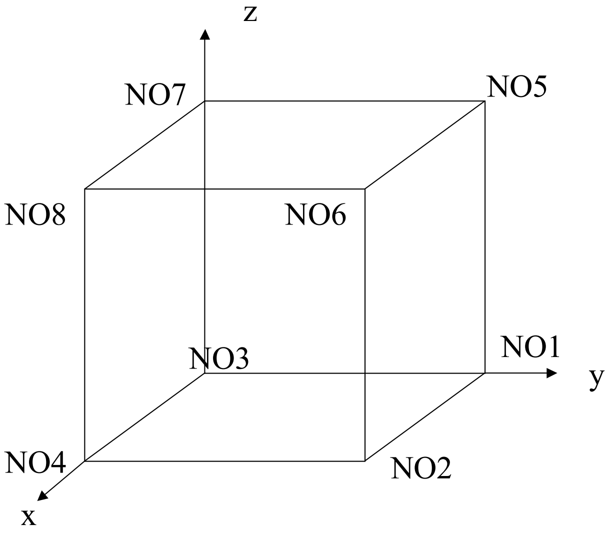
2.4 Bibliographical reference

- Charlez pH. A. (Total Ratio): example of model poroplastic: the model of Cam_Clay

3 Modelization C

3.1 Characteristic of the modelization

Modelization `3D`



3.2 Characteristic of the mesh

Many nodes:	8
Number of meshes:	1 of type `HEXA 8` 6 of type `QUAD4`

One defines the meshes following ones:

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 represent the 1/8ème of 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 the same distributed pressure in compression on the 3 meshes: $HAUT$, $DROITE$ and $ARRIERE$ to simulate a hydrostatic test.

3.3 Quantities tested and results

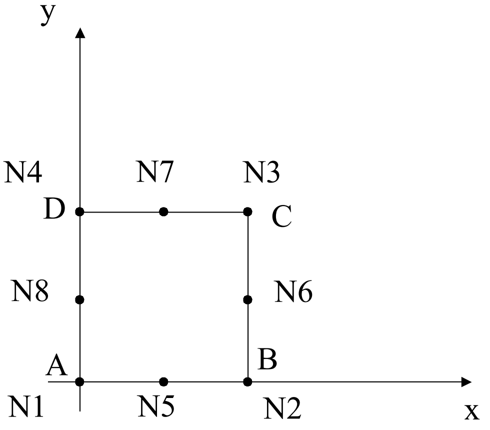
the component ε_{xx} with the node $NO6$ was tested, in this Urgent $\varepsilon_{xx}=\varepsilon_{yy}=\varepsilon_{zz}$

case	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 Modelization D

4.1 Characteristic of the axisymmetric

modelization Modelization



4.2 Characteristics of the mesh

Many nodes:	8
Number of meshes:	1 of type `QUAD 8` 4 of type `SEG3`

One defines the meshes following ones: AB BC , CD and DA
to represent a quarter of structure, the following boundary conditions are put:
On AB : $DY=0$
On AD : $DX=0$
One imposes an equal pressure on meshes BC and CD to simulate a hydrostatic test.

4.3 Quantities tested and results

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

case	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

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